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The effect of reservoirs on water availability

O efeito de reservatórios na disponibilidade de água

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ABSTRACT

The difficulty in satisfying water demands is a critical issue in our society. Storing water in reservoirs is a widely employed alternative to guarantee water supply. The objective of this study was to assess the effect of constructing streamflow regularization reservoirs on water availability throughout the hydrography in a case study for the Entre Ribeiros River Basin. The effects assessed the substitution of superimposed streamflows by streamflows distributed over time and the possibility of considering the stored water criterion for issuing water withdrawal permits instead of that used for natural conditions. Distributing streamflows over time increased the potential for using water resources by up to 60%; when the stored water criterion for issuing water withdrawal permits was considered, there was an increase of up to 1,610% in water availability.

Keywords: *Streamflow regularization. Water resources. Water availability. Water storage. Planning and management of water resources.*

RESUMO

Um dos principais problemas enfrentados na atualidade é a dificuldade em atender à demanda de água requerida pela sociedade, sendo utilizado para esta finalidade o processo de armazenamento de água em reservatórios. Objetivou-se com o presente trabalho avaliar o impacto do uso de reservatórios de regularização na disponibilidade hídrica ao longo da hidrografia, sendo, para tanto, feito um estudo de caso para a bacia do ribeirão Entre Ribeiros. Foi realizada a avaliação do impacto da construção de reservatórios na disponibilidade hídrica com base no efeito que o armazenamento de água potencializa em relação à substituição das vazões superpostas pelas vazões distribuídas no tempo e na possibilidade de consideração do critério de outorga para barramentos em substituição ao critério de outorga a fio d'água. Considerando a substituição das vazões superpostas por vazões distribuídas no tempo o aumento da potencialidade de utilização dos recursos hídricos foi de até 60% e quando da consideração do critério de outorga para barramentos em substituição ao critério de outorga a fio d'água houve um aumento na disponibilidade hídrica de até 1610%.

Palavras Chave: *Armazenamento de água. Disponibilidade hídrica. Planejamento e gestão dos recursos hídricos. Regularização de vazões.*

INTRODUCTION

Water is a precious natural resource that is essential for life and economic growth. The increasing water demand, in both quantitative and qualitative terms, has required planners to use more comprehensive projects for the management of water resources (Li et al., 2010a).Ensuring food security for an increasing population has become a complex issue. The adequate quantitative water availability is a great challenge, particularly for irrigated agriculture (SCHULTZ; De WRACHIEN, 2002).

One of the main challenges faced by water resources managers is the quantification of stream flows and their space-time variability along the hydrography, which is essential for meeting the water consumption demands of our society. Storing water allows for the use of excess water during drought periods (CAMPOS, 2005).

Streamflow regularization is an efficient way to promote the sustainable development and optimize water resources management (LI et al., 2010b). By altering the runoff space-time distribution, reservoirs may have many beneficial uses, such as flood control, hydropower generation, municipal water supply, navigation and recreation, therefore reducing human's dependence on the natural water availability (LI et al., 2010b; XU et al., 2011).

Water can be stored through a number of small individual reservoirs located in the headwaters of the main watercourse or its tributaries, or by means of large reservoirs located in the downstream reach (SWIECH, 2012). In many regions, the sustainability of agriculture depends on the stored water during scarcity periods, which is usually achieved by the construction of small reservoirs. The negative effects of the reservoirs are of little significance as compared to the benefits they provide.

In southern Brazil, the irrigated rice crop has a high water requirement that cannot be supplied exclusively by river flow during the periods of highest demands, i.e., the spring and summer months. Within the last 100 years, thousands of small reservoirs have been built to guarantee the irrigation water supply; most were built by the land owners and are usually located completely within their properties (COLLISCHONN et al., 2011).

Watersheds with a large number of small reservoirs, for which basic characteristics such as storage volume are unknown, are common in Brazil. A recent study based on images of the *China-Brazil Earth Resources Satellite* (CBERS) enabled the identification of more than 4,000 reservoirs with flooded areas over 20 ha, only in northeastern Brazil (MARTINS et al., 2007).

The use of streamflow regularization reservoirs modifies the distribution of flows in rivers and changes the downstream water supply, i.e., the minimum available streamflow downstream of the reservoir tends to increase and approach the long-term average streamflow. The water availability cannot surpass the potential of the watershed, represented by the maximum streamflow that can be regulated, unless water is imported from other areas (ASFORA; CIRILO, 2005).

