Evaluating the Intelligibility of Cartographic Representation Techniques used for Water Quality Monitoring Framework in Brazil.

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Key words: water quality monitoring framework, cartography, semiology, intelligibility

SUMMARY

The Brazilian water quality monitoring framework (WQMF) is a tool used for land and water zoning revealing the establishment of qualitative biochemical and physical parameters according to water uses. Intelligible maps are essential for WQMF as social participation is constant during all the process. The absence of consensus among professionals when representing categories of water in maps imposes comparison difficulties amongst studies. Evaluating public perception of WQMF maps consisted in offering 5 different maps to 25 professionals and asking them to classify these according to their understanding of 3 main aspects: understanding of map purposes, continuity of water bodies and visual accuracy of the border between water categories. The results showed there was a better interpretation of the map composed by two different lines: one blue and continuous external line for the water bodie and a color-variable internal line for water quality categories. The conclusion is that colors and semiology aspects are essential to WQMF mapping due to it´s role in participatory phases of WQMF establishment, thus correct and fast interpretation by steakholders is desired. Therefore it is suggested that more detailed studies take place in order to generate guidelines for the semiology for WQMF map representation locally and, if posible, globally.

SUMMARY - PORTUGUESE

O Enquadramento de Corpos d'água (ECA) é um instrumento de ordenamento do uso da água no qual se estabelece classes qualitativas que são propostas para cada corpo hídrico de acordo com os usos preponderantes. A geração de mapas que possibilitem um bom entendimento pelos atores na gestão da água é essencial no processo de ECA, sendo requerida atenção especial na geração de mapas para as propostas de enquadramento. O desafio é a inexistência de consenso acerca da representação cartográfica das classes de água com uma oferta de mapas construídos com lógicas distintas, dificultando a comparação entre os estudos. Para avaliar a percepção do público em relação a inteligibilidade de mapas de ECA, foram apresentados, a 25 técnicos, 5 mapas e questionários estruturados avaliando quesitos de entendimento global, continuidade e clareza da fronteira entre classes. Os resultados revelam maior inteligibilidade do mapa que apresenta uma conjugação de 2 linhas: uma borda azul e um centro de cores distintas. Conclui-se que as matizes e os aspectos semiológicos são importantes no entendimento de mapas de enquadramento principalmente por causa do papel destes nas fases participativas, já que um entendimento rápido e conciso por parte dos atores é desejável. Assim, se sugere que mais estudos sejam realizados para que se faça um esforço na definição de uma comunicação cartográfica consensual a respeito ECA tanto em nível local como em nível global, se possível.

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1. INTRODUCTION

The Brazilian water quality monitoring framework (WQMF) is a tool used for land and water zoning revealing the establishment of qualitative biochemical and physical parameters according to water uses. The juridical aspects of the Brazilian water quality monitoring framework where established in 1997 by the Brazilian law 9.433 - National Policy on Water Resources Management.

The framework tool was developed in order to promote a better understanding among water users and stakeholders to achieve multiple water use and ensure a more intricate management of the existing water resource tools.

As water quality depends on all the substances that compose the hydrical solute system and due to geographical aspects, water that precipitate brings many residues from the soil, atmosphere, vegetation and urban areas to the lower parts of the watersheds (water bodies) as a result of gravity. For water management purposes it means that water quality is determined by all land uses in the drainage basin (Von Sperling, 1996).

For this reason, water quality monitoring framework is an important tool for land use regulation and discipline, thus the water categories chosen depend on land use in the drainage basin and at the same time after a category is determined, some activities may occur and some may not regarding the water quality aim.

Due to this strict relation between social, economical and sanitary issues and watershed management the subject is complex and demands articulation and participation. The Brazilian water quality monitoring framework, as a law, requires the participation of as many stakeholders as possible and may take place progressively and according to social and technical decisions (ANA, 2006). Social engagement is important for the decision making and for the discussion of social, political, economical, regional and environmental aspects.

Water quality monitoring framework in Brazil may be applied with the other existing tools for water management and shall not be centralized as it may occur as a result of a participative process. The resolution number 91/2008 of the Brazilian National Council of water Resources (CNRH) defines the techniques that may be used in order to develop the whole WQMF process.

These guidelines suggest the following phases: diagnosis, prognosis, Water quality objective proposals and water framework effectiveness program. All these phases may occur with stakeholder participation. The diagnosis phase also requires mapping vulnerable areas regarding the risks and effects of water contamination, water overexploitation and scarcity, the potential conflicts between water uses, the erosion and material deposition potential, and still, the identification of areas that may be landslide and flood prone.

For participative purposes mapping is needed in a WQMF process, but because many stakeholders are laic the intelligibility of cartographic representation may be good, so that understanding spatial information is not an obstacle.
Water categories are determined by the resolution 357/2005 of the national environmental council of Brazil and each one of them has qualitative demand. Many studies regarding Water quality monitoring framework were taken in Brazil, and there are no rules for the creation of cartographic material, thus frequently studies apply different semiology and color patterns, what is rather confusing and misleading.
The water classes (categories) were disciplined by CONAMA resolution number 357 from 2005 (CONAMA - Brazilian National Environmental Council). These classes mentioned are separated in terms of water quality objectives and environmental goals. The water classes represent mainly the water quality aimed for each water body or water body segment. The cartographic ways of representing these classes, in Brazil, is not yet standardized, what incurs in the use of all sorts of different semiology in maps regarding Water Quality Framework.
In Brazil there are several water classes established, for continental superficial freshwater there are 5 classes (special, class 1, class 2, class 3 and class 4), for superficial continental brackish water there are four classes (special, class 1, class 2 and class 3) and for salty water (sea) there are four classes as well (special, class 1, class 2 and class 3).
Water quality objectives (such as classes) are combinations of measurable values which are determined (technically, economically and socially) to obtain a certain water quality, thus it can offer the protection and or maintenance of the environmental values aimed.
Mapping is an important part of the Water quality monitoring framework process since the information dissemination depends on written documents and maps which shall be intelligible, thus the capacity building of many stakeholders relies on that. In this case, especially because there are technicians as well as people specialized in many other matters, maps should be easily understood.
According to Resolution number 91 edited by the Brazilian Water Resource Council (CNRH) the establishment and revision of water quality objectives is related to participation in almost every stage. The participation mentioned involves stakeholders from different backgrounds and epistemologies, such as general social agents that live or work in the watershed affected, governmental representatives and water users and economic groups (Hydro energy producers, fishermen, nature conservancy groups, industry leaders, aquiculture producers, sanitation enterprise leaders, water management technicians, etc).
This study aims to evaluate the intelligibility of cartographic representation techniques used on water quality monitoring framework processes in Brazil considering that many authors, such as Taylor (1994), mention that through cartographic cognition the human mind is able to recognize patterns and the relation between them in a special context.
Therefore it is essential that a Geographic Information System for Water framework processes is compiled and organized, and attention is needed in this sector in order to organize and represent good enough water quality preliminary, intermediate and final objectives.
The greatest challenge faced, in this subject, is that there are no guidelines, standards and therefore no consensus worldwide regarding semiology that may be applied when representing water quality objectives, what generates WQO maps showing absolutely different semiology attributes.

