sociedade
& natureza

DOI: http://dx.doi.org/10.14393/SN-v31-2019-41033

Optimization of surface water utilization in the upper reach of the Uberaba River, Triângulo Mineiro region

Emiliano Silva Costa[1]
Marcio Ricardo Salla[2]
Carlos Eugenio Pereira[3]
José Eduardo Alamy Filho[4]
Guilherme de Lima[5]

Abstract
Water resources have major importance in Brazilian and global economic development because of water's multiple uses, such as drinking, irrigation, hydroelectric generation and livestock consumption, among others. Aiming to minimize water use pressure, computational tools are under development to support the planning and maintenance of water resources at the watershed level. This article has the general objective to discuss alternatives for optimization of surface water use in the upper reach of the Uberaba River, located in the Triangulo Mineiro region of Minas Gerais, Brazil. We find that the replacement of the flow calculation on the yearly $Q_{7,10}$ base by corresponding monthly base in the rainy season (December until May) and the maintenance of the yearly $Q_{7,10}$ base in the dry season (June until November) can optimize the surface water use. Among the criteria for granting water use permission, the criterion of 50% of the seasonal $Q_{7,10}$ brings the biggest increase of granted flow. Moreover, regarding the remaining flow in the watercourse, the morphology of the stretch of the Uberaba River studied guarantees the natural reoxygenation and maintenance of benthic area sufficient for the reproduction and development of aquatic life.
Keywords: Optimization of water use. Reference flow. Environmental Protection Area. Procedure to grant water use. Uberaba River.

Introduction

The conflict over the multiple uses of water is longstanding and is aggravated by the expansion of economic development, in particular the competition between agricultural and urban demands. In Brazil, the regions

[1,2,3,4,5] Federal University of Uberlandia, Uberlandia, Minas Gerais, Brazil.
[2]Corresponding author: marcio.salla@ufu.br
Article received in: 01/19/2018. Accepted to publication: 04/24/2019.

of the country in which there is a combination of low availability and large demand experience situations of water scarcity and stress.

The governmental grant of water use is a management tool that aims to ensure the quantitative and qualitative control of the underground and surface water and the effective access to entitlements. For the water use grant in the state of Minas Gerais, according to the SEMAD-IGAM Joint Resolution 1,548/12 (SEMAD, 2012), the reference flow for water supply adopted is the minimum flow with duration of seven days and recurrence of 10 years ($Q_{7,10}$), applying 50% of this flow in most of the state. This criterion in Minas Gerais is the most restrictive among those used in other Brazilian states, which can sometimes cause denial of water use grants when there is still sufficient water availability in the river basin (CASTRO et al., 2004).

In order to minimize the pressure on water resources, as well as the conflicts among its users, many studies have been carried by management bodies and research institutions to optimize water exploitation (AMORIM JÚNIOR, 2014; ANA, 2009, 2014; BOF, 2010; FERREIRA, 2014; MAS, 2013; MOREIRA et al., 2014; OLIVEIRA et al., 2013; PAREDES-ARQUIOLA et al., 2010a, 2010b; SALLA et al., 2014a, 2014b; SILVA, 2012). These studies are commonly performed using computational tools to support decision making on a watershed scale.

In the Uberaba River watershed, located in the Triangulo Mineiro region (state of Minas Gerais, Brazil), there is a conflict of considerable magnitude in the dry season, when the river flow is insufficient for public supply to the city of Uberaba. In response, since 2002, one of the emergency solutions has been the transposition of part of the water from the Claro River, which belongs to the Araguari River watershed, directing it to one of the tributaries of the upper course of the Uberaba River (UBERABA, 2008).

In light of this situation, the present work examines the hypothesis that considering the temporal and spatial water variability and the use of less restrictive criteria would increase the grantable flow to the Environmental Protection Area (APA, in Portuguese) of the Uberaba River watershed. The general objective of the underlying study was to optimize the surface water exploitation in the APA, based on analysis of new grant criteria and inclusion of seasonality in those criteria.

Materials and methods

Study area

The APA of the Uberaba River watershed covers from the headwaters to the surface catchment point for supply to the city of Uberaba (Figure 1), with estimated population of 322,126 inhabitants (IBGE, 2015). The withdrawal grant is 0.9 m^3/s, according to IGAM Edict 01656/2010 (IGAM, 2010). In the drought months, between August and October, transposition is allowed of flow of 0.56 m^3/s from the Claro River (belonging to the Araguari River watershed) to the Saudade River (Figure 1), which is the main tributary of the Uberaba River watershed.

The total area of the APA is 528.1 km^2 and corresponds to 22% of the watershed area and 12% of the municipal area. As shown in Figure 1, the APA is divided into 13 hydrographic sub-basins (with areas larger than 4 km^2). The sub-basin identified as “diffuse” includes the sub-basins with percentage areas less than 1% (which are upstream from the Uberaba River) and the diffuse areas along the watercourse (UBERABA, 2004).

