On water resources management instruments – Framing – as a tool for river rehabilitation

Dos instrumentos de gestão de recursos hídricos – o Enquadramento – como ferramenta para reabilitação de rios

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ABSTRACT The Framing of Water Bodies in Preponderant Uses Classes, according to Conama Resolution nº 357/2005, enables the establishment of goals to be achieved, or maintained, in a body of water according to its predominant uses. Its proposal is the responsibility of the River Basin Committees, in the Mountain Region of the state of Rio de Janeiro; The Piabanha Committee has set the Framing of the Piabanha River as a priority. In this sense, the objective of this article was to compare the extent to which the Framing behaves as a process of rehabilitation of river health. It seeks to build a theoretical approach and define methodological guidelines for water resources framing projects. In the conclusions, five recommendations that are considered key to the framing process are emphasized.

KEYWORDS Water use. River pollution. Water quality.

RESUMO *O Enquadramento dos Corpos Hídricos em Classes de Usos Preponderantes, de acordo com a Resolução Conama nº 357/2005, possibilita o estabelecimento de metas a serem alcançadas, ou mantidas, em um segmento de corpo d'água de acordo com seus usos preponderantes. Sua proposição é responsabilidade dos Comitês de Bacia Hidrográfica, na Região Serrana do estado do Rio de Janeiro; o Comitê Piabanha definiu como prioridade o Enquadramento do Rio Piabanha. Nesse sentido, o objetivo deste artigo foi comparar em que medida o Enquadramento comporta-se como um processo de reabilitação da saúde dos rios. Busca-se construir um referencial teórico e definir diretrizes metodológicas para projetos de enquadramento de recursos hídricos. Nas conclusões, são destacadas cinco recomendações consideradas chave para o processo de enquadramento.*

PALAVRAS-CHAVE *Usos da água. Poluição de rios. Qualidade da água.*

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Introduction

In Brazil, few continuous monitoring data demonstrate the improvement of river water quality[1,2]. Proper spatial distribution and continuity of historical series are a constant challenge in the operation of a qualitative and quantitative network. Such discontinuities impair the monitoring of the environmental health of rivers and make it impossible for the inspection agent to make factual decisions.

In analogy to clinical tests, requested by a physician, of parameters such as blood count, glucose rates, cholesterol among many others that measure human health, water quality parameters such as Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Potential Hydrogen (pH), among others, measure the health of a water body.

An appropriate study 'Observing Rivers', produced by SOS Mata Atlântica, brought data collected and analyzed from the period March 2016 to February 2017, containing worrying results on the health of the rivers, badly affected and requiring care. "1.607 water quality analyses were performed at 240 collection points, distributed in 184 water bodies, in 73 municipalities of 11 states of the Atlantic Forest biome"[1(6)], concluding that 51 rivers presented poor or terrible quality; and 97, regular, according to Water Quality Index (WQI) standards. How to treat these rivers? Is it possible to recover them?

Among the management instruments established by the Brazilian National Water Resources Policy[3] (Law nº 9.433/97), the Framing of Water Bodies in Classes of Predominant Uses, in accordance with Conama (National Council of Environment) Resolution nº 357/2005, enables the establishment of goals to be achieved, or kept, in a segment of water body according to its predominant uses[4].

The parameters established for the framing classes are a reference for river health checkup, encompassing all elements that measure water quality from continuous monitoring.

It is known that water is the precursor of life and that without it in quantity and quality there is no well-being, therefore, human health is enormously compromised. This logic has led human settlements to, historically, settle near rivers, lakes and estuaries.

However, with the urbanization process, the characteristics of natural environments were strongly changed, bringing undesirable consequences, such as: the loss of aquatic life-supporting capacity, the reduction in the amount of water due to its uses and changes in the local[5] geomorphology, in addition to undesirable water-borne diseases.

Aiming at reversing this history of degradation, the United Nations (UN), recognizing sanitation and access to water as a human right, proposed the Millennium Development Goals Program[6] which established, among others, the Sustainable Development Goals (SDG 6.6), concerning the protection and restoration of water-related ecosystems. Another major milestone was the general assembly statement of the UN, March 1, 2019, which established the period from 2021 to 2030 as the decade of ecosystem restoration[7].

In the local scenario, the Piabanha Committee[8,9], which is part of the State Water Resources Management System[10], has set the Framing of the Piabanha River as a priority, located in the Mountain Region of the state of Rio de Janeiro. It is expected that the methodology applied in this project will be the reference for the framing of the other rivers in the region.

In this sense, the objective of this article is to compare the extent to which the Framing behaves as a process of rehabilitation of the health of rivers. The aim is to construct a theoretical background and define methodological guidelines for water resource framing projects.