Pruski et al. (2007) performed a study in the Entre Ribeiros River Basin (ERRB), in Minas Gerais. The study observed the estimated streamflow withdrawn for irrigation in the contributing area corresponding to the section in which the Barra da Égua stream-gage is located. In August (the highest demand month) of 1996, the streamflow withdrawn represented87.1% of the 7-day 10-year low flow ($Q_{7,10}$), which is a statistical estimate of the lowest average flow that would be experienced during a consecutive 7-day period with an average recurrence interval of ten years. The authors also reported that the total average streamflow consumed by the four segments considered in that study(urban supply, human supply in rural areas, animal watering and irrigation)corresponded to only 2.1% of the long-term average streamflow (Q_{lt}), which highlights the great potential for increasing availability by regulating water runoff in the hydrography.

Reservoirs increase water availability and also enable water use permits to be issued to more users, resulting in an efficient way to promote the multiple uses of water. According to the joint resolution SEMAD-IGAM nº 1548, of March 29, 2012, in a large part of the State of Minas Gerais, water use permits are issued for natural conditions and streamflow values equivalent to a maximum of 50% of the $Q_{7,10}$. Because this criterion has been defined based on the analysis of critical drought periods, such reference streamflow is restrictive regarding the expansion of water use systems. If streamflow regularization practices are implemented, however, water use permits are issued until the long-term average streamflow is achieved to guarantee instream flows (that remains in the river) of at least 50% of the $Q_{7,10}$.

The issuance of water use permits is one of the instruments necessary for more efficient water resources management, particularly in many Brazilian watersheds in which conflicts over water use are common. In the Paracatu River Basin, a sub-basin of the São Francisco River, many conflicts have arisen since the 1970s resulting from the expansion of irrigated agriculture, mostly in the Entre Ribeiros and the Preto River sub-basins.

Pruski et al. (2007) stated that irrigation is responsible for over 92% of the total water consumption in the ERRB, and according to the Environmental Diagnosis of the ERRB, this watershed is currently in a critical situation with respect to water availability and presents a concerning scarcity scenario. The increase in the cultivated area, intensification of agricultural water use, inadequate management practices and lack of planning in the use of natural resources, specifically water, have all contributed to the environmental and social conflicts.

A study performed by Oliveira et al. (2013) for optimizing the use of surface water in the ERRB found that the substitution of the annual $Q_{7,10}$ for the monthly $Q_{7,10}$, and the consideration of the most positive scenario (the criterion of 50% of the monthly $Q_{7,10}$)were not enough to ensure that the demand would be lower than the amount of water available for all hydrographic segments. The analysis identified a need to build impoundment structures in nine of those reaches.

Therefore, the present study was based on the hypothesis that streamflow regularization practices are important techniques to improve the use of water in a watershed. The study aimed to assess the effects of streamflow regularization reservoirs on the water availability along the hydrography in a case study for the ERRB.

METHODOLOGY

Study area

The ERRB, a sub-basin of the Paracatu River Basin in the state of Minas Gerais, is located between latitudes 16°30'Sand 17°16'Sand longitudes 46°15'Wand47°05'W (Figure1) and occupies an area of 3,973 km^2.

Given the geographic location of the watershed, the climate is predominantly tropical-rainy, characterized by rainy springs and summers, awell-marked dry season and the coldest month having an average temperature above 18°C. The average annual precipitation is 1,453 mm, with arrange between 1,100 and 1,600 mm, not uniformly distributed throughout the year.

The annual average reference evapotranspiration is 1,140 mm, with minimum monthly values between 50 and 80 mm in June and July, and maximum monthly values between 90 and 163 mm from October to March. The hydroclimatic balance shows a water deficit between May and September, whereas from December to February, there is excess water available in the watershed.