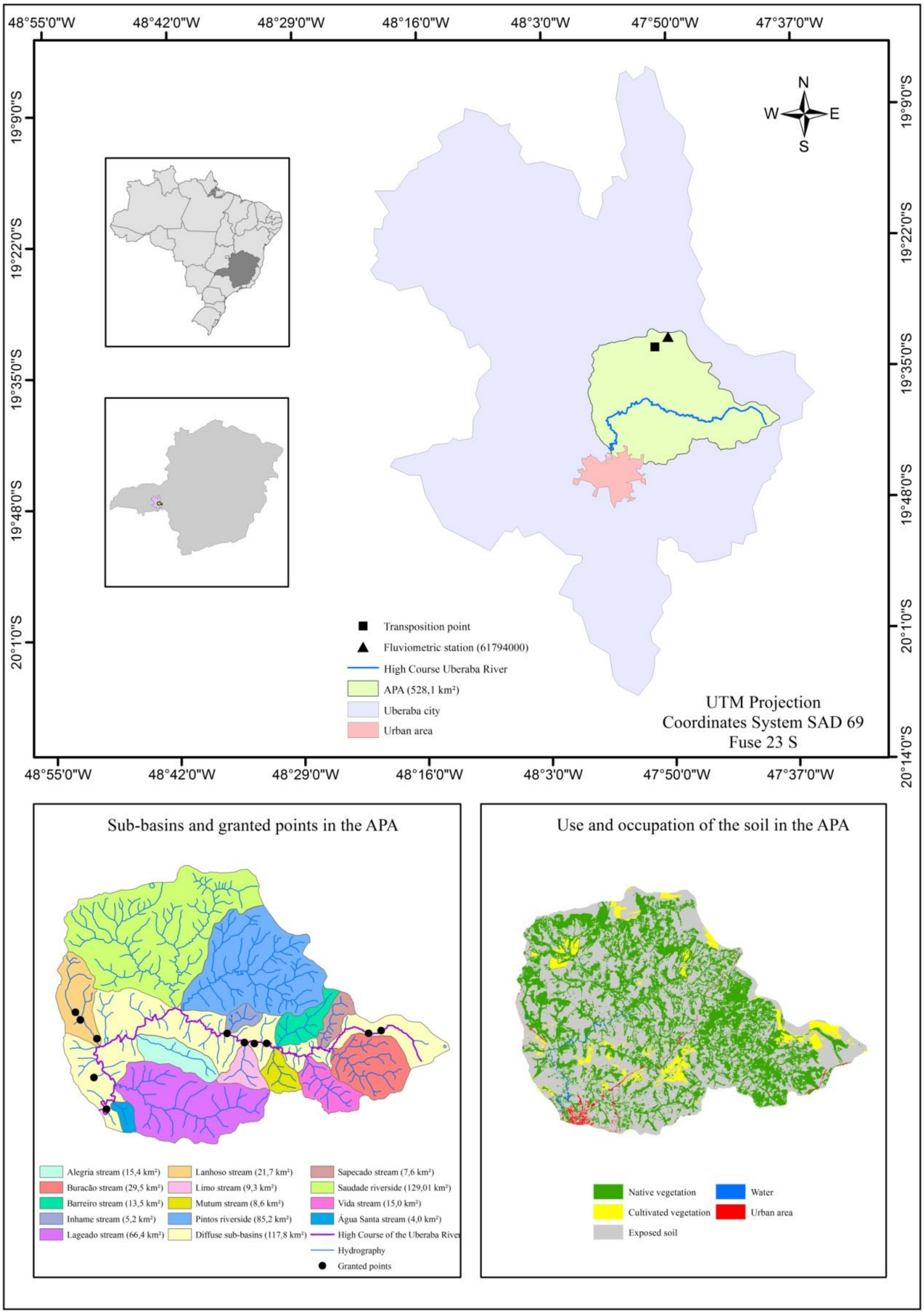
According to the Köppen climate classification, the city of Uberaba is humid hot tropical, with rains mainly in the summer (between October and March) and drought in the winter (between May and September), with an average yearly rainfall of 1,474 mm (FERNANDES et al., 2011). The annual average maximum temperature varies between 27 and 30ºC, while the minimum averages are between 15 and 18ºC (CRUZ, 2003).

As also shown in Figure 1, the land use and occupation class called “native vegetation” denote permanent preservation areas (banks of the Uberaba River and its tributaries), occupying 36.50% of the total area of the APA. The class called “cultivated vegetation” represents the areas of crops and/or pastures, occupying 4.97% of the total area. The “exposed soil” is defined as areas without vegetation cover, which in most cases is in the process of preparation for crops and/or pastures, occupying 57.47% of the total area. “Water” is represented by the main watercourse, the Uberaba River, and impoundments, occupying only 0.34% of the total area. The “urban” area represents the impermeable areas (buildings and roads), with only 0.72% of the total area. In general, an APA is a homogeneous area from the standpoint of land use and occupation, since the classes with a higher percentage of occupation are “native vegetation” and “exposed soil”.

Identification of the land use and occupation in the APA was based on geoprocessing of images from remote sensing (Operational Land Imager of the satellite Landsat-8, resolution of 30 m), with classification through the computational tool MultSpec W32.

According to the information provided by the State Environmental Department (SUPRAM, 2014), the surface water grants in the APA are allocated to drinking water, irrigation and livestock consumption. The biggest grant is for supply of drinking water to Uberaba, with a fixed value of 2.333 hm^3/month. The other grants vary from 0.0052 to 0.0700 hm^3/month. Figure 1 presents the spatialization of grant points by the Minas Gerais Water Management Institute (IGAM) in the upper course of the Uberaba River until 2014.

Figure 1 - Location of the study area



Org: Authors, 2016.

Hydrologic methodology

We estimated the regional $Q_{7,10}$ flow for optimization of surface water exploitation in the APA, based on the substitution of the yearly minimum flow by the monthly minimum and changes in the grant criterion for the right to use water.

The yearly $Q_{7,10}$ was estimated with the computational program SisCAH 1.0 - Computational System for the Hydrologic Analyses (SOUSA, 2009), with naturalized discharge data from fluviometric station 61794000, based on the historic series going back 29 years (1977 to 2006), considering for the calculation the start of the hydrologic series in January and discarding years with 5% or more of gaps in the historic series. For the naturalization of the flow besides the fluviometric station (basis value for the reference flow calculation), we added the granted flows to the measured flows at the station.

The monthly $Q_{7,10}$ was estimated by the same procedures as the yearly $Q_{7,10}$, but with values of Q_7 for each month of each year of the base period. The set of all the Q_7 values in each month was used to compose a new series of events. Formation of the series of Q_7 events, both annual and monthly, was based on analysis of probability distributions. The best estimate of $Q_{7,10}$ values corresponds to the probability density distribution with smallest amplitude of the confidence interval among the estimates obtained for each distribution.

The minimum $Q_{7,10}$ flows in the various hydrographic sub-basins were estimated through regionalization of specific flow, according to Equation (1). The study area was considered small and homogeneous from the standpoint of land use and occupation (Figure 1), and the small number of fluviometric stations in the watershed is a positive aspect of this method (Chaves et al., 2002; Silva et al., 2009).

$$Q_{7,10\,i} = (A_i \,/ A_{total}).\ Q_{7,10\ \text{upper course of the Uberaba River}}$$

In which: $Q_{7,10\ i}$ is the estimated flow in sub-basin i (m³/s); $Q_{7,10\ upper\ course\ of\ the\ Uberaba\ River}$ is the $Q_{7,10}$ flow obtained for the river's upper course (m³/s); A_{total} is the total area of the contribution to the fluviometric station (km²); and A_i is the contribution area of sub-basin i (km²) (Figure 1).