Material and methods

For the topic Framing of Water Resources, we conducted a systematic literature search covering the period from 2008 to 2019. The initial year is justified by the publication of Resolution nº 91/2008 of the Brazilian National Water Resources Council[11] (CNRH) which provides for general criteria for the framing of water bodies.

For the survey of scientific articles, we used the Capes Periodical platform, consisting of 520 databases, which includes the Scopus database, the Web of Science, Springerlink and the Scientific Electronic Library Online (SciELO). In addition to these bases, the search tools of the 'Brazilian Journal of Water Resources' and the 'Saúde em Debate' journal were also used.

The following search terms were used: 'water resources framing', 'rivers framing', 'water bodies framing', 'implementation goals framing', 'water use classifications goals', 'water use designation target'.

The areas of knowledge considered were 'Water Quality, Environmental Sciences, Rivers, Water Resources, Public Health, Environmental Monitoring, Watersheds, Engineering/Environmental, River Basins, Water Pollution, Water Resources Management, Brazil, Water Resources, Water Quality'.

For the topic Waterborne Diseases, a targeted search for the Hydrographic Region IV (HR-IV) was carried out, area of activity of the Piabanha Committee. The following descriptors were used: 'waterborne diseases in the Mountain Region of the state of Rio de Janeiro', 'schistosoma mansoni in the state of Rio de Janeiro', 'schistosoma mansoni in the Mountain Region of the state of Rio de Janeiro', 'schistosomiasis mansoni' in the municipality of Sumidouro'. The Capes Periodical platform and PubMed bases were used.

The selection criteria were: 1) Peer-reviewed articles; 2) Explicit mention of search terms in title; 3) Explicit reference in the summary of experiences or methodologies or guidelines for Framing; 4) Explicit reference in the summary of waterborne diseases occurring in the municipalities that take part of HR-IV.

For the theme River Rehabilitation, guiding documents of the Society for Ecological Restoration (SER) were searched. The thematic documents produced at the UN level were also searched.

In addition to the literature review, we discussed a historical series of water quality data at two points on the Piabanha River, between 2014 and 2018. The systematized data come from systematic monitoring by the State Environment Institute (Inea).

Study area

The HR-IV Rio de Janeiro represents an area of 4.484 km² and comprises, in its entirety, the territories of the municipalities of Teresópolis, Areal, São José do Vale do Rio Preto, Sapucaia and Sumidouro, and partially the municipalities of Petrópolis, Paty do Alferes, Paraíba do Sul, Três Rios and Carmo[12].

The Piabanha River Basin, included in HR-IV and located in the Mountain Region of the state of Rio de Janeiro, has 2.050 km² of area[12]. The two largest cities in the region, Petrópolis and Teresópolis, occupy the headwaters of the basins and give rise to the Piabanha River and Preto River, respectively.

Sanitation is one of the biggest environmental health problems in the region, as cities have grown in a disorderly manner along the local watershed. The territory is home to a population of approximately 500.000 inhabitants[12] and has a diversified economy with industries, commerce, services and agriculture, especially vegetables. The Piabanha River, with 80 km long, drains the municipalities of Petrópolis, Areal and Três Rios, its main tributaries are Preto River and Fagundes River.

The Piabanha Committee is responsible for promoting the management of water resources of HR-IV of Rio de Janeiro. Among its attributions, are the approval and implementation of the Framing of Water Resources under the terms of State Law nº 3.239/1999.

Results and discussions

Water Quality in the Piabanha River Basin

The Piabanha River Basin has five systematic monitoring points of the Inea[13], one in Preto River, one in Paquequer River, one in Santo Antônio River and two points in Piabanha River – one in Petrópolis and another in Três Rios, respectively at the headwaters and at the river mouth.

The water quality parameters measured are BOD, Total Phosphorus, Nitrate, OD, pH, Turbidity, Thermotolerant Coliforms, Total Dissolved Solids (TDS) and Temperature (*charts 1* and *2*). Based on these parameters, it is possible to calculate the Water Quality Index of the National Sanitation Foundation (WQI_{NSF}), officially adopted by the state of Rio de Janeiro.

In the case of thermotolerant coliforms, all samples in the historical series violate the 100 NMP/100 ml standard established for class 2 by Conama nº 357/2005. The high concentrations of coliforms show the sewage discharge in the Piabanha River, providing the presence of pathogens in these waters.

The absence and/or inefficiency of collection and treatment of sanitary effluents that, for water bodies, cause pollution; for the population, it is the cause of countless waterborne diseases. Endemic diseases such as schistosomiasis in the municipality of Sumidouro are well documented by articles[14,15] covering research for more than half a century, and, even today, the problem persists in rural areas: this disease was also detected in the municipality of Carmo[16].