All water quality monitoring framework studies analyzed, produced by diverse groups of technicians, offer maps that are hard to compare, which are based on distinguished logical systems and cannot be associated easily to the main theme. Therefore, considering the previous problematic there was a need to start discussing this subject to pursue on the definition of standards and methods for the production cartographic material associated to WQMF studies and processes.

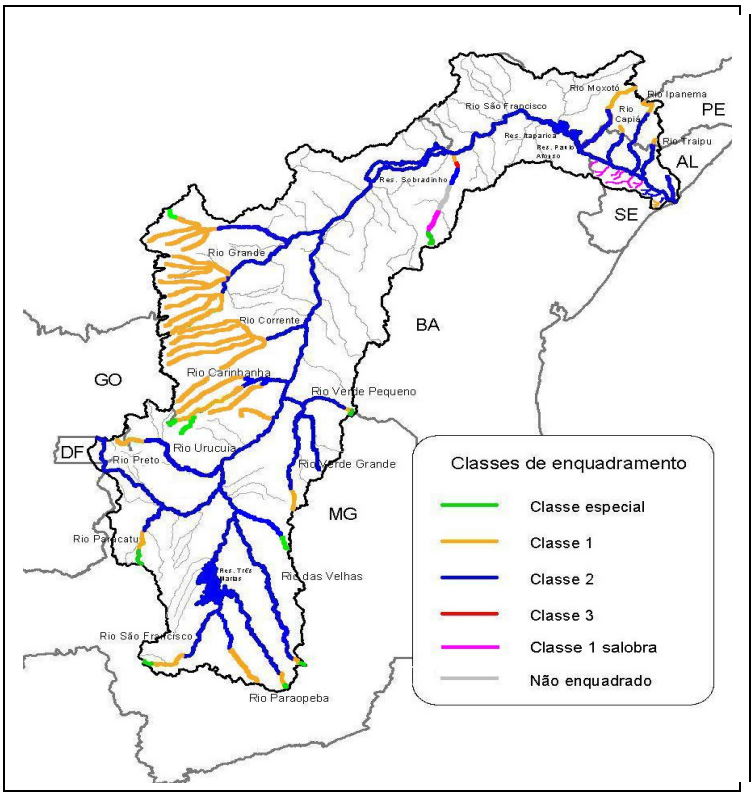
2. DEVELOPMENT

Supposing to analyze different water quality monitoring framework cartographic material, the researchers scrolled and picked 2 studies/processes held in different watersheds in Brazil and reviewed many of their semiology aspects in a pursuit to get enough material to evaluate the actual need to take this theme to light.
Among the WQMF studies analyzed the researchers observed that there was random color designation for water quality objectives represented by water classes. That seemed confusing at a first glance, and therefore the color scheme observed was tested and will be described later on this paper.

2.1 The Integrated land and watershed activity management on the Sao Francisco River Basin watershed.

- Original name of the project: Projeto de Gerenciamento Integrado das Atividades Desenvolvidas em Terra na Bacia do São Francisco
- Entities involved on this research

ANA - Brazilian National Water Agency – www.ana.gov.br
GEF - GEF International Waters – World bank – www.worldbank.org
UNEP (PNUMA) United Nations Environment Program PNUMA http://www.unep.org/)
OAS (OEA) - Organization of American States - http://www.oas.org)
Within this Project there was the proposition a water quality monitoring framework for the River São Francisco Basin, they used as a basis the pre existing study n° 715 done by IBAMA (Brazilian Environmental Institute) for the same watershed published in 1989 that defined water quality objectives (WQOs) to main federal domain rivers and recommended WQOs to state domain rivers as well. Other main data was taken in account.
As it is a product of many distinct Water quality monitoring framework Directives produced along many decades by different entities, what is presented is a converging proposal considering water uses in the present, past and future (prognosis) and reveals prospects of economical values to be invested in the watershed aiming to achieve them.
In 2004, general public had access to this data (including maps) and discussed it heading towards a final proposal that was accepted by all entities implied.