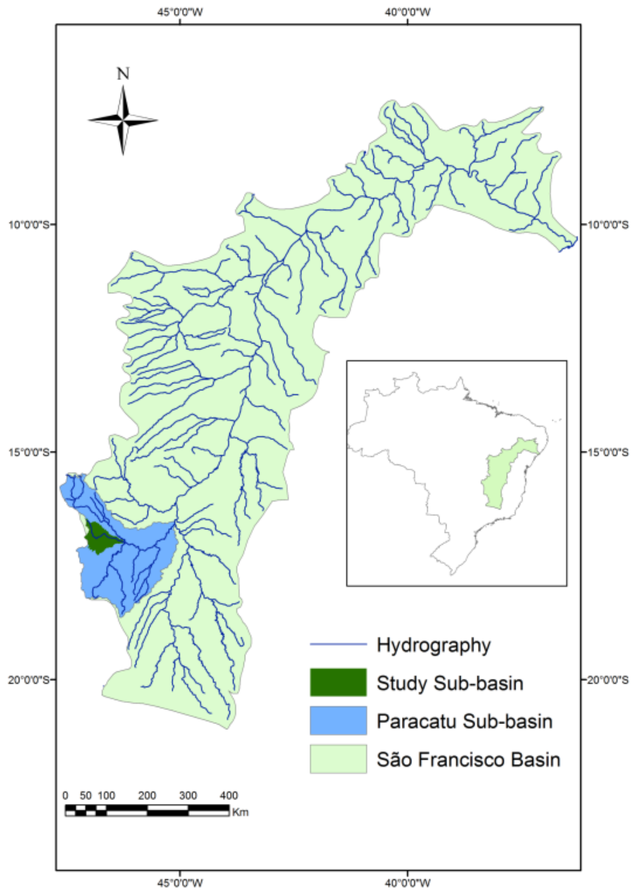

Figure 1 – Location of the Entre Ribeiros River Basin (ERRB)

Demands for water use in the ERRB

To identify the water uses and their respective demands in the ERRB, we considered surface water, natural and stored water permits, issued until 2010 by the Minas Institute of Water Management (IGAM, responsible for the granting of water use rights in Minas Gerais).

Figure 2 shows the locations corresponding to permitted water with drawals within the ERRB, most of which are in the headwaters, in which the high demand and the low availability are responsible for shortage situations during most of the year.

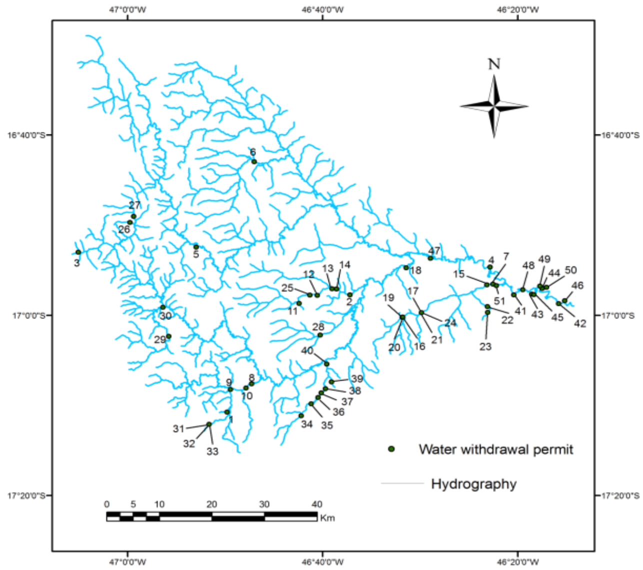

Figure 2 – Water withdrawal permits within the ERRB

Demand analyses were performed on a monthly basis. The total demand for each hydrographic segment was calculated from the sum of the amount of water withdrawal permits in the segments upstream of the confluence of the respective reach with the subsequent segment.

Reference streamflow for the issuance of water with drawal permits in the ERRB

To match the requirements of the State of Minas Gerais, the $Q_{7,10}$ is the reference streamflow in this study. The $Q_{7,10}$ value was estimated from annual data through a streamflow regionalization study performed for Minas Gerais (GPRH& IGAM 2012). The regionalization equation is expressed by:

$$Q_{7,10} = 0.1167\ P_{q\ 750}^{\ 0.9870} \qquad (1)$$

where Peq$_{750}$ is the streamflow equivalent of the annual rainfall volume minus the abstraction factor for streamflow formation, m³ s1.