Other authors report the occurrence of pathogens such as *Cryptosporidium parvus* in vegetables in Teresópolis[17,18]. Cases of hepatitis A, leptospirosis, giardiasis, among others, are common and may occur in greater amounts during flood periods, when river water overflow is common[19]. Overall, the perception of the authors residing in this region indicates that HR-IV presents an epidemiological picture with underreporting of cases, since not every episode of gastroenteritis is registered.

The DO parameter in water is directly related to the biological activity in the river and its respective BOD, allowing to infer the aerobic and anaerobic processes of biodegradation in the river. In general, low levels of DO are mostly related to water pollution by organic material and other nutrients, especially sanitary sewage[20].

Chart 1. Historical series from 2014 to 2018 of the systematic monitoring of Inea in Piabanha River after the urban center of Petrópolis

Date	WQI_{NSF}	WQI category	BOD (mg/L)	Total Phosphorus (mg/L)	Nitrate (mg/L)	DO (mg/L)	pH	Turbidity (uT)	Coliforms* NMP/100mL	TDS (mg/L)	Water temperature
2014/01/08	48.5	Bad	4.2	0.22	0.88	4.8	6.9	4.8	33.000	78	17
2014/03/12	43.5	Bad	5	0.32	5.23	4.2	7.1	3.8	79.000	135	20
2014/05/26	42.7	Bad	7.2	0.76	5.64	4.6	6.9	4.4	33.000	101	18
2014/07/22	35.3	Bad	7.2	0.98	6.86	3.2	7.5	4.1	92.000	111	15
2014/10/28	44	Bad	7.2	0.27	4.84	6	7	6	1.600.000	129	17
2015/06/16	N/A	N/A	8.4	0.82	ND	3	7.2	8	120.000	109	12
2015/09/21	36	Bad	6	0.89	0.06	1.4	7.6	3.1	19.000	140	18
2015/11/17	62.3	Average	2	0.31	3.69	7.2	7.4	22.8	3.400	100	25
2016/02/02	51.9	Average	9	0.24	1.91	5.8	7	2.3	14.000	63	20

Chart 1. (cont.)

2016/03/21	45.9	Bad	4.4	0.39	0.92	4.4	6.9	3.7	56.000	95	20
2016/09/22	39.4	Bad	8	0.45	0.25	3.8	7.1	8.3	20.000	140	15
2017/02/14	49.1	Bad	5	0.29	0.93	5.6	7.1	3.0	24.196	77	18
2017/11/28	55.8	Average	4	0.58	0.22	4.2	7	4.1	2.300	122	21
2018/02/20	51	Average	3.4	0.37	1.08	5.6	8.2	5.3	24.000	89	20
2018/05/15	N/A	N/A	4.6	0.51	ND	4.8	7.4	5.5	54.000	105	18
2018/09/18	N/A	N/A	6	0.39	ND	6.6	7.3	6.4	35.000	116	17
2018/12/12	50.8	Average	2	0.5	0.38	3	7.4	3.9	3.300	114	19
Average	**46.87**	**N/A**	**5.5**	**0.49**	**2.35**	**4.6**	**7.2**	**5.9**	**130.129**	**107**	**18**
Median	**47.20**	**N/A**	**5.0**	**0.39**	**1.01**	**4.6**	**7.1**	**4.4**	**33.000**	**109**	**18**
Standard Deviation	**7.49**	**N/A**	**2.1**	**0.24**	**2.38**	**1.5**	**0.3**	**4.7**	**380.200**	**22**	**3**
Class 2	**N/A**	**N/A**	**<5**	**<1.4**	**<10**	**>5**	**N/A**	**<100**	**<100**	**<500**	**N/A**

Source: Own elaboration with data provided by Inea.

* Thermotolerant coliforms. Data highlighted in gray refer to Class 2 violations of Conama 357.

In the monitoring point in Petrópolis (*chart 1*), it can be seen that most of the DO values are below the Minimum Value Allowed (MVA) for class 2; similarly, the BOD parameter also has violations. Dates with DO values above 5 mg/L are mostly associated with rainy periods, when the dilution effect increases DO levels. Unfortunately, quantitative data, that is, flow measurement, is not performed simultaneously with taking samples for laboratory water quality analysis, which would allow the quantification of polluting loads.