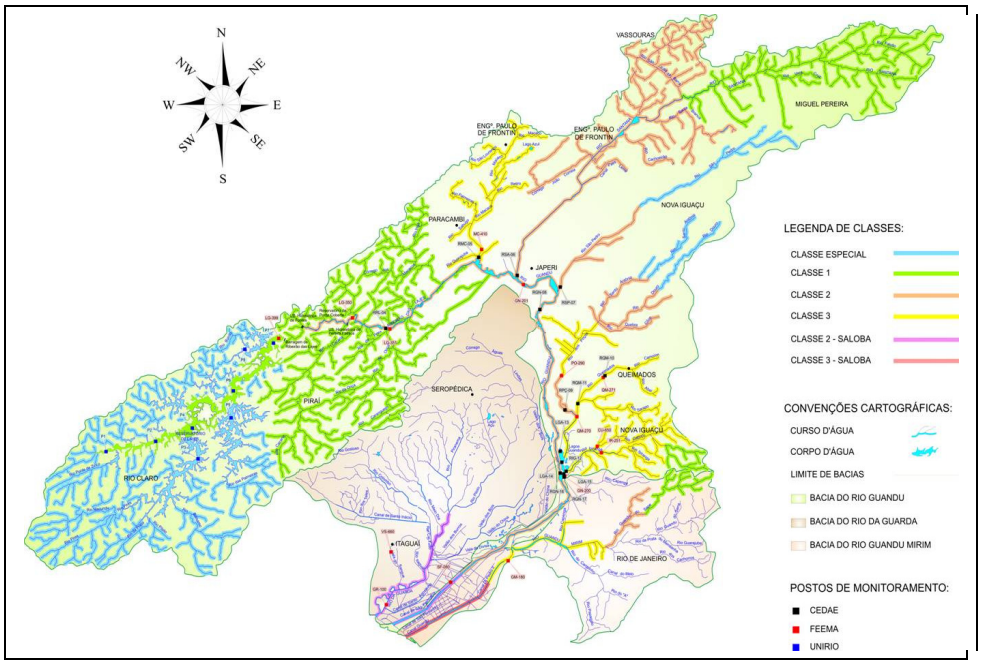


Map # 1 - Water Quality Objectives Map in the quality framework for the River São Francisco Basin, 2004

2.2 Water Strategic Plan for the River Guandu, Da Guarda and Guandu Mirim Watersheds.

- Original name of the project: Plano Estrategico de Recursos Hídricos das Bacias Hidrográficas dos Rios Guandu, da Guarda e Guandu Mirim
- Entities involved on this research : Sondotecnica

This study was done by a technical staff and later approved by the Rio de Janeiro State Water Council (resolution number 20 of 2007), attempting to define water quality classes, the staff involved made a table using present water quality data an comparing this data to the water quality objectives they understood to be more adequate. This generated ratios relation water quality and water quality objectives that lead to their composition of the Water quality monitoring framework Proposal.



Map # 2 - Water Quality Objectives Map in the Water Strategic Plan for the River Guandu, Da Guarda and Guandu Mirim Watersheds – Reference : SONDOTECNICA, 2007

Both maps were analyzed took in account linear nominal symbols and the visual appearance variable "color" to specify each Water Quality Objective (WQO class). Since there are no Standards for water quality representation in Brazil, the studies reviewed followed color and appearance attributes chosen by each staff.
The maps studied have different color Standards to represent the same WQO class. Both maps have the same semiology complexity and same intelligibility difficulties, amongst which the researchers concluded for a lack of continuity of the river or water body itself and a lack of continuity for the criteria observed in each WQO class that could be represented, for example, by a gradual change in the absorption tinting strength.

3. STATEMENT OF OBJECTIVES

The main objective of this study is to start a discussion about the need of Standardization of the cartographic material representing water quality objectives on freshwater quality monitoring frameworks focusing on cognition and intelligibility factors.
The specific objectives are based specially on the evaluation of five different Maps representing water quality objectives.
Regarding the five offered Water Quality Objectives Maps, the following criteria was analyzed:

- General Intelligibility
- Continuity of the water body represented
- Visibility of the frontier between Water Quality Objectives (WQO) in the water body

The goals, considering the exposed criteria, where to:

- Evaluate the intelligibility of the maps offered, what could possibly guide researchers when establishing standards to represent Water Quality Objectives.
- Create a scale of understanding (intelligibility) considering the answers given by the observers after the receipt of the stimuli and understanding partially their sensation when exposed to the Five Maps.
- Collecting data and ideas about appearance attributes to promote a better understanding of cognition aspects to solve standardization of water quality issues.

4. METHODOLOGY

To perform the evaluation of intelligibility aspects related to cartographic material involved on Water Quality Objectives and Monitoring Frameworks, five different Maps representing water quality objectives where put together and further exposed by both authors to a series of technicians.

All maps produced had the same basis, which is the map exposed previously as the Water Quality Objectives Map in the quality framework for the River São Francisco Basin, 2004.

The Maps where planned and executed on Arc GIS 9.3 software and the techniques applied were cartographical representations of water quality classes using qualitative data in Five distinguished manners.

Many visual qualitative variables were used such as appearance attributes including colors and textures. Grades (from zero to ten) were used to evaluate satisfaction and understanding of maps to make quantification viable**.**

The Maps were identified by alphabetical elements, A, B, C, D and E and presented to different people from distinct backgrounds between June 5th and 9th 2009.