The explanatory variable P_{eq750} represents the physical and climatic characteristics of the watershed. Although average annual rainfall is an explanatory variable in the formation of low and average stream flows, it does not effectively reflect the contribution to the formation of such stream flows. To better represent the physical processes involved in streamflow formation, GPRH e IGAM (2012) used the 750 mm value as the factor to account for abstractions. This factor considers the portion of rainfall that is not converted to runoff due to other processes, principally evapotranspiration (PRUSKI et al., 2013)

The effect of issued water withdrawal permits on the availability of natural water in the watershed

Each location of permitted water with drawal was associated with its respective monthly demand, assuming that natural withdrawals were performed regardless of the real condition (withdrawal from a reservoir on the river or directly from the river)for 24 hours a day for 30 days. Such assumptions were based on the principle of superposition of the streamflow demands: all permitted water withdrawals are used simultaneously, and referred to throughout this study as “superimposed stream flows”.

The principle of superposition of information is a basic principle used by management agencies to ensure that water resources are available to all users. The percentage of the reference streamflow that has been issued upstream (Equation 2) of each hydrographic segment was obtained from data related to existing permitted water withdrawals.

$$O_{low\_s\%\,i} = \frac{\sum Q_{s\,i}}{Q_{7,10\,i}}\,100 \qquad (2)$$

where $O_{low\_s\%\,i}$ is the percentage of the reference low flow which has been issued upstream of the segment i, including i, considering the superimposed streamflows; $\sum Q_{s\,i}$ is the sum of the superimposed streamflows upstream of the segment i, including i, $m^3\,s^{-1}$; and $Q_{7,10\,i}$ is the reference low flow in segment i, $m^3\,s^{-1}$.

For each hydrographic segment during each month, we analyzed the ratio between the sum ofthe superimposed streamflows issued for points located upstream of the confluence of a given reach with the subsequent segment and the$Q_{7,10}$, which was calculated on an annual basis.

The analysis considered the IGAM’s criterion of fixing 50% of the $Q_{7,10}$ as the maximum value for consumptive withdrawals to be granted in the portion of the watershed limited by each given section in natural conditions.

The analysis of the effect of reservoirs on water availability

The principle of superposition provides a safety measure to ensure that the demand will be supplied; however, the principle is no longer required if impoundment structures are built. Reservoirs allow for withdrawals to be distributed along the hours and days of use within a month by storing water and ensuring streamflow regularization.

There fore, for reaches in which the sum of the permitted water with drawals exceeds the maximum allowable streamflow, the effect of streamflow regularization reservoirs on water availability was assessed considering two situations: the effect of the substitution of superimposed streamflows for streamflows distributed over time, and the effect of using the maximum allowable streamflow for the issuance of water withdrawal permits under streamflow regularization (stored water) conditions.

The analysis of the effects is presented in this study only for the months of highest demand, i.e., the most critical condition.

The effect of reservoirs on streamflow requirements

The superposition of water withdrawals is necessary under natural conditions because there is no structure for streamflow regularization. However, if impoundment structures are present, the superimposed stream flows are no longer necessary. Therefore, when a streamflow regularization reservoir is required, the analysis was performed based on the principle that streamflows are distributed over time.

The streamflows distributed over time (Q_{dt}) were calculated as follows:

$$Q_{dt} = \frac{Q_s\,N\,M}{K} \qquad (3)$$

where Q_{dt} is the streamflow distributed over time, $m^3\,s^{-1}$; Q_s is the superimposed streamflow, $m^3\,s^{-1}$; N is the daily hours of use, h day^{-1}; M is the monthly days of use, day $month^{-1}$; and K is the conversion factor, 720.

The Q_{dt} data were divided by the allowable streamflows to provide a comparison with the original scenario (Equation 2). For each hydrographic segment, the percentage of the reference low flow issued upstream was calculated according to the following equation:

$$O_{low\_dt\%\,i} = \frac{\sum Q_{dt\,i}}{Q_{7,10\,i}}\,100 \qquad (4)$$

where $O_{low\_dt\%\,i}$ is the percentage of the reference low flow which has been issued upstream of the segment i, including i, considering the streamflow distributed over time; and $\sum Q_{dt\,i}$ is the sum of the streamflows distributed over time upstream of the segment i, including i, $m^3\,s^{-1}$.