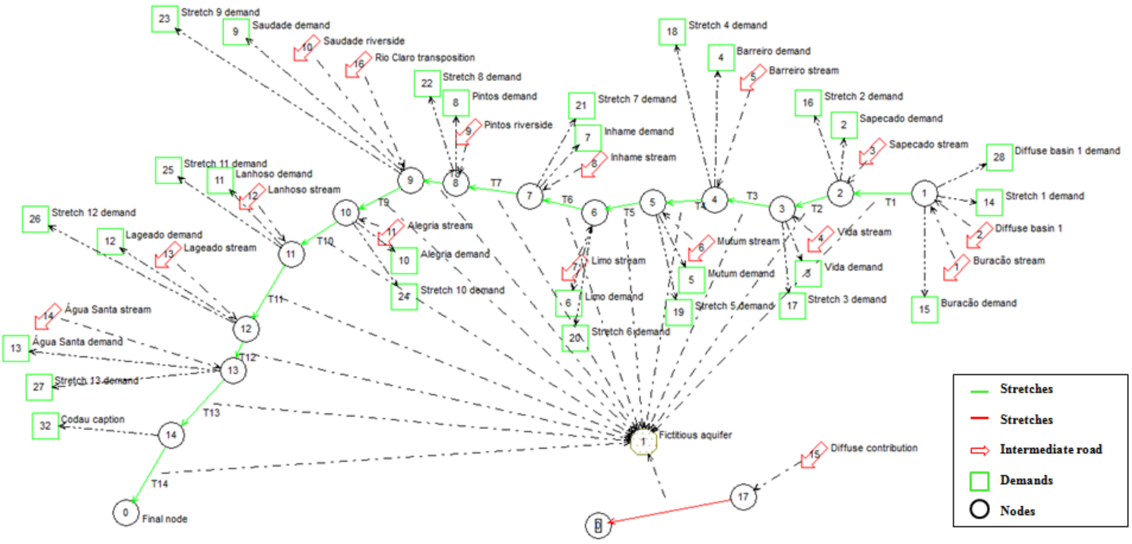
Water use optimization in the APA

This evaluation was realized through a comparison of the current grantable flow (considering the current grant criteria) with the grantable flow for distinct situations, both for the monthly and yearly period and/or for the change of grant criteria. The method for grantable flow evaluation was based in Bof (2010) and Oliveira et al. (2013).

The creation of the water system topology and the consequent water balance for each configuration (current situation and the different hypothetical situations) was carried out with the computational tool AQUATOOL (SOLERA et al., 2007). As shown in Figure 2, the comparative analyses were performed: at the mouth of each tributary stream of the Uberaba River and the downstream node of each stretch in the APA, for a total of 14 stretches, called T1 to T14, besides of a stretch upstream of T1, identified as "diffuse basin 1", which corresponds to the stretch between the Uberaba River source and the confluence with the first tributary (Buracão Stream).

In the AQUATOOL tool, the watercourse paths are represented by stretches (the green arrow denotes an impermeable channel without connection with the fictitious aquifer, while red arrow indicates a channel with total water infiltration to the aquifer). The intermediate entrances represent all the tributaries and diffuse entrances, while the demands represent the withdrawals granted along the river stretch and in the affluent sub-basins. The node elements are positioned at all the confluences between the Uberaba River and its tributaries. The fictitious aquifer served to receive all the diffuse contributions and distribute them (without losses) along 14 stretches of the Uberaba River (Figure 2).

Figure 2 – Topology of the water system



Org: Authors, 2016.

- Replacement of the yearly minimum reference flow by the monthly minimum flow

The comparative analysis between the current flow grant situation and the optimized situation was performed by applying Equation (2). In this equation, the current situation is represented by the Q_{yearly} flow and the optimized situation is represented by the $Q_{monthly}$ flow. This method was also used by Bof (2010).

$$RD\% = \{(Q_{monthly} - Q_{yearly}) / Q_{yearly}\}.100 \qquad (2)$$

Where: RD% is the relative difference between the monthly and yearly optimized situation (%); $Q_{monthly}$ is the $Q_{7,10}$ obtained on a monthly basis (m^3/s); and Q_{yearly} is the $Q_{7,10}$ obtained on the yearly basis (m^3/s).

Alteration of the grant criterion

The changes in the grant criterion were evaluated for the minimum annual and monthly reference flows, as shown below:

- Use of 30% of the yearly $Q_{7,10}$: this criterion was analyzed because 30% is still used for water use grants in some watersheds in Minas Gerais. It implies that a minimum flow of 70% of the $Q_{7,10}$ must be maintained in the watercourse.

- Use of 50% of the yearly and monthly $Q_{7,10}$ flows: current criterion used in Minas Gerais, as stipulated in SEMAD-IGAM Joint Resolution 1,548/12 (SEMAD, 2012). It implies that a minimum flow of 50% of the $Q_{7,10}$ must be maintained in the watercourse.

- Use of 70% of the yearly $Q_{7,10}$: this criterion was evaluated intending to overestimate the grantable flow by evaluating that flow with a less restrictive criterion. It implies that minimum flow of 30% of the $Q_{7,10}$ must be maintained in the watercourse.

To identify, in each river stretch, the percentage of grants used based on the above criteria, we considered the minimum reference flow and the grants already issued for the upstream stretches and the stretch itself. In this sense, the percentage already granted in each stretch is expressed by Equation (3).

$$Q_{granted\ i\ (\%)} = (\sum Q_{mt\ i}\ .100)\ /\ \{(x/100).\ Q_{7,10}\} \quad (3)$$

Where: $Q_{granted\ i\ (\%)}$ is the used percentage of the $Q_{7,10}$ available for grant in segment i (m^3/s); x is the percentage of the $Q_{7,10}$ available for grant (%) – one of the criteria previously defined; and $\sum Q_{mt\ i}$ is the sum of the flows already granted upstream from segment i, plus the flow granted in segment i (m^3/s).