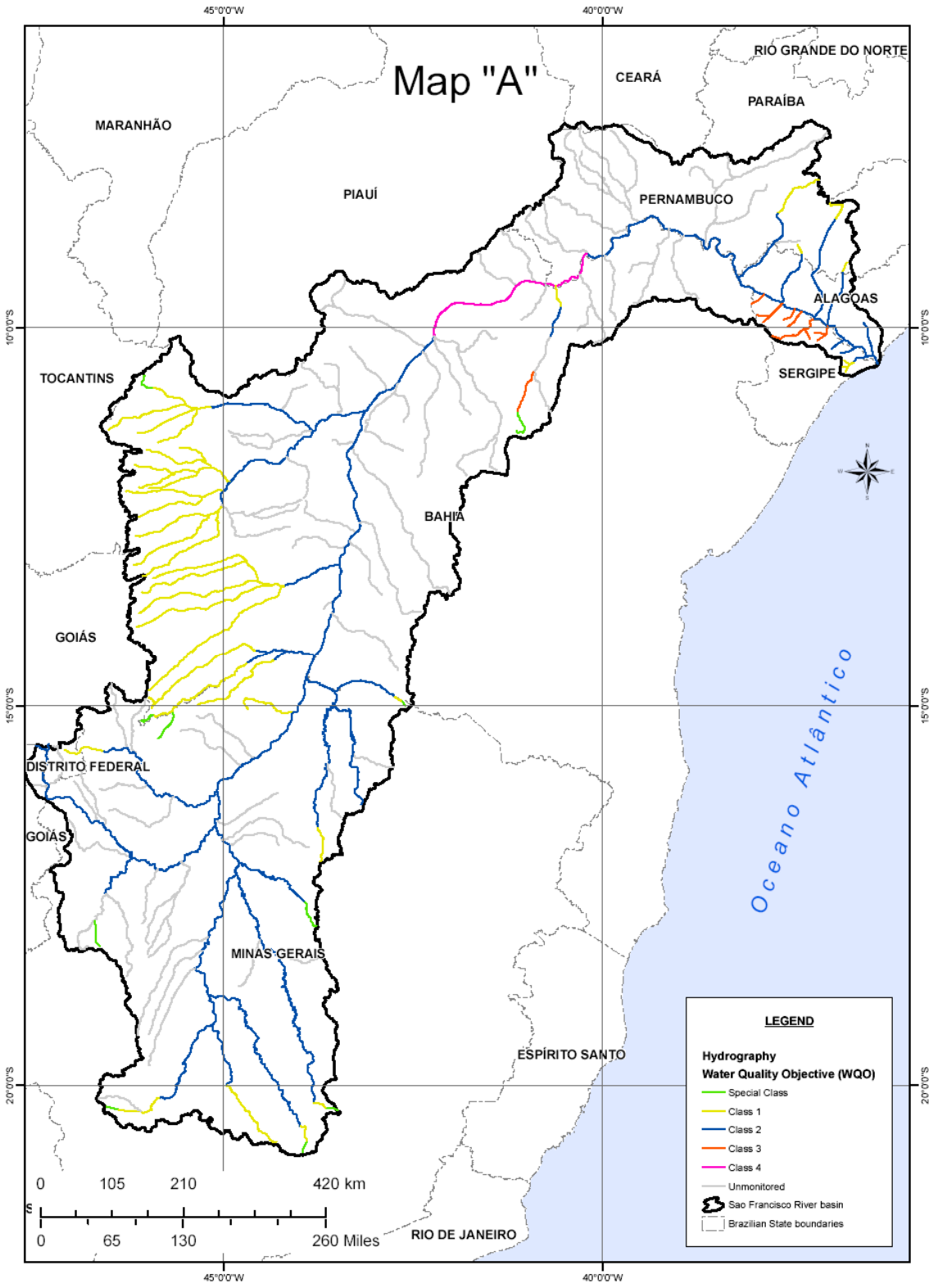
Map A was very much alike the original map produced by the Brazilian National Water Agency for the São Francisco River Basin in 2004. This map is based on a qualitative data through linear nominal symbols, represented by the variable color.

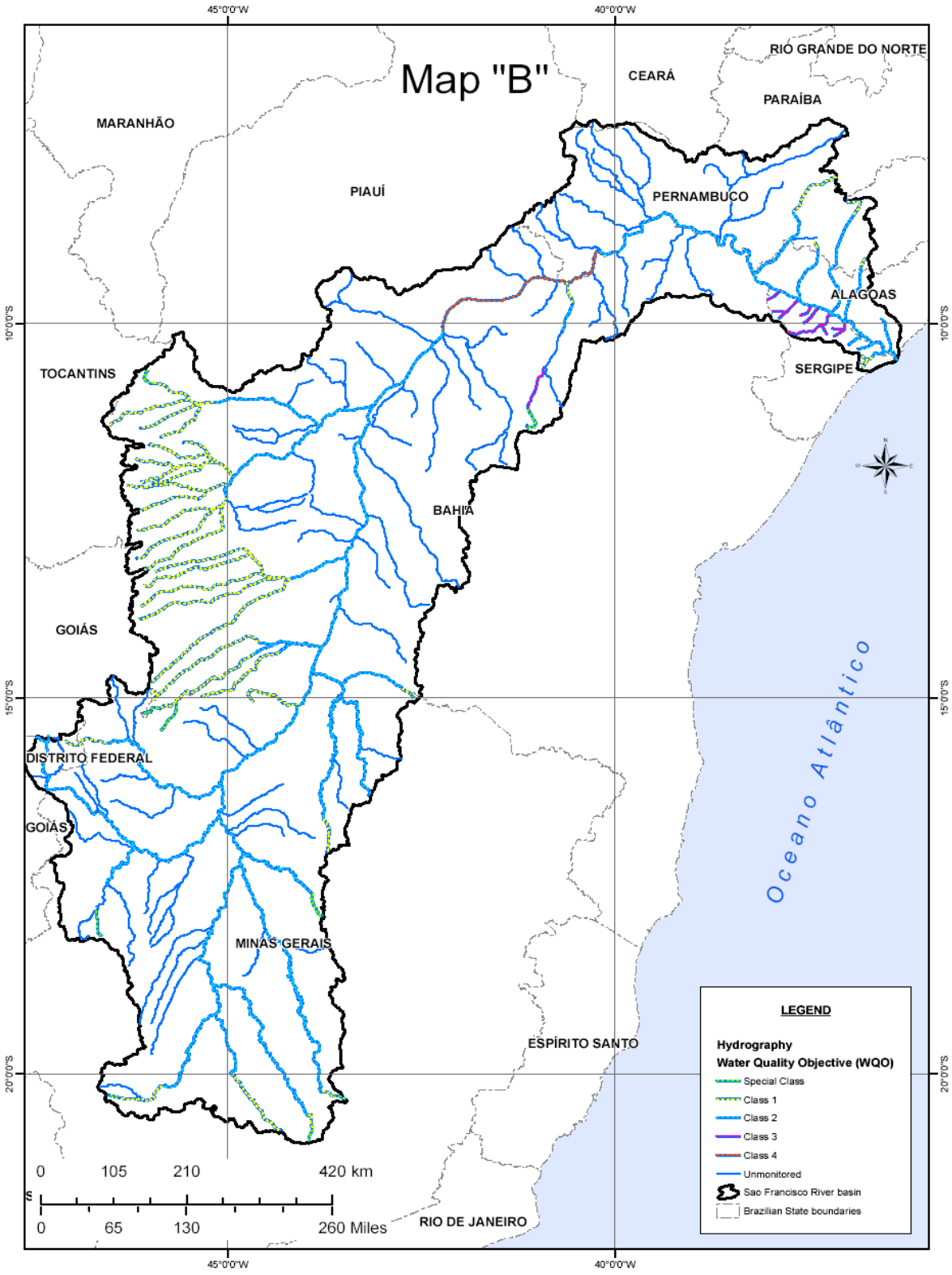
In Map B, the Cartographer applied the same method as for Map A, adding to that two different elements: a longitudinal blue line and many transversal blue lines. What the authors intended was to cause an idea of "continuity" by using the blue color and texture.