From the comparison of the scenarios, we produced the “Δ Demand$_{\%}$” map to represent the percentage reduction in terms of demand, given the substitution of Q_s by Q_{dt}, according to the following equation:

$$\Delta\,\text{Demand}_{\%} = \frac{Q_{dt} - Q_s}{Q_s}\,100 \qquad (5)$$

The effect of reservoirs on the available allowable streamflow

The main purpose of a reservoir is to stabilize the flow of water, and therefore the guarantee of water supply tends to approach the watershed’s potential, represented by the long-term average streamflow. In that case, streamflows downstream of the reservoir no longer represent the minimum or natural flow, but a portion of the watercourse streamflow potential.

The increase in water availability as a result of such effect enables the issuance of less restrictive water withdrawal permits. If regularization practices are implemented in sections of Minas Gerais, these permits will be granted until the long-term average streamflow is achieved and in streamflows are maintained above 50% of the $Q_{7,10}$.

The "Δ Availability$_{\%}$" map was produced to account for changes in terms of the guarantee of water supply to all users caused by using a different value for the allowable streamflow. This map represents the increase in water availability after the change in the criterion used for issuing permits due to the construction of reservoirs. The difference between the "Q_{lt} – 50% of the $Q_{7,10}$" (stored water) and"50% of the$Q_{7,10}$"(natural condition)criteria was assessed according to the following equation:

$$\Delta\ \text{Availability}_{\%} = \frac{(Q_{lt} - 0.5\ Q_{7,10}) - (0.5\ Q_{7,10})}{(0.5\ Q_{7,10})}\ 100 \qquad (6)$$

The assessment of the potential of streamflow regularization to mitigate the conflicts over water use in the ERRB

The potential to mitigate conflicts over water use in the ERRB by constructing flow regulation reservoirs was assessed by considering the use of streamflows distributed over time and the change in the water with drawal criterion.

The locations of permitted water with drawal corresponding to segments with insufficient water availability were associated to demand values for the most critical month of the year, considering that withdrawals are distributed over time (Q_{dt}). The analysis confronted the Q_{dt} and allowable streamflow values considering the streamflow regularization condition.

The regionalization equation used to estimate Qlt was obtained from a study of streamflow regionalization that generated a model for the automated prediction of low and average streamflows for the state of Minas Gerais (GPRH& IGAM 2012).

$$Q_{lt} = 0.9884\ P_{eq750}^{\ 0.9714} \qquad (7)$$

The percentage of the average streamflow issued upstream of each hydrographic segment is expressed by:

$$O_{ave\%\ i} = \frac{\sum Q_{dt\ i} + 0.5\ Q_{7,10}}{Q_{lt\ i}}\ 100 \qquad (8)$$

where $O_{ave\%\ i}$ is the percentage of the average streamflow which has been issued upstream of the segment i, including i; and $Q_{lt\ i}$ is the average streamflow in segment i, $m^3\ s^{-1}$.

RESULTS AND DISCUSSION

The assessment of the effect of issued water withdrawal permits on the natural water availability in the ERRB

Figure 3 shows the map with the percentage of the low flow that has been issued considering superimposed streamflows for the months of May, June and July. These months display the highest number of reaches in which the maximum allowable streamflow is exceeded.

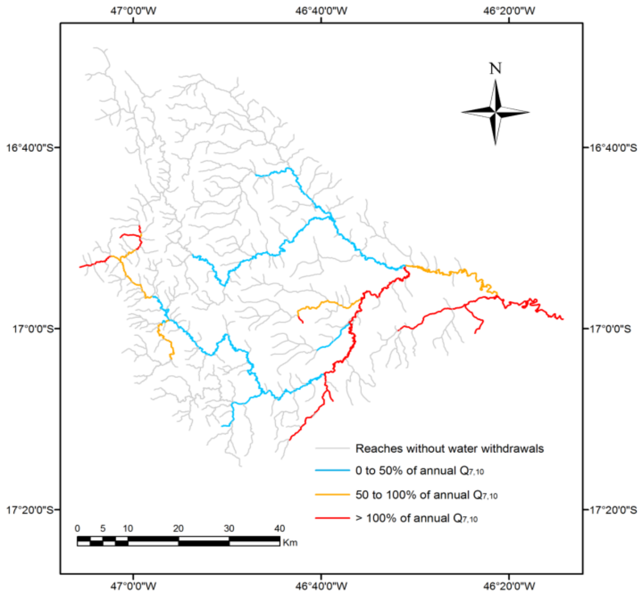

Figure 3 – The percentage of the low flow that has been issued using superimposed streamflows for the most critical months (May, June and July)

Of the total number of reaches in which permits have been issued, 50.7% of the reaches did not exceed the maximum allow able streamflow. The situation is even more critical when we consider 27.5% of reaches exceeded the reference streamflow.