Chart 2. Historical series from 2014 to 2018 of the systematic monitoring of Inea near the mouth of the Piabanha River, in Três Rios

Date	WQI_{NSF}	WQI category	BOD (mg/L)	Total Phosphorus (mg/L)	Nitrate (mg/L)	DO (mg/L)	pH	Turbidity (uT)	Coliforms* NMP/100mL	TDS (mg/L)	Water temperature
2014/01/08	66.3	Average	2	0.15	1.46	7.4	7.2	54.0	780	117	26
2014/03/12	67.8	Average	2	0.09	1.2	7.8	7	42.0	790	73	25
2014/05/26	68.3	Average	2.8	0.28	2.88	9	7	12.0	790	63	18
2014/07/22	72	Good	2	0.4	2.75	8.6	7.5	11.0	230	79	16
2014/10/28	54.6	Average	5.8	0.25	1.27	8	7.1	70.0	5.400	75	20
2015/06/16	N/A	N/A	2	0.2	ND	8.4	7.2	11.0	3.300	78	19
2015/09/21	N/A	N/A	2	0.18	3.12	ND	7.5	7.9	600	53	23
2015/11/17	31.7	Bad	12	0.86	0.17	1.6	7	5.3	49.000	114	21
2016/02/02	61	Average	2.2	0.15	1.53	8.2	7.1	32.5	4.900	64	23
2016/03/21	49.3	Bad	2	0.5	1.36	8	6.9	145.0	4.900	91	24
2016/09/22	66.3	Average	2	0.23	4.12	8.2	7.2	14.2	1.300	112	21

Chart 2. (cont.)

2017/02/14	70.8	Boa	2	0.15	1.21	7.8	6.9	14.6	556	58	24
2017/11/28	68.9	Média	2	0.21	0.93	8	7.5	29.5	790	64	22
2018/02/20	49	Ruim	2	0.16	0.78	5.6	8.1	11.9	92.000	81	21
2018/05/15	N/A	N/A	2	0.13	ND	8.4	7.4	16.7	780	70	20
2018/09/18	N/A	N/A	3	0.28	ND	8.6	7.5	96.7	2.300	72	20
2018/12/12	67.2	Média	2	0.24	1.58	7.4	7.5	19.5	930	52	23
Average	**61.02**	**N/A**	**2.9**	**0.26**	**1.74**	**7.6**	**7.3**	**34.9**	**9.962**	**77**	**22**
Median	**66.30**	**N/A**	**2.0**	**0.21**	**1.41**	**8.0**	**7.2**	**19.7**	**930**	**73**	**21**
Standard Deviation	**11.74**	**N/A**	**2.5**	**0.18**	**1.07**	**1.8**	**0.3**	**37.8**	**24.080**	**20**	**3**
Class 2	**N/A**	**N/A**	**<5**	**<1,4**	**<10**	**>5**	**N/A**	**<100**	**<100**	**<500**	**N/A**

Source: Own elaboration with data provided by Inea.

* Thermotolerant coliforms. Data highlighted in gray refer to Class 2 violations of Conama 357.

The WQI_{NSF} oscillates between the medium and bad categories *(chart 1)*, being the bad category the most frequent. It is noteworthy that when a single parameter that make up the WQI_{NSF} is not available, the calculation of the index becomes unfeasible, thus justifying the break in the historical sequence.

Near the river mouth of the Piabanha River, in the municipality of Três Rios *(chart 2)*, there is an improvement in water quality. At this point, virtually all analysis for the DO parameter were above 5 mg/L, that is, within the standard for class 2. The BOD parameter had only two violations for the point. As a result of this improvement in quality, WQI_{NSF} *(chart 2)* also oscillated between the medium and bad categories, but with values at the limit of the good category.

Improvement in water quality in the region near the river mouth is due to the self-purification capacity of the Piabanha River, which goes through regions full of waterfalls, which allows high rates of natural water aeration. However, mainly, it is due to the dilution conferred by its confluence with the Fagundes River and the Preto River, where, in the field, it is already visually possible to perceive the diluting effect.

Other monitored parameters are below the maximum allowed value for the class.

Based on the WQI_{NSF} presented, it can be seen that the Piabanha River is highly impacted by anthropogenic pressures, from the discharge of effluents and/or the unregulated practice of agriculture to the irregular occupation of its banks. In this aspect, restoration/rehabilitation of degraded sections and maintenance/protection of less impacted sections is essential.

In order to improve the quality of the Piabanha River, it was necessary to consider the necessary instruments, whether conceptual in the science of ecological restoration or legal in the case of the Framing of Water Bodies.

Ecological restoration

Ecological restoration is defined by SER[21,22] as the process of assisting in the recovery of an ecosystem that has been degraded, damaged or destroyed. This definition is the result of a broad analysis of the most cited scientific papers, which were discussed in the Primer report of the SER[21]. It is an intentional and planned activity aimed at restoring any type of degraded ecosystem to its historical trajectory, not to its historical condition[21]. This means that the restored ecosystem will not necessarily regain its former state, as contemporary constraints and conditions may cause it to develop along an altered trajectory[22]. Restoration activity will put the ecosystem on a recovery path where it can persist, and its species can adapt and evolve.

The first stage of restoration project planning and design is the identification of a reference ecosystem, which can be defined as a characteristic ecosystem model that represents the restoration project goal[22]. This reference is synthesized with past and present information and anticipates future restoration conditions, reinforcing the importance of monitoring. Projects that seek to reinstall some form of functionality without seeking to recover a substantial proportion of the native biota found in a reference ecosystem should be described as rehabilitation projects[22].