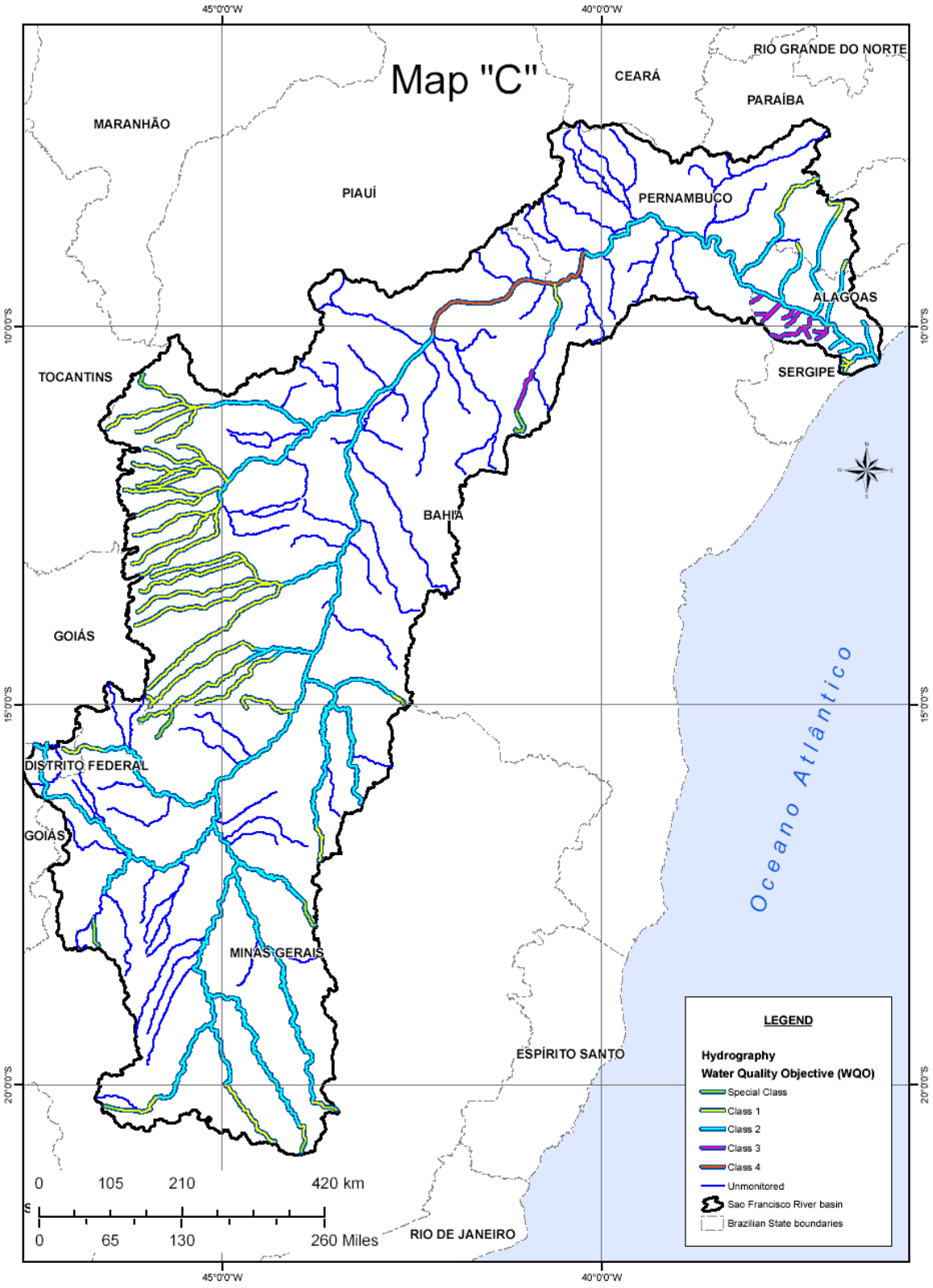
Map C was made using as basis Map A and the longitudinal blue line applied on Map B, using as variable two distinguished lines (one blue and broader under and one colored to show water classes straighter over the first one)