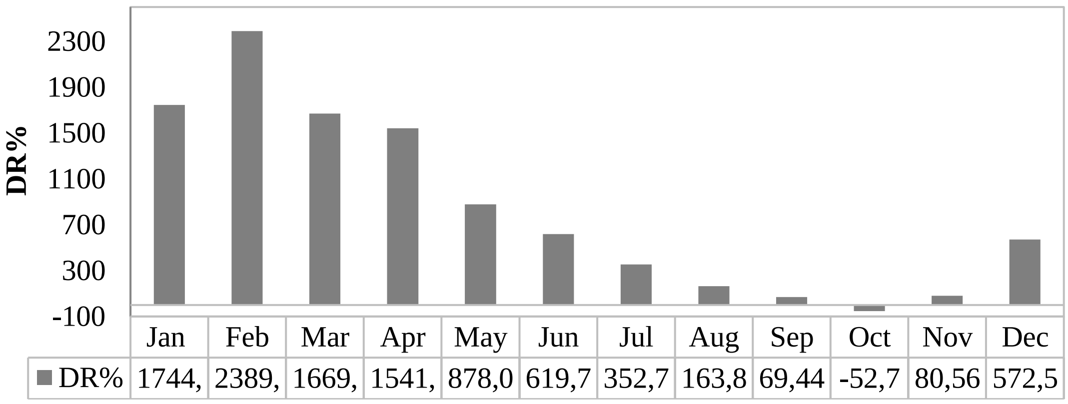
The results were evaluated in the sub-basins and in the stretches ("Diffuse basin 1" and T1 to T14) in the APA, for which we prepared maps in which the stretches are colored according to the proportion of grantable flow actually allowed (according to each criterion) of flow $Q_{7,10}$. This method was initially used by Oliveira et al. (2013).

Results and Discussion

Replacement of the yearly $Q_{7,10}$ by the monthly $Q_{7,10}$

The yearly $Q_{7,10}$ flow obtained at the APA mouth (stretch T14), near to the accumulation reservoir for the public supply to Uberaba, corresponds to 0.36 m³/s. Still in this stretch, the RD presents marked variation throughout the year, reaching values higher than 100% between December of one year and August of the next. In contrast, in the months of September, October and November, which are driest of the year, the values of RD were less than 100%. The $Q_{7,10}$ flow calculated on a monthly basis had higher RD than the flow calculated on an annual basis, of 2,389% in February. However, in October the flow calculated on a monthly basis was lower than that calculated on a yearly basis, whose RD presented a reduction of 52.7% (Figure 3).

Figure 3 – RD between the monthly and yearly $Q_{7,10}$ flows.



Org: Authors, 2016.

However, we found that the seasonality in calculating the grantable flow, i.e., replacement of the yearly $Q_{7,10}$ flow by the monthly flow in the rainy season (December to May) and maintenance of the $Q_{7,10}$ flow in the dry season (June to November), would optimize the surface water exploitation in the APA. The main explanations are:

- In line with what was previously mentioned, the Operational Center for Development and Sanitation of Uberaba (CODAU) has a grant of 0.09 m³/s for the public supply of the city of Uberaba, according to IGAM Edict 01656/2010 (IGAM, 2010). Because of the yearly basis for calculating the $Q_{7,10}$ flow, there is permission for water transposition of 0.56 m³/s from the Claro River to the Saudade River. In this context, in the rainy months, the potential accumulation of surplus in reservoirs would supply the deficit in the water supply to Uberaba between August and October, eliminating the need for transposition.

- In function of the granted flow being constant throughout the year, the maintenance of the yearly calculation basis for the $Q_{7,10}$ flow in the dry season would be enough to meet the granted demands.

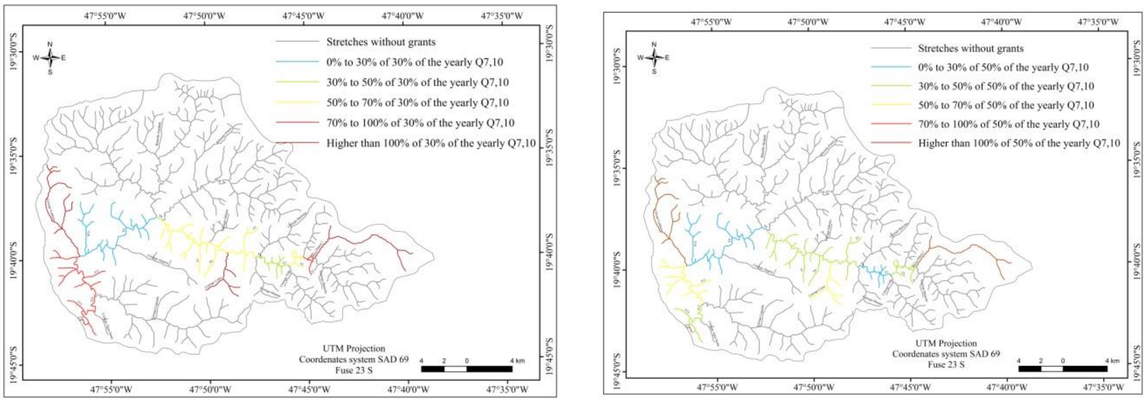
It is important to highlight that this seasonality in calculation of the grantable flow would maintain environmental conditions propitious to preservation of the aquatic ecosystem. The morphology of the studied stretch of the Uberaba River, specifically in function of the existence of small cascades and outcrops of basaltic stones in some regions, favors natural reoxygenation along the watercourse (SALLA et al., 2015). Likewise, in other stretches of the Uberaba River, the low longitudinal slope of the river associated with a well-defined cross section (without obstructions) favors the reproduction and development of the aquatic life, because the slower current speed and the expansion of the wet perimeter favor a healthy ichthyofauna habitat (ANA, 2004; DE PAULO, 2007).

Change in the grant criterion

- 30% of the yearly $Q_{7,10}$

The grant based on the criterion of 30% of yearly $Q_{7,10}$ was used throughout Minas Gerais until the promulgation of SEMAD-IGAM Joint Resolution 1,548/12 (SEMAD, 2012), which established the criterion of 50% of the same reference flow. However, in some state watersheds, the previous percentage is still applied. In the Uberaba River watershed, 50% of the yearly $Q_{7,10}$ is used, but we evaluated the use of 30%, whose result is depicted in Figure 4a.

Figure 4 - Analysis of the water percentages used, considering: a) 30% of the yearly $Q_{7,10}$ flow; b) 50% of the yearly $Q_{7,10}$ flow.



(a) (b)

Org: Authors, 2016.

When applying the criterion of 30% of the yearly $Q_{7,10}$ flow (Figure 4a), the tributaries with grants presented flow higher than 100% of the allowed flow. With respect to the Uberaba River stretches, the first one, called "Diffuse basin 1", and T14 presented values granted higher 100% of the allowed flow. Stretches T1, T11, T12 and T13 presented granted flows from 70% to 100% of the allowed. Stretches T2, T5, T6 and T7 presented granted flows from 50 to 70% of the allowed value, and the remaining stretches presented good water availability, indicating that the granted values reached 50% or less. The results for this criterion indicate that a large part of the upper course of the Uberaba River is susceptible to water use conflicts. Hence, there is a need to adopt less restrictive criteria, as was established in the new resolution.