Planning, implementation, monitoring and maintenance of ecological restoration projects

The reference document prepared by SER[22] devotes its third section to recommending standard practices for planning, implementing, monitoring and maintaining ecological restoration projects. The main recommendations are summarized below.

During the planning and design phase, eight generic and standard actions must be observed that must be adapted to the specificities of each project, they are[22]:

1. Engagement of the interested parties: the greater the engagement and building the perception of belonging, the greater the potential for project success. The participation of political authorities, environmental agencies, the population, industries and others is crucial.

2. External context analysis: The surrounding neighborhood of the project, its interaction with the landscape and the aquatic environment should be analyzed in order to mitigate or manage threats and, above all, to allow connectivity and gene flow.

3. Base inventory of the ecosystem: consists of a detailed diagnosis of the current state of the ecosystem to be recovered. Identifies the causes of degradation.

4. Definition of a reference ecosystem: describes a native and local ecosystem as a quality reference to be achieved by the restoration project.

5. Identification of objectives and goals: the project must clearly identify its purposes.

6. Indication of restoration actions: clearly describes the actions that should be performed, such as, when, by whom, in what order and priority. Adaptive management should be a priority.

7. Property rights guarantee: before investing in restoration actions, site ownership rights must be checked to ensure access for maintenance and long-term continuity of restoration.

8. Logistic analysis: The necessary human and financial resources for the project should be evaluated. A detailed schedule should be constructed and the necessary permits and licenses applicable to the project identified.

During the implementation phase, restoration projects should be managed in such a way that six standard issues are observed, they are[22]:

1. No additional damage: restoration work should be conducted in such a way that it does not negatively impact any natural

resources or landscape features or water resources.

2. Qualified follow-up: responsible, effective and efficient execution of actions by suitably qualified and experienced persons or under their supervision.

3. Support for natural processes: all interventions should focus on enhancing natural recovery processes.

4. Adaptive management: adopt formally documented corrective changes to adapt to unexpected ecosystem responses in a timely manner.

5. Legal compliance: exert full compliance with labor, health and safety legislation and all legislation, including the ones related to soil, air, water, heritage, species and ecosystem conservation.

6. Communication: is a key factor for all interested parties.

Once we highlight the state of the art in terms of the ecological restoration advocated by SER, we are going to emphasize a little more the river environments.

In order to maintain the etymological preciosity of the word 'restoration' and following the recommendation of the SER, we have adopted in this paper the use of the word 'rehabilitation' to describe all the efforts to reinstall some form of ecosystem functionality without the intention of recovering a significant proportion of the native biota found in a reference ecosystem.

Rehabilitation of rivers

The United Nations Educational, Scientific and Cultural Organization (Unesco) launched, in 2016, the book 'River Restoration: A Strategic Approach to Planning and Management'[23].

In this international reference, the term 'river restoration' is used to refer to any intervention to improve ecosystem function, river health and related ecosystem services. These interventions include measures aimed at achieving a state that differs from the original natural condition of the river. Restored river systems do not necessarily reflect the function or structure of the original system, but show improved functions or structures compared to the degraded system.

1. Work with geographical cutoff of the river basin: understand the physical, chemical and biological conditions that affect the health of the rivers to then understand the causes of their decline and identify possible restoration measures.

2. Integrate with broader activities: recognize, incorporate and involve all existing plans, programs and projects that affect the river.

3. Work at the appropriate scale: planning, implementation and monitoring actions are required at the regional scale, with the gathering of various works at the local scale.

4. Define clear, achievable and measurable goals: they must be specified in terms of measurable changes in ecosystem function, ecosystem service provision and, when possible, socioeconomic factors.

5. Build resilience for future changes: consider likely landscape changes over time, including climate, land use, hydrology, pollutant loads, river channel and riparian vegetation.

6. Ensure sustainability of restoration results: restoration strategies must be planned, implemented and managed with the aim of achieving long-term sustained results.

7. Involve all relevant interested parties: an integrated approach, including land and water issues, and involving interinstitutional and community collaboration, is likely to achieve the best results.

8. Monitor, evaluate and report evidence of restoration outcomes: monitoring defined and measurable objectives is critical as a means of guiding adaptive management.