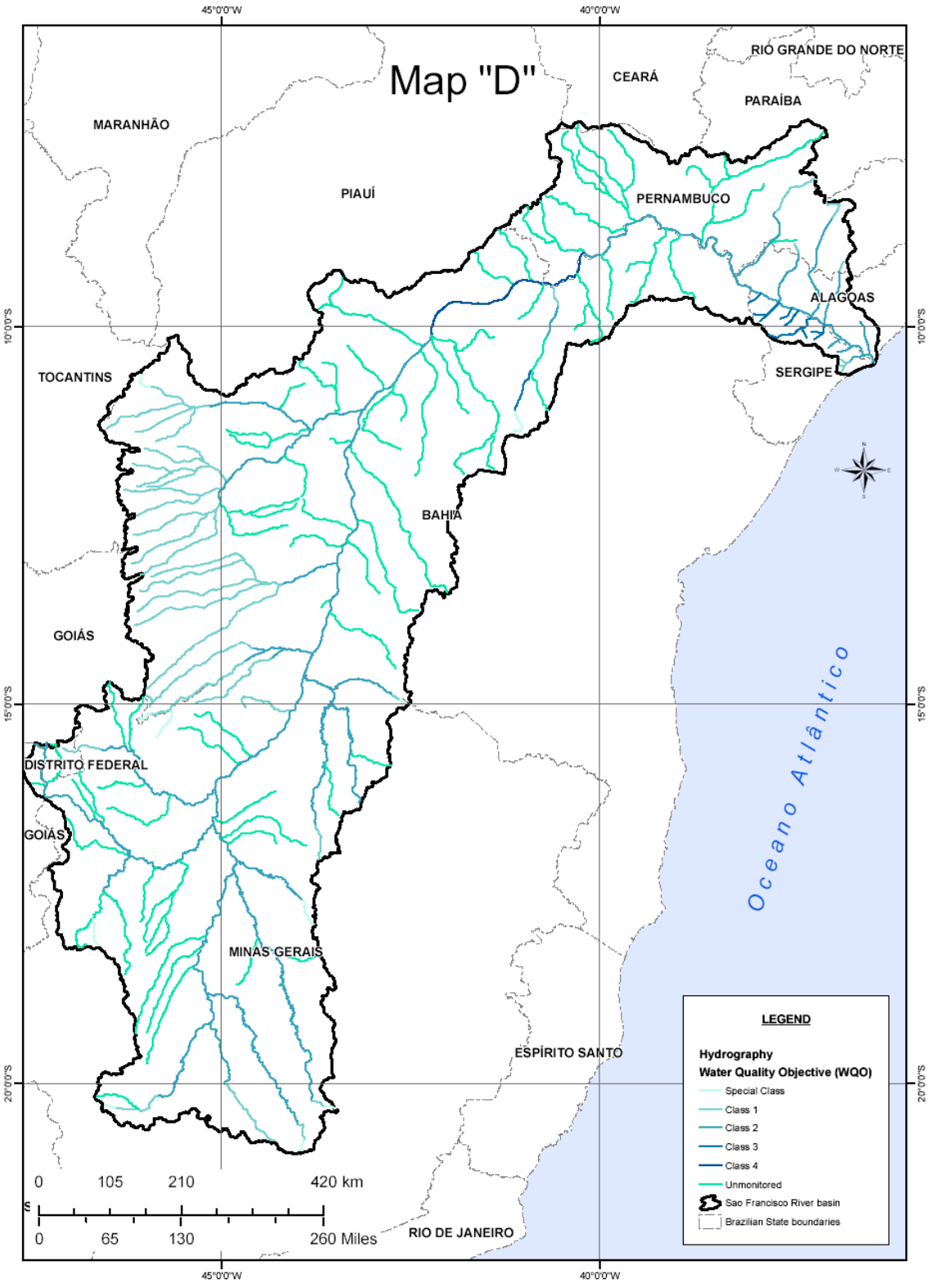
On Map D, intending to represent water quality classes as a gradual change in water quality criteria, a variance of brilliance was used for the same color (blue for instance), in this map the brighter blue represents WQO special class (greater land and water use restrictions and better water quality conservation) and the deeper blue represents WQO class 4 (less land and water use restrictions plus less water conservation status).

Map E is based mainly on the blue line with brilliance variance representing WQO classes' conjunct with a blue steady (always same value) broad line under the first.


Map "A"
45°0'0"W
40°0'0"W
10°0'0"S
15°0'0"S
20°0'0"S
RIO GRANDE DO NORTE
CEARÁ
PARAÍBA
MARANHÃO
PIAUÍ
PERNAMBUCO
ALAGOAS
SERGIPE
TOCANTINS
BAHIA
GOIÁS
DISTRITO FEDERAL
GOIÁS
MINAS GERAIS
ESPÍRITO SANTO
RIO DE JANEIRO
Oceano Atlântico
0 105 210 420 km
0 65 130 260 Miles
LEGEND
Hydrography
Water Quality Objective (WQO)
Special Class
Class 1
Class 2
Class 3
Class 4
Unmonitored
Sao Francisco River basin
Brazilian State boundaries


Map "B"
45°0'0"W
40°0'0"W
10°0'0"S
15°0'0"S
20°0'0"S
MARANHÃO
PIAUÍ
CEARÁ
RIO GRANDE DO NORTE
PARAÍBA
PERNAMBUCO
ALAGOAS
SERGIPE
TOCANTINS
BAHIA
GOIÁS
DISTRITO FEDERAL
GOIÁS
MINAS GERAIS
ESPÍRITO SANTO
RIO DE JANEIRO
Oceano Atlântico
LEGEND
Hydrography
Water Quality Objective (WQO)
Special Class
Class 1
Class 2
Class 3
Class 4
Unmonitored
Sao Francisco River basin
Brazilian State boundaries
0 105 210 420 km
0 65 130 260 Miles


Map "C"
45°0'0"W
40°0'0"W
10°0'0"S
15°0'0"S
20°0'0"S
RIO GRANDE DO NORTE
CEARÁ
PARAÍBA
MARANHÃO
PIAUÍ
PERNAMBUCO
ALAGOAS
SERGIPE
TOCANTINS
BAHIA
GOIÁS
DISTRITO FEDERAL
GOIÁS
MINAS GERAIS
ESPÍRITO SANTO
RIO DE JANEIRO
Oceano Atlântico
0 105 210 420 km
0 65 130 260 Miles
LEGEND
Hydrography
Water Quality Objective (WQO)
Special Class
Class 1
Class 2
Class 3
Class 4
Unmonitored
Sao Francisco River basin
Brazilian State boundaries