- 50% of yearly and monthly $Q_{7,10}$

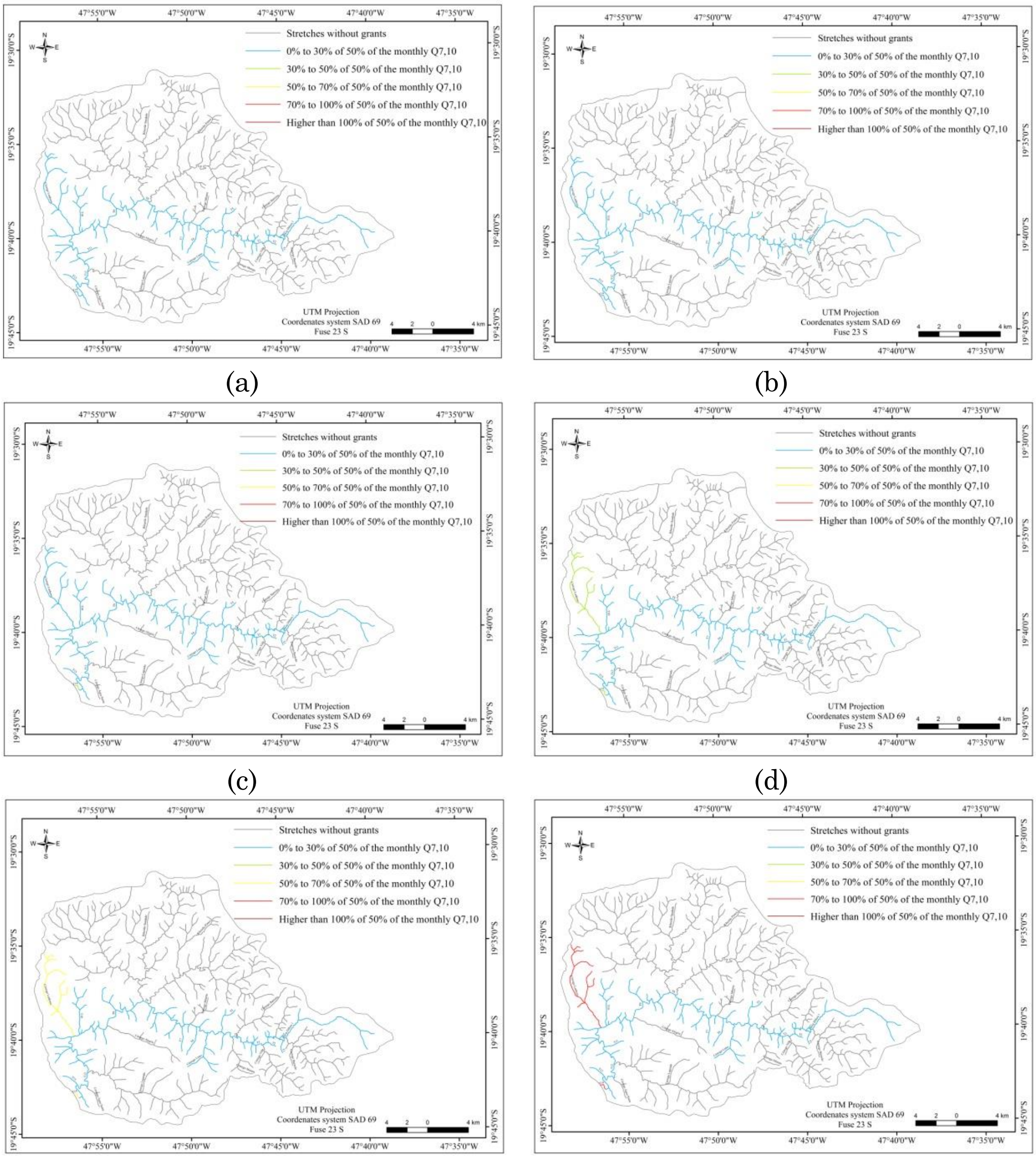
This analysis permits the comparison between the current grant criterion in Minas Gerais (annual basis) with another less restrictive criterion (monthly basis).

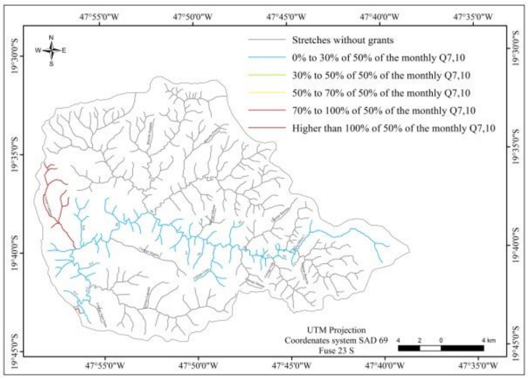
Figure 4b depicts the real situation of grants in the APA starting at 50% of the yearly $Q_{7,10}$ flow. Some stretches present critical situations regarding grantable flow, considering that the initial stretch of the river

("Diffuse basin 1"), the Lanhoso Stream sub-basin, and the stretch after the water catchment point of CODAU have granted flows higher than 100% of the allowed value, compromising the water availability in the downstream stretches.

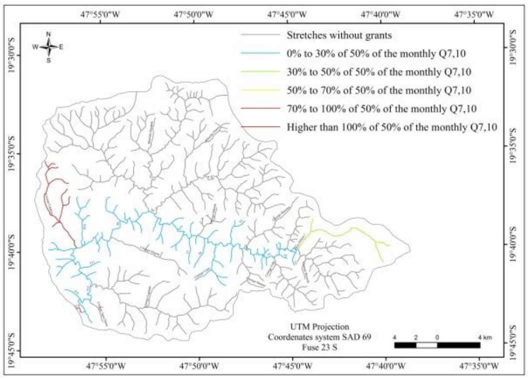
Figure 5 shows the water percentage used based on an optimized situation, considering the criterion of 50% of the $Q_{7,10}$ flow calculated on a monthly basis.

Figure 5 – Analysis of the water percentage used, based on 50% of the monthly $Q_{7,10}$ flow, from January (a) to December (l).