Figure 3 identifies hydrographic segments in which the sum of the demands exceeds the maximum allowable streamflow, which indicates the need for streamflow regularization reservoirs.

The analysis of the effect of reservoirs on water availability

To analyze the effect of constructing reservoirs on water availability along the hydrography, we assessed the effect of distributing demands over time and using the allowable streamflow criterion for streamflow regularization conditions.

The effect of reservoirs on streamflow demands

Figure 4 shows the map with the percentage of the low flow that has been issued for streamflows distributed over time for the months of May, June and July. It is important to highlight that the analysis was not performed for the reaches in which the sum of the permitted water withdrawals did not exceed the maximum allowable streamflow for natural conditions (without any structure for water storage).

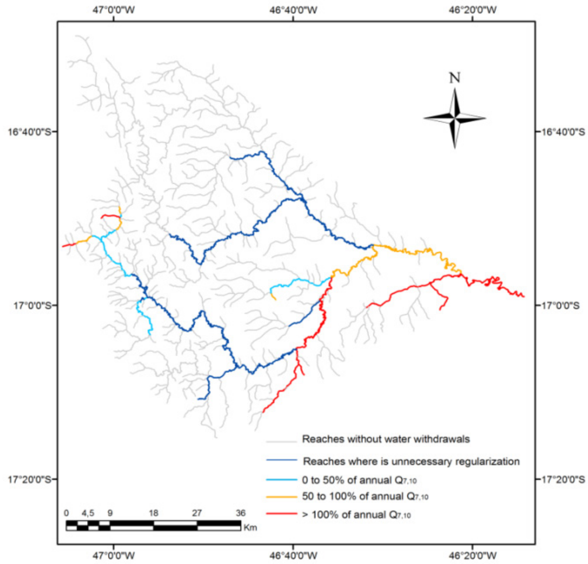

Figure 4 – The percentage of the low flow that has been issued for streamflows distributed over time for the most critical months (May, June and July)

The reaches in which the sum of the permitted water withdrawals do not exceed the maximum allowable streamflow (50% of the $Q_{7,10}$) represented 50.7% of the total hydrographic segments affected by permits when the Qs was considered; after the substitution of Qs by Qdt, this percentage increased to 68.1%.The reaches exceeding the reference streamflow previously representing 27.5% of the affected segments accounted for 18.8% after the substitution.

The distribution of streamflows over time directly increased the remaining water availability. Figure 5 shows the

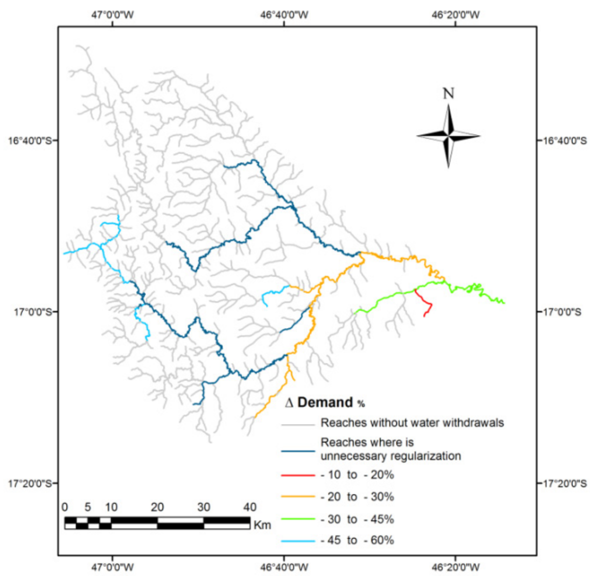

Figure 5 – Streamflow demand reduction after the substitution of Q_s by Q_{dt}

streamflow demand reduction after the substitution of Q_s by Q_{dt}.

Figure 5 shows that the substitution reduced demand between 10 and 60% along the reaches. In this case, a decrease of 60% in streamflow demand is equivalent, in practical terms, to an increase of 60% in supply of water resources. Nearly 57% of the reaches exceeding the maximum allowable reduced streamflow demand by over 30%, except for one segment in which the reduction was below 20%.