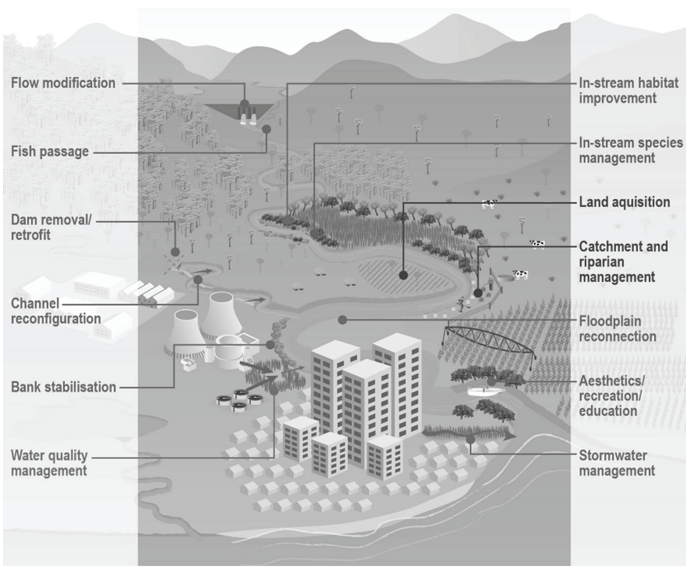
Techniques for river restoration/ rehabilitation

The River Restoration Center of the United Kingdom is a non-profit organization founded by members from the public, private and Non-governmental Organizations (NGOs) of that country, which has promoted the restoration of rivers since 1997. The RRC is a center of 'information and specialized advice' for all aspects of river basin restoration and river basin management.

Since the creation of the RRC, 3.947 river restoration/rehabilitation projects have been accounted for[24]. The main techniques used in these projects include the restoration of meanders, the removal of barrages, the fencing of rivers, the regeneration of riparian vegetation, the control of pollution sources, the creation of fish passages, the formation/maintenance of flooded areas, stabilization of margins and improvement of rainwater delivery points.

Speed et al.[23] describe 13 categories of river revitalization interventions, as shown in *figure 1*.

Figure 1. Categories of interventions for river rehabilitation



Source: Adapted from Speed et al.[23].

Framing of Brazilian water bodies

The framing of water bodies, according to the predominant uses of water, in the same way as the Water Resources Plan, is a planning instrument provided by the Brazilian National Water Resources Policy (Federal Law nº 9.433/1997) and other State Water Resources Policies. According to the National Water Agency (ANA)[25]:

> The framing of water bodies represents the establishment of the water quality goal to be achieved, or maintained, in a water body segment, according to the intended uses, according to Conama Resolution nº 357/2005.
> The purpose of this instrument is to assure water quality compatible with the most demanding uses for which it is intended, as well as to reduce the costs of combating water pollution through permanent preventive actions.
> To establish a water quality objective it is necessary: to evaluate the current condition of the river, that is, 'the river we have'; to discuss, with the population of the basin, the desired quality condition for that river, 'the river we want'; and, finally, to discuss and agree the goal with the different actors of the river basin, 'the river we can have', taking into account the technical and economic limitations for its reach[25(39)].

Framing is related to other instruments of water resources management, such as: the granting of water resources and their respective charge for their use, as well as environmental licensing, which, although the latter is not an instrument of the National Water Resources Policy, it must observe the classes of classification in the licensing of activities that capture or release effluents in framed rivers[25].

The absence of effective definition of a framework may cause damage to society by not guaranteeing the objectives for which the instrument is intended.

The framing proposal is a technical activity and should be carried out by water agencies and discussed in the Basin Committee, which, in turn, should submit it for approval by the respective Water Resources Council[25]. A brief history of the framing process is described in ANA[25].