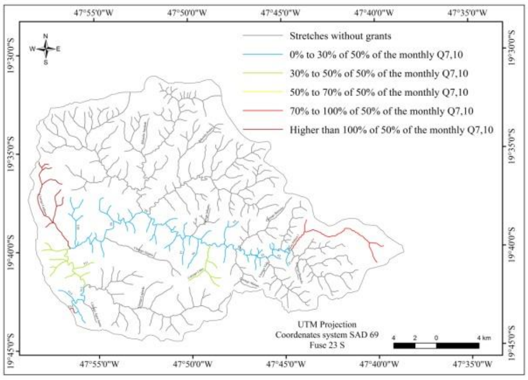




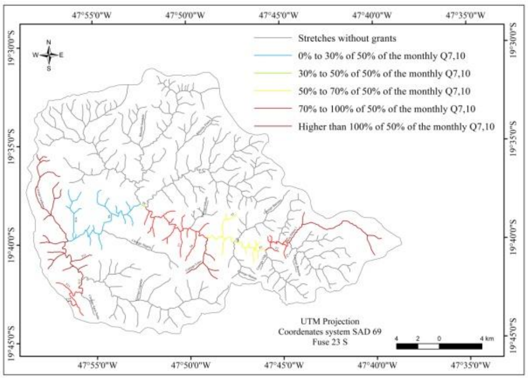
(g)



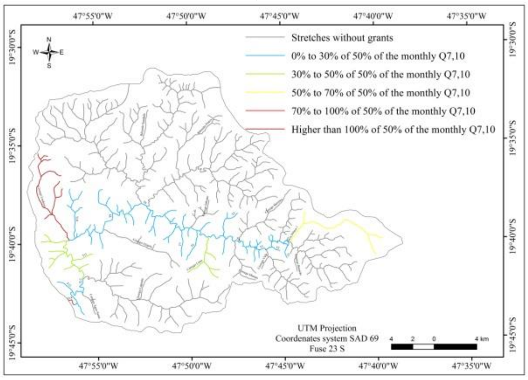
(h)



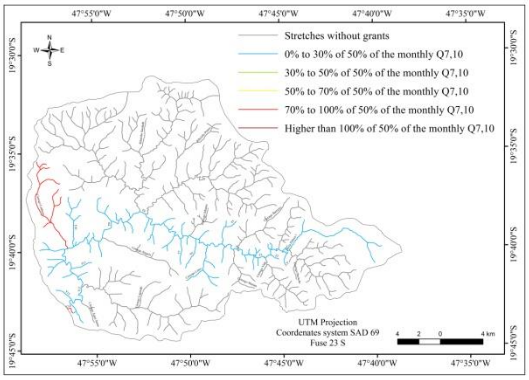
(i)



(j)



(k)



(l)

Org: Authors, 2016.

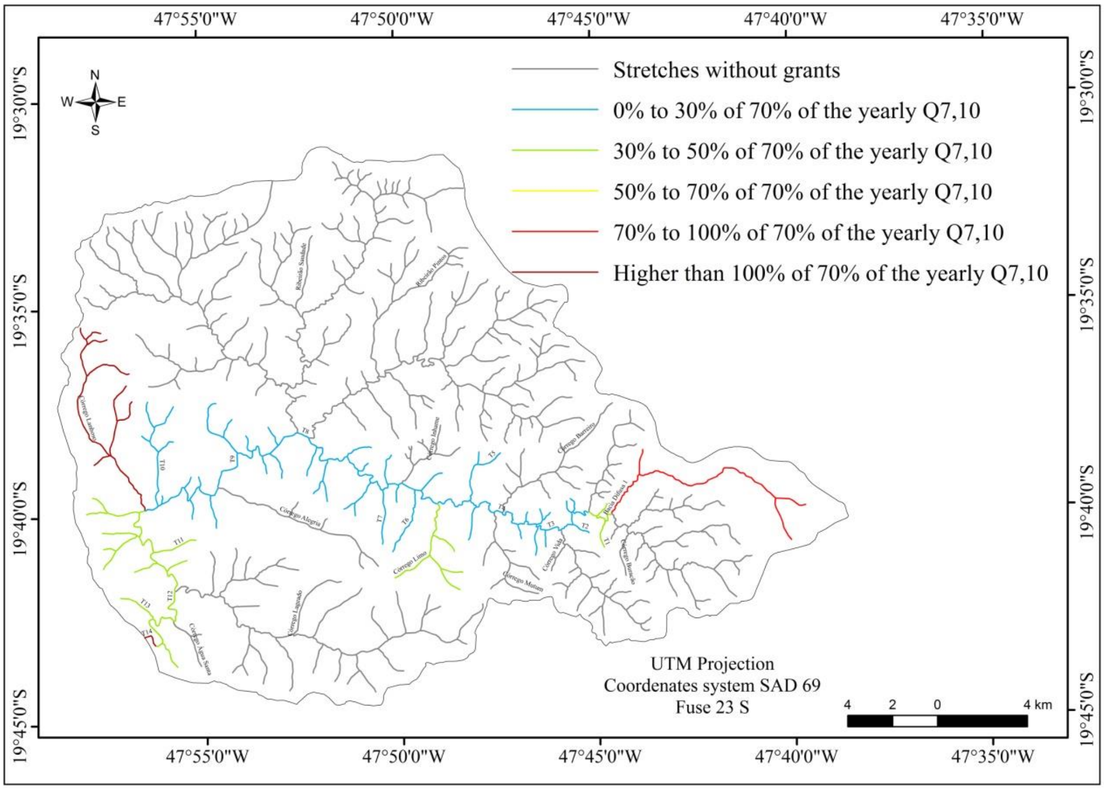
It is possible to observe that despite the less restrictive criterion, there is still susceptibility to conflicts in many months (June to December), with the most critical situation in the Lanhoso Stream sub-basin and in stretch T14. The stretch "Diffuse basin 1" presented a percentage used higher than 100% of the allowed grant in September and October (Figure 5).

For the rainiest months (January, February, March and April), the least restrictive grant criterion significantly increased the water availability in comparison of the availability calculated on the annual basis. In January and February, all the sub-basins and all the stretches presented water use percentages from 0% to 30% of the allowed portion, while in March and April, this situation continued, except in the Lanhoso Stream sub-basin and stretch T14, with uses from 30% to 50%.

- 70% of the yearly $Q_{7,10}$ flow

The grantable flow criterion based in the use of 70% of the yearly $Q_{7,10}$ flow was proposed aiming to overestimate the granted volume to supply the demands of public supply and irrigation. Figure 6 shows that some upper stretches of the Uberaba River still are out of compliance with the proposed criterion. The biggest part presented positive grantable water availability, indicating there still is volume available to be granted.