In the headwaters, the reductions were over 30%, which strongly indicates that the construction of small streamflow regularization reservoirs has the capacity to solve established conflicts even in areas of low availability. We highlight the fact that many of the reaches in the ERRB with water withdrawal permits are located in the headwaters, in which high demands associated with low availabilities contribute to shortage situations during most of the year.

The scenario presented in Figure 5 shows the benefits that small stream flow regularization reservoirs are able to provide. The implementation of an individual reservoir for every user to guarantee water supply may be a feasible alternative, both technically and economically, as long as environmental concerns are mitigated.

The effect of reservoirs on the available allowable streamflow

Distributing the streamflow over time is not the only benefit provided by reservoirs. These structures modify the distribution of streamflow along the rivers, improve the guarantee of water supply in downstream areas and consequently change the allowable streamflow value. Figure 6 presents the increase in water availability (Δ Availability) resulting from the use of the stored water criterion ($Q_{lt} – 0.5Q_{7,10}$) instead of the natural criterion (0.5 $Q_{7,10}$).This condition corresponds to the maximum increment of the potential water availability (represented by Q_{lt}), regardless of the evaporation influence.

The analysis was performed for all hydrographic segments because the increase in water availability resulting from the increase in the allowable streamflow does not depend on the reaches having water permits.

The increase in the allowable streamflow designated by the regulated maximum after the construction of reservoirs ranged from 1,390 to 1,610%. Despite the small variation amplitude, a greater increase in the headwaters is clearly observed, with availabilities 15timesgreater than those before the construction of reservoirs. To better understand this tendency, Figure 7 presents the $Q_{lt}/Q_{7,10}$ ratiosalong the hydrography.

The $Q_{lt}/Q_{7,10}$ ratio ranges between 8.3 and 9.0 along the hydrography. In addition, higher values tend to be found toward the headwaters, i.e., Q_{lt} presents a less pronounced decrease in that direction than the $Q_{7,10}$.

Because the $Q_{7,10}$ is associated with the groundwater contribution (groundwater runoff), and the Q_{lt} is associated with both the groundwater and surface water runoff contributions, some physical characteristics of the headwaters explain the different tendencies in the streamflow formation. The slope is usually steep near the headwaters, thus runoff tends to be

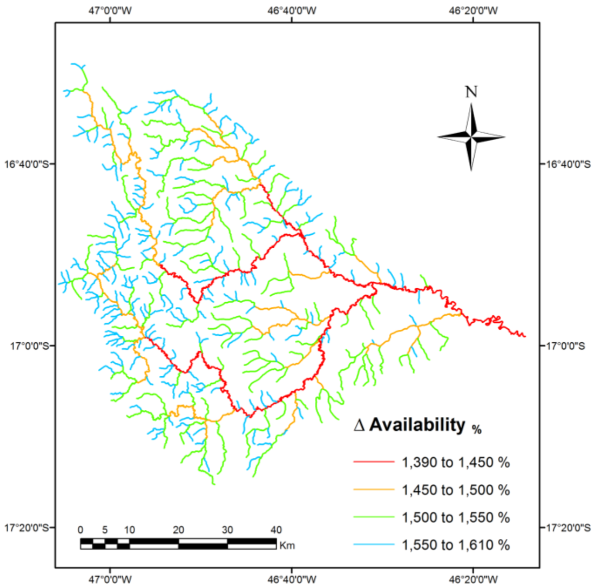

Figure 6 – The increase in water availability after considering stored water criterion

faster and finds less infiltration opportunities, which represents greater contribution to the formation of Q_{lt} in relation to $Q_{7,10}$. The fact that rainfall tends to decrease towards the outlet of the watershed also contributes to the ratio (ARAI et al., 2010; ERMENEGILDO et al., 2012).

The headwaters are usually characterized by higher risks of conflicts over water use, mostly because of low availability. Therefore, the construction of reservoirs is a potential alternative to mitigate these conflicts.