Map "D"
45°0'0"W
40°0'0"W
10°0'0"S
15°0'0"S
20°0'0"S
MARANHÃO
PIAUÍ
CEARÁ
RIO GRANDE DO NORTE
PARAÍBA
PERNAMBUCO
ALAGOAS
SERGIPE
TOCANTINS
BAHIA
GOIÁS
DISTRITO FEDERAL
GOIÁS
MINAS GERAIS
ESPÍRITO SANTO
RIO DE JANEIRO
Oceano Atlântico
0 105 210 420 km
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Hydrography
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Class 1
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Class 4
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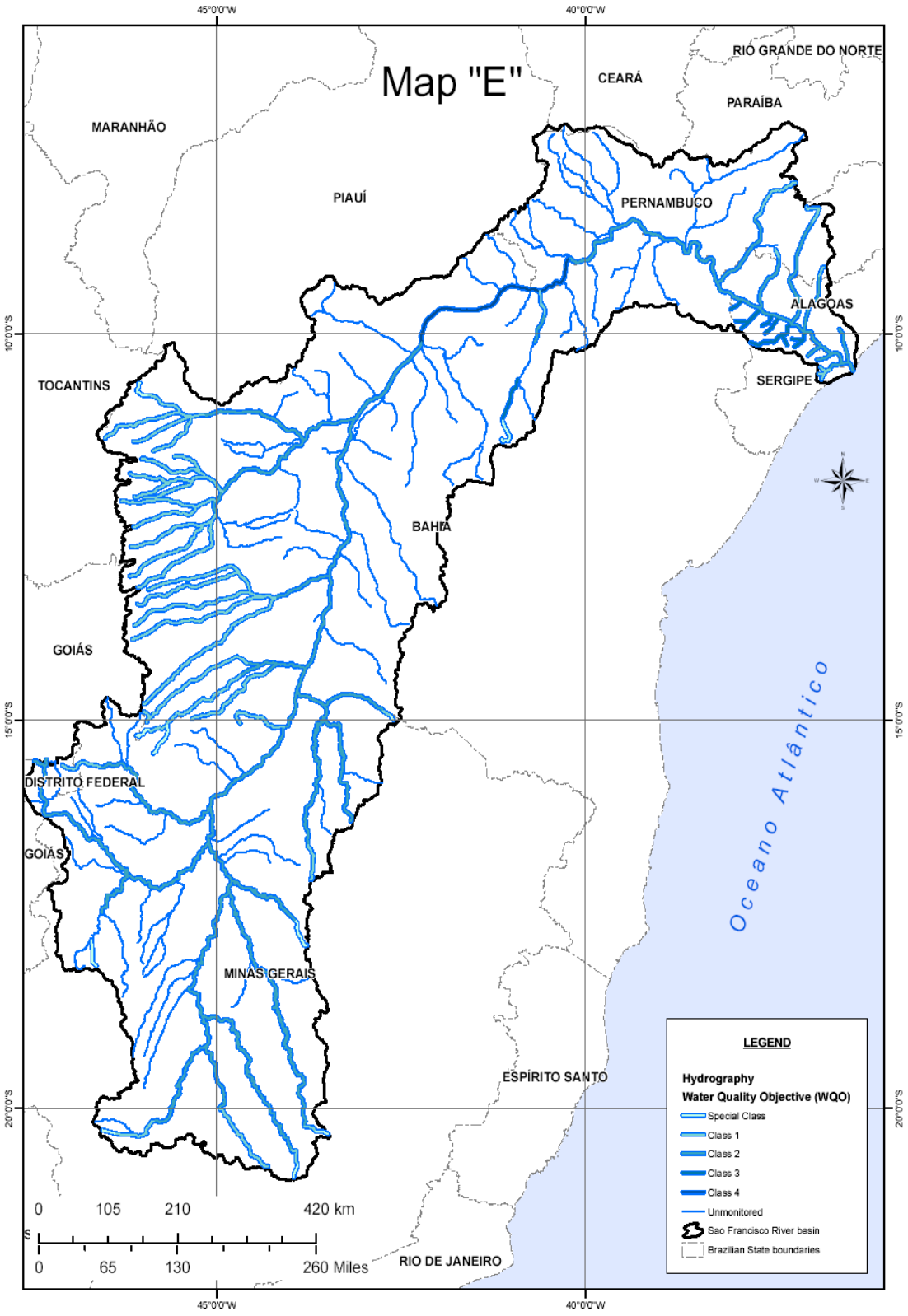
Sao Francisco River basin
Brazilian State boundaries


Map "E"
45°0'0"W
40°0'0"W
10°0'0"S
15°0'0"S
20°0'0"S
RIO GRANDE DO NORTE
CEARÁ
PARAÍBA
MARANHÃO
PIAUÍ
PERNAMBUCO
ALAGOAS
SERGIPE
TOCANTINS
BAHIA
GOIÁS
DISTRITO FEDERAL
GOIÁS
MINAS GERAIS
ESPÍRITO SANTO
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0 105 210 420 km
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LEGEND
Hydrography
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Unmonitored
Sao Francisco River basin
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The Technicians interviewed were:

- 7 Geography undergraduate students taking GIS as a chair in Santa Catarina Federal University
- 11 Water Resource Management Technicians that serve the Sustainable Economic Development State Secretariat (Santa Catarina State) in Florianopolis
- 5 Multi professional Technicians of the Regional Development Policy Secretariat of the National Integration Ministry of Brazil in Brasilia
- 2 Technicians from an Enterprise specialized on Environmental Planning in Brasília.

The Maps were printed twice, one set for the evaluation of the Technicians interviewed in Florianopolis, the other set for those in Brasilia).
In Florianopolis the Papers used were clean light recycled paper sheets of an A4 size and the printer used was a Hewlett-Packard DeskJet 9300 A3. The printer used for the same Map set in Brasilia was a Hewlett-Packard DeskJet D1560 filled with White A4 size paper.
The Five maps were printed in A4 size in both cases to simulate the real practice in Participative dynamics in Brazil, in these kind of event, the lack of map printers and adequate paper is frequent and if this article was tested using maps printed in appropriate glossy paper and Professional Map printers, probably the situation simulated would be very distant from what actually happens on Watershed organisms and the results may not suit Water management effectively.
Aiming to prepare the technicians that evaluate the five maps, simulating the stakeholder and social participation, a brief explanation about the theme (Water Quality Monitoring Framework) was given. The capacity building was not complete or intended to be, but was enough to prepare people to observe water quality maps and know water quality, not quantity, was the main subject discussed.