Figure 6 – Analysis of the water percentage used based in 70% of the yearly $Q_{7,10}$ flow



Org: Authors, 2016.

In general, the most critical situation is found in the initial stretch of the river, identified as Diffuse basin 1, and in the Lanhoso Stream sub-basin, with used water percentages from 70% to 100% and higher than 100% of the reference flow, respectively.

For all the changes in the grant criterion described previously, the optimization of surface water exploitation was in harmony with maintenance of the aquatic ecosystem health. As explained before, the morphology of the studied stretch the Uberaba River favors the maintenance of the ichthyofauna habitat.

Many studies have been published of the optimization of surface water exploitation since the change in the grant criterion. According to Bof (2010), in his study in the Paraopeba River watershed, the monthly $Q_{7,10}$ flow grant criterion “enables better water using planing, since it allows higher water use in the periods of ample availability and imposes a more realistic restriction in critical periods.”

On the other hand, Oliveira (2011) and Oliveira et al. (2013) concluded that the seasonality of the grantable flow is satisfactory for optimization of surface water availability in the Entre-Ribeiros watershed. The same affirmation about flow seasonality was made by Euclydes et al. (2006), in a study of the seasonal grant criterion for the irrigated agriculture in the Grande River watershed, Minas Gerais, and by Maia (2003) in the Alto Sapucaí watershed, Minas Gerais.

Final Considerations

There are many criteria for the grant of surface water use entitlements, besides the criteria presented here, adaptable to the different regions of Brazil in function of the local demands, climate conditions and the morphological characteristics of the watercourse.

This study indicated that seasonality in the grantable flow calculation is positive in the APA, mainly for the possibility of reserving water in the rainy period to meet needs (mainly the public supply) in Uberaba in the dry season.

Acknowledgment

We thank the Office to Coordinate Improvement of University Personnel (CAPES) for the master's scholarship provided to the first author and the Minas Gerais State Research Support Foundation (FAPEMIG) for the financial support conceded via process APQ-CRA-01024/14 – Universal Demand.

References

AMORIM JÚNIOR, J. C. Disponibilidade hídrica para outorga de captação: critérios anual e mensal para definição de vazões mínimas de referência. 2014. Dissertação (Mestrado) – Universidade Federal do Espírito Santo, Vitória, ES, 2014.

ANA - Agência Nacional de Águas (2004). **Plano Decenal de Recursos Hídricos da Bacia Hidrográfica do Rio São Francisco - PBHSF (2004-2013)**. Estudo Técnico de Apoio ao PBHSF – Nº 16: Alocação de Água. 2004. Available at: < http://www.saofrancisco.cbh.gov.br/_docs/planos/PlanoDecenaldeRecursosHidricos.pdf>. Consulted on: January 15, 2015.

ANA – Agência Nacional de Águas. **Plano estratégico de recursos hídricos da bacia hidrográfica dos rios Tocantins e Araguaia**. 2009. Available at: < https://www.senado.gov.br/comissoes/CDR/AP/AP20090528_ANA-Jos%C3%A9LuizZobiRioTocantins-Araguaia.pdf >. Consulted on: January 15, 2015.

ANA – Agência Nacional de Águas. **Subsídios para a discussão da compatibilização da geração de energia hidrelétrica com expansão da agricultura irrigada na bacia do rio São Marcos.** 2014. Available at: <file:///C:/Users/Marcio/Downloads/UsosMultiplosdaAguanabaciadoRioSaoMarcos%20(2).pdf>. Consulted on: January 16, 2015.

BOF, L. H. N. Análise de critérios de outorga de direito de uso de recursos hídricos. 2010. Dissertação (Mestrado) – Universidade Federal de Viçosa, Viçosa, MG. 2010.

CASTRO, L. M. A.; DINIZ, M. G. M.; SILVA, A. G. **Aplicação do instrumento da outorga no gerenciamento dos recursos hídricos em Minas Gerais: A bacia do Ribeirão Entre Ribeiros.** In: SIMPÓSIO DE RECURSOS HÍDRICOS DO NORDESTE, 2004, São Luis. Anais... São Luis: ABRH, 2004.

CHAVES, H. M. L.; ROSA, J. W. C.; VADAS, R. G.; OLIVEIRA, R. V. T. Regionalização de vazões mínimas em bacia através de interpolação e em Sistemas de Informação Geográfica. **Revista Brasileira de Recursos Hídricos**, Porto Alegre, v. 7, n. 3, p. 43-51. 2002. https://doi.org/10.21168/rbrh.v7n3.p43-51

CRUZ, L. B. S. Diagnóstico ambiental da bacia hidrográfica do rio Uberaba-MG. 2003. Tese (Doutorado) – Universidade Estadual de Campinas, Campinas, SP. 2003.

DE PAULO, R.G.F. Ferramentas para a determinação de vazões ecológicas em trechos de vazão reduzida: destaque para a aplicação do método do perímetro molhado no caso de Capim Branco I. 2007. Dissertação (Mestrado) – Programa de Pós-graduação em Saneamento, Meio Ambiente e Recursos Hídricos. Universidade Federal de Minas Gerais, Belo Horizonte, MG, 2007.

EUCLYDES, H.P.; FERREIRA, P.A.; FILHO, R.F.F. Critério de outorga sazonal para a agricultura irrigada no estado de minas gerais. Estudo de caso. Revista ITEM – Irrigação & Tecnologia Moderna, v. 71-72, n. 3-4, p. 42-50. 2006.

FERNANDES, A. L. T.; FRAGA JÚNIOR, E. F.; TAKAY, B. Y. Avaliação do método Penman-Piche para a estimativa da evapotranspiração de referência em Uberaba, MG. **Revista**