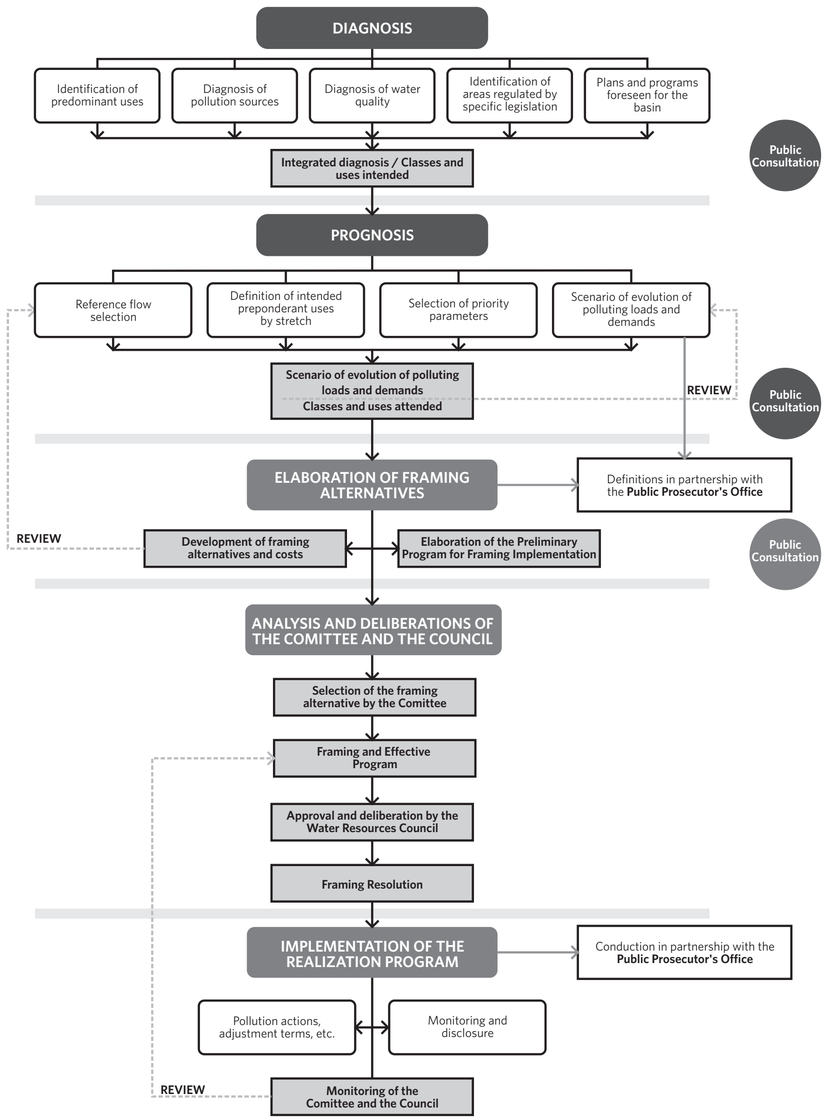
> The first water body classification system of Brazil was proposed in São Paulo, in 1955, by State Decree nº 24.806. At the federal level, the first classification initiative took place in 1976, in which the Ministry of Interior, through Ordinance nº 3, classified freshwater according to the preponderant uses for which the waters were intended. Ten years later, this Ordinance was replaced by Conama Resolution nº 20, which established a new classification for the fresh, brackish and saline waters of the National Territory, distributed in nine classes according to the predominant uses for which the waters were intended. In 1997, with the enactment of Law nº 9.433, the instrument was incorporated into the National Water Resources Policy. It is noteworthy that the framing is also a reference for the National Environment System, as it represents, among others, water quality standards for licensing and environmental monitoring actions.
> In 2005, Conama Resolution nº 357 is published, replacing Resolution nº 20, which governs the framing of water bodies, together with Conama Resolution nº 396/2008, which deals with groundwater framing.
> Finally, the CNRH approves Resolution nº 91/2008, which provides for general procedures for framing surface and underground water bodies[25(44)].

In the state of Rio de Janeiro, with the exception of the Guandu Committee, the other State Committees have not yet proposed the framing of state-owned rivers, so they are considered Class 2, unless current quality conditions are better, which will determine application of the corresponding strictest class, according to art. 42 of Conama Resolution nº 357. The portions of the Paraíba do Sul River, of federal domain, were framed by Ordinance GM/086, of June 4, 1981, and are between Classes 1 and 2.

The Resolution of the CNRH nº 91/2008[11] divides the framing activity into five basic steps (*figure 2*): diagnosis, prognosis and elaboration of framing alternatives, Committee deliberation and implementation of the framing program. The first three steps can be considered technical, but should be conducted in close relationship with the Basin Committee, in order to conduct public consultations, outline scenarios and define actions.

The last two actions have a more political/decision-making character that should be conducted by the Basin Committee together with its Technical Agency.

Figure 2. Flowchart of the steps to implement the framing of surface water bodies based on the Resolution of CNRH nº 91/2008.



Source: Adapted from ANA[25].

The diagnostic stage concerns the current state of the basin, it is a momentary portrait that should have primary and secondary data. In this regard, it should be noted that there is a widespread practice of performing diagnoses with only secondary data, but in the specific case of framing, there should be, rather, primary data collection, because there is no way to frame stretches of rivers where water quality is unknown. The diagnosis should minimally include[25]:

1. Identification of the predominant uses in the basin: it can be done based on the register of water resource users in the region, by consulting the Basin Committee, based on information from Emater for agricultural uses, from Firjan for industrial uses, from enterprises licensed etc.

2. Identification of sources of pollution: the same sources can be used to identify predominant uses. In addition, fieldwork is strongly recommended to determine if databases are consistent with field reality.

3. Water Quality Diagnosis: systematic monitoring data can be used if there are stations in the study region. Academic papers are also a valuable source of data. On the other hand, it is extremely important to conduct field campaigns to collect updated data in the places of interest.

4. Identification of areas with specific regulation: this is the case of protected areas, industrial districts, indigenous and quilombola areas, etc. Such information should be gathered from a detailed local survey.

5. Articulation with other instruments: framing must know and be articulated with other plans and programs, such as, Municipal Master Plan, Economic Ecological Zoning, Water Resources Plan, Sanitation Plan etc.