5. RESULTS

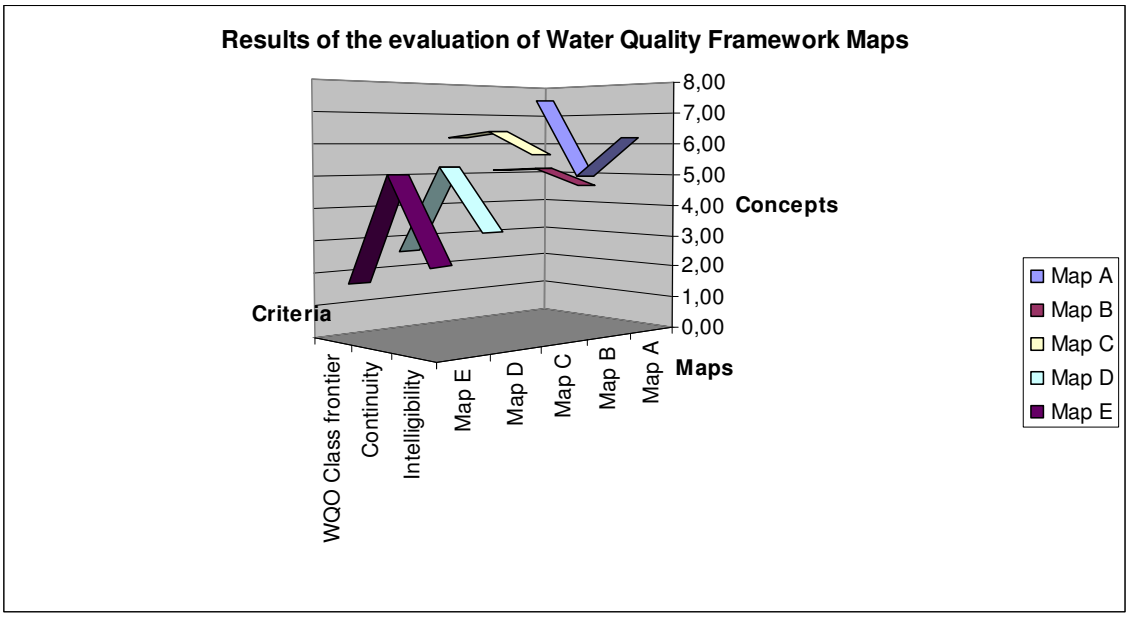
The Five maps were exposed to 25 technicians between 5th and 9th June, 2009, and the results were based on the grades given by them regarding the criteria questioned, general intelligibility, continuity of the water body represented and visibility of the frontier between Water Quality Objectives (WQO) in the water body.

Maps received grades from *a* to *e* in which
Grade a represented qualitatively Excellent comprehension and quantitatively 10,00 points
Grade b represented qualitatively Very Good comprehension and quantitatively 7,50 points
Grade c represented qualitatively Good comprehension and quantitatively 5,00 points
Grade d represented qualitatively Poor comprehension and quantitatively 2,50 points
Grade e represented qualitatively unsatisfactory comprehension and quantitatively 0,00 points

All results were analyzed for each criterion and generally Map by Map and then an average value was observed for each criterion in each map as shown in the table.

Table 1 – Results of the tests run to perceive the understanding of WQO Maps.

	MAP				
CRITERION	**A**	**B**	**C**	**D**	**E**
General Intelligibility	6,2	4,7	5,7	3,4	2,5
Continuity of the water body represented	4,9	5,2	6,4	5,3	5,1
Visibility of the frontier between Water Quality Objectives	7,5	5,1	6,2	2,6	1,7
Average value	6,2	5,0	6,1	3,7	3,1
extent of inequality among the 3 criteria	2,6	0,5	0,7	2,7	3,4



The results point to two Maps that have got better grades on the general sum according to technician's evaluation: Maps A and C, what leads the researchers to the insight that for water quality issues colors may be good semiology attributes.

Map A uses linear nominal symbols, represented by the variable color and Map C was made using as basis Map A and the longitudinal blue line using as variable two distinguished lines (one blue and broader under and one colored to show water classes straighter over the first one). Map C, even though rated with an average slightly worse than Map A (0,1 points), was concluded to be the best among the five test maps analyzed because it has a better equilibrium between the criteria, what is exposed on table 1 as the extent of inequality among the 3 criteria (Understanding, Continuity and WQO Class Frontier).

Probably this result was given because the broad blue line gives the idea of continuity while the colored thin line makes it easier to distinguish the water quality objective classes and exact location of the frontier between them.

In Map A one of the main problems observed (written by technicians that observed the Maps) was actually recognizing the Hydrography in the Map and the lack of continuity. In some parts of the map it seemed to them that water bodies were not connected. This is quantified

and qualified by the grade average of this criteria for Map A, that was considered unsatisfactory (4,9).

Observing public preferences and cognition aspects, we suggest that further research is done, taking in account some aspects observed on this paper:

- For water quality representation colors are good semiology attributes, especially because they lead to a better understanding of category changes such as WQO classes and makes the border among them clearer.
- Blue border on water bodies may be a good attribute thus it makes the interpretation of Hydrography easier and show the continuity of the river or freshwater body system.
- Additional research involving brackish and salty Waters should be complementary and important.
- Water Quality Cartographic Representation Standards and Guidelines could be established based on research on cognition and intelligibility of maps on many national or international bases, preferably international, after more research and work is done.

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7. BIOGRAPHICAL NOTES

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Thobias achieved a bachelor in science degree in Cartographic Engineering (2003) in the São Paulo State University (UNESP) and Master in science degree by Civil Engineering program (2005) in the Federal University of Santa Catarina (UFSC) in Florianópolis. His master studies were based the development of Web Mapping for ecotourism purposes. The researcher worked previously as a Cartographer in many enterprises and his own Rotta Engenharia LTDA with his associates and is a former temporary professor on the Federal University of Santa Catarina (UFSC) where he was responsible for the GIS chair between 2007 and 2009. Since 2008 Thobias works at the Sustainable Economic Development Secretariat of Santa Catarina State –SDS (Florianopolis, Brazil) at the Water Resource Management department as a Cartographer Engineer focused on Water Resources.

7.2 Marina Christofidis

Marina is a Bachelor in Biological Sciences since 2001 by the University of Brasilia (UnB) and a Master in Science in Environmental Engineering (2006) by the Federal University of Santa Catarina (UFSC) in Florianopolis. The Researcher has published many studies on Water Quality Monitoring Framework and water management. She has worked as an Environmental Consultant in Brazil and for Global Water Partnership (GWP) and is a former temporary professor at the Santa Catarina State University (UDESC) where she taught Ecology and Urban Forestry among other themes. In the present, Marina is a Water Infrastructure Analyst at the Brazilian National Integration Ministry and is a Professor for the chairs of Water Resources Management and Ecology for the Brazilian National Environmental Guard, serving the Justice Ministry when required.

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