Brasileira de Engenharia Agrícola e Ambiental, v. 15, n.3, p.270–276, 2011. https://doi.org/10.1590/S1415-43662011000300008
FERREIRA, A. M. Capacidade de autodepuração nos cursos médio e baixo do rio Uberaba, UPGRH-GD8. 2014. Dissertação (Mestrado) - Universidade Federal de Uberlândia, Uberlândia, MG, 2014.
IBGE – Instituto Brasileiro de Geografia e Estatística. **Cidades**. Available at: <http://www.ibge.gov.br>. Consulted on: November 28, 2015.
IGAM. Instituto Mineiro de Gestão das Águas. **Portaria IGAM n.º 01656**, 19 de junho de 2010. 2010. Available at: <http://www.igam.mg.gov.br/component/docman/cat_view/14-portarias-de-outorga>. Consulted on: February 20, 2014.
MAIA, J.L. Estabelecimento de Vazões de Outorga na Bacia Hidrográfica do Alto Sapucaí, com a utilização de sazonalidade. 2003. 116 p. Dissertação (Mestrado em Engenharia de Energia) – Universidade Federal de Itajubá, Itajubá, 2003.
MAS, A. G. C. Evaluación del recurso hídrico en la cuenca del río Turia (España) mediante la aplicación de modelos semiagregados de Precipitación-Escorrentía. 2013. Proyecto Final de Carrera. Ingeniería de Caminos, Canales y Puertos, Universidad Politécnica de Valencia, Valencia, 147 p., 2013.
MOREIRA, M. C.; SILVA, D. D. da.; LARA, M. dos. S.; PRUSKI, F. F. Índices de conflito pelo uso da água da bacia do Ribeirão entre Ribeiros. **Revista Brasileira de Recursos Hídricos**, Porto Alegre, v. 19, n. 1, p. 221-228 – Jan-Mar 2014. https://doi.org/10.21168/rbrh.v19n1.p221-228
OLIVEIRA, J. R. S. Otimização do aproveitamento da disponibilidade de águas superficiais na bacia do Ribeirão Entre Ribeiros. 2011. 86 p. Dissertação (Mestrado em Engenharia Agrícola) - Universidade Federal de Viçosa, Viçosa, 2011.
OLIVEIRA, J. R. S.; PRUSKI, F. F.; NUNES, A. A. Otimização do aproveitamento da disponibilidade de Águas Superficiais na Bacia do Ribeirão entre Ribeiros. **Revista Brasileira de Recursos Hídricos**, v. 18, n. 4, 157-172, 2013. https://doi.org/10.21168/rbrh.v18n4.p157-172
PAREDES-ARQUIOLA, J.; ÁLVAREZ, J. A.; SOLERA, A. A decision support system for water quality issues in the Manzanares River (Madrid, Spain). **Science of the Total Environment**, v. 408, n. 12, p. 2576–2589, 2010a. https://doi.org/10.1016/j.scitotenv.2010.02.037
PAREDES-ARQUIOLA, J.; ÁLVAREZ, J. A.; MONERRIS, M. M.; SOLERA, A. Water quantity and quality models applied to the Jucar River Basin, Spain. **Water Resources Management**, v. 24, n. 11, p. 2759-2779, 2010b. https://doi.org/10.1007/s11269-010-9578-z
RIBEIRO, M. M. R.; LANNA, A. E. L. A outorga integrada das vazões de captação e diluição. **Revista Brasileira de Recursos Hídricos**, Porto Alegre, v. 8, n. 3, p. 151-168, 2003. https://doi.org/10.21168/rbrh.v8n3.p151-168
SALLA, M. R.; PAREDES-ARQUIOLA J.; SOLERA, A.; ÁLVAREZ, J. A.; PEREIRA, C. E.; ALAMY FILHO, J. E.; OLIVEIRA, A. L. de. Integrated modeling of water quantity and quality in the Araguari River basin, Brazil. **Latin American Journal of Aquatic Research**, Valparaíso, v. 42, n. 1, p. 224-244, 2014a. https://doi.org/10.3856/vol42-issue1-fulltext-19
SALLA, M. R.; PAREDES-ARQUIOLA J.; SOLERA, A.; ÁLVAREZ, J. A.; PEREIRA, C. E.; ALAMY FILHO, J. E.; OLIVEIRA, A. L. de. Sistema de Suporte à Decisão em Recursos Hídricos na Bacia Hidrográfica do Rio Uberabinha, Minas Gerais. **Revista Brasileira de Recursos Hídricos**, Porto Alegre, v. 19, n. 1, p. 189-204. 2014b. https://doi.org/10.21168/rbrh.v19n1.p189-204
SALLA, M. R.; MAGALHÃES, A.A.B. ; ALVES, L. A. ; SCHMIDT, M. A. R. ; LIMA, G. Sensibilidade de características morfológicas no comportamento de parâmetros de qualidade da água em rio de porte médio. **Ciência & Engenharia**, v. 24, p. 29-37, 2015. https://doi.org/10.14393/19834071.2015.32256
SEMAD. Secretaria de Estado de Meio Ambiente e Desenvolvimento Sustentável. **Resolução Conjunta SEMAD-IGAM n.º 1548**, de 29 de março de 2012. Available at: < http://www.agencia.baciaspcj.org.br/docs/resolucoes/resolucao-semad-igam-1548.pdf>. Consulted on: February 20, 2014.

SILVA, D. D. da; MARQUES, F. de A.; LEMOS, A. F. Avaliação de metodologias de regionalização de vazões mínimas de referência para bacia do rio São Francisco. **Engenharia na Agricultura**, Viçosa, v. 17, n. 5, p. 392-403. 2009. https://doi.org/10.13083/1414-3984.v17n05a07

SILVA, B. M. B. da. Influência da sazonalidade da disponibilidade hídrica nos critérios de outorga de uso da água e avaliação de índices para a gestão e planejamento de recursos hídricos na bacia do rio Paraopeba. 2012. Dissertação (Mestrado) – Universidade Federal de Viçosa, Viçosa, MG, 2012.

SOLERA, A.; PAREDES-ARQUIOLA, J.; ANDREU, J. AQUATOOLDMA: Entorno de desarrollo de sistemas de ayuda a la decisión en materia de planificación de la gestión de cuencas hidrográficas incluyendo utilización conjunta y criterios de calidad de aguas. **Manual de usuario**. Valência: UPV, 2007. Available at: < https://aquatool.webs.upv.es/aqt/en/home/>. Consulted on: January 14, 2015.

SOUSA, H. T. de. Sistema computacional para regionalização de vazões. 2009. Dissertação (Mestrado) – Universidade Federal de Viçosa, Viçosa, 2009.

SUPRAM. Superintendência Regional de Regularização Ambiental – Triângulo Mineiro e Alto Paranaíba. Available at: <http://www.meioambiente.mg.gov.br/suprams-regionais>. Consulted on: August 14, 2014.

UBERABA. Prefeitura Municipal. Secretaria de Desenvolvimento Econômico e Turismo. **Uberaba em dados**. Uberaba, 2008. Available at: < https://pt.slideshare.net/prefeituradeuberaba/uberaba-em-dados-17>. Consulted on: September 15, 2015.