The prognosis, the second stage, concerns the projection of possible trajectories of the watershed over a considered time horizon, its activities should, at a minimum, comprehend[25]:

1. Reference Flow: selection of a reference flow for use in simulations, generally adopted at Q_{95} or $Q_{7,10}$.

2. Predominant Uses: definition by excerpts in close articulation with the Basin Committee, whose excellence is the representation of the segments impacted by this decision.

3. Monitoring parameters: selection of priority parameters to be monitored and modeled in future scenarios. Although not formally documented, there is a tacit consensus that it is not possible to conduct a framing based on all the parameters of Conama nº 357/2005. As a result, it expresses the importance of verifying the parameters effectively monitored by the environmental agency and, as far as possible, to consult the framing processes already carried out. For greater process safety, consultation with the State Water Resources Council, which is ultimately responsible for validating the Framing process, is recommended.

4. Polluting load: definition of the evolution scenarios of the polluting load, at this point must be considered both the increase of the loads that may be due to the population increase, the economic growth, etc., as well as the decrease of the load due to investments in treatment and their reduction.

The elaboration of the framing alternatives, the third step, is based on the scenarios modeled in the prognosis. Essentially, it should contain the main actions to be taken to reach the adopted scenario, as well as the cost estimates associated with a realization program of the framing.

The analysis and deliberation of the Committee, as well as validation by the

Water Resources Council, are more political activities involving the consensus of the segments represented in the Basin Committee and other local political actors, given that a program of investments and actions by various actors, such as city halls, sanitation agencies, environmental agencies, etc. is needed.

The last and most complex step is the realization of the framing program. It is the most challenging activity to understand the actions themselves, works, reforestation, construction of sewage and treatment plants, expropriations in risk areas etc.

Based on this brief exposition of the framing steps, it can be seen that the effective implementation of a framing program is ultimately a river rehabilitation project or, in the second instance, an instrument that maintains the existing quality.

Conclusions

The monitoring data synthesized by the WQI_{NSF} presented show that the Piabanha River is highly impacted, and if structural interventions are not performed in the basin, there is a growing trend of water quality degradation, and consequently, an increase in waterborne diseases.

The implementation of a framing program improves the water quality of a river and, in this respect, resembles a river rehabilitation project.

Some concepts applied to ecological restoration and described in this paper are highly recommended to be applied in framing projects, namely: engagement of the interested parties; clear specifications of objectives and goals; clarification of rehabilitation actions; guarantee of property rights in the intervention areas; logistic analysis; no additional damage caused by the project steps; qualified follow up; support for natural processes; adaptive management; legal compliance and communication.

In addition to the stages listed in CNRH Resolution nº 91/2008, which provides for the framework, we can highlight five guidelines that we consider pertinent to the framing's success, namely:

1) Knowledge of water quantity and quality characteristics is fundamental for water resources management, so it is recommended that the Water Basin Committees define, in partnership with their technical agencies and the state water management body, the systematic monitoring points and its periodicity. Ultimately, it is recommended that the cost of monitoring be incorporated and absorbed by charging for water use.

2) The Water Basin Committees are legally obliged to propose the Framing and its short, medium, and long-term goals. On the other hand, the same legislation that confers this duty does not give the Committees coercive and supervisory mechanisms for its implementation. Given the complexity of the Framing and the diversity of intervening institutions involved in its implementation, it is recommended that this process be conducted in partnership with the Public Prosecutor's Office so that, in fact, a commitment to the goals of the project is agreed.

3) The Multiannual Investment Plans of the Committees should reflect in their budget the goals of the Framing, this means making the investment plan so as to avoid 'scattering of resources' in several (and important) projects, but that do not actually return direct qualitative and quantitative increments.

4) Engagement of the interested parties is a key factor for the success of any project, therefore, social communication is essential. It is recommended the elaboration of newsletters, with high visual quality, to be broadcasted in different media categories.

5) Regional knowledge and institutional articulation are strategic factors for the

success of the Framework project. It is recommended to set up, in partnership with the Public Prosecutor's Office, a working group composed strictly of technical experts representing the institutions involved in the project. It is desirable that this group be highly qualified and composed of a small number of technicians, ideally one representative from each institution.

In order to complement the guidelines, the experience of the participation of the authors in the Piabanha Committee allows to emphasize highly recommended experiences to be resumed/expanded, such as Piabanha River Park and the Payments for Environmental Services (PES). Another highly successful initiative is the Piabanha River Riparian Forest Range (FMP), which, however, lacks a specific program of forest restoration, in association with other actions, already discussed by the Committee, as information boards and implementation of physical limits of FMP.

Finally, it is understood that the success of the Framing process and its goals depend on the universalization of sanitation in the basin.

Collaborators

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