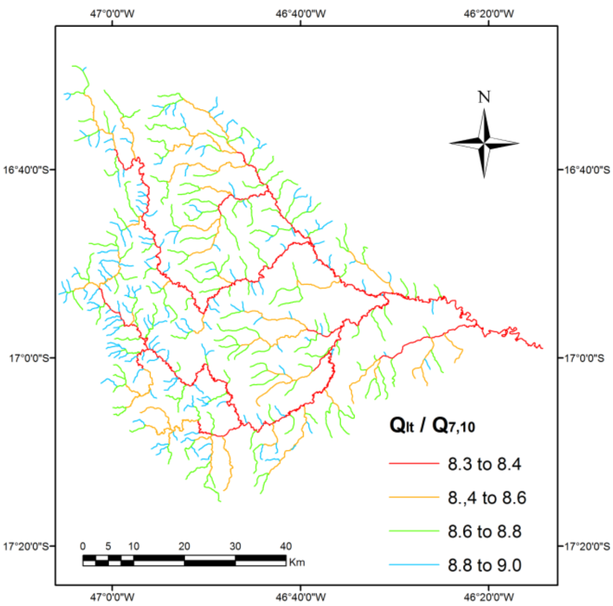

Figure 7 – The $Q_{lt}/Q_{7,10}$ ratios along the hydrography

The assessment of the potential of streamflow regularization to mitigate the conflicts over water use in the ERRB

Figure 8 presents the reaches affected by water withdrawal permits after the construction of streamflow regulari-

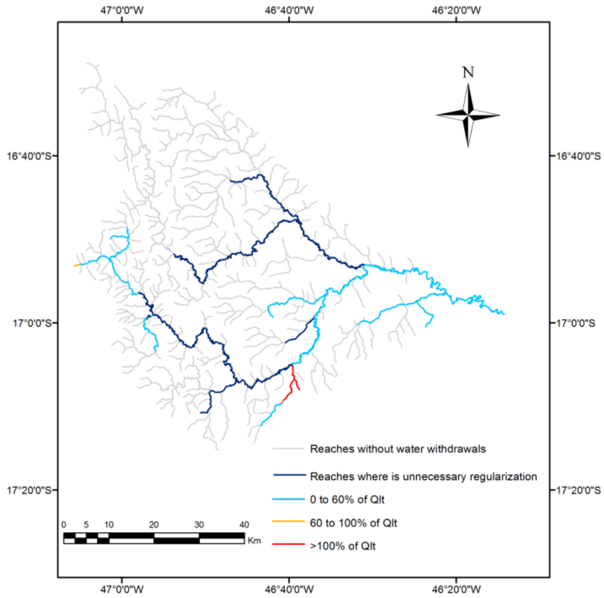

Figure 8 – The percentage of the average streamflow that has been issued considering the streamflow distributed over time and the maintenance of instream flows above 50% of the Q7,10 for the most critical months (May, June and July)

zation reservoirs for the months of May, June and July. The percentage of the permitted average streamflow was determined for streamflows distributed over time and the maintenance of instream flows above 50% of the $Q_{7,10}$.

The Q_{lt} represents the maximum streamflow which, in theory, can be regulated, i.e., without taking into account evaporation and infiltration losses. Based on this theoretical limit (Q_{lt}), the maximum allowable streamflow would correspond to Q_{lt} – 0.5 $Q_{7,10}$, which is exceeded in 5.9% of the reaches in which streamflow regularization is necessary. In these situations, the demand can be met only with the adoption of additional measures such as the transposition of streamflow from other portions of the watershed or even from different watersheds (KHRAN et al., 2012), or by reviewing the water withdrawal permits issued for the areas upstream of those reaches.

Streamflow transposition can be an important design alternative in many regions, reducing the pressure on the use of water resources. However, a full understanding and investigation of the transposition process is required to guarantee the sustainability of the watersheds involved.

Water losses by evaporation and infiltration are important in the analysis prior to the construction of reservoirs, thus the estimation of these values is essential for a comprehensive analysis of actual water losses and gains after the construction of reservoirs. Reliable evaporation estimates are essential for the planning and management of water resources and for studies on the environmental effects of the construction of reservoirs (PEREIRA et al., 2009). Albuquerque e Rêgo (1998) recommend that in humid regions, the maximum stream flow that can be regulated should be 60% of the Q_{lt}, whereas Tucci (2012) recommends values between 60 and 80%, depending on the topographic conditions.

If the value of 60% of the Q_{lt} is recommended for the maximum regulated streamflow, 92.6% of the reaches that exceed the maximum allowable streamflow (light blue segments in Figure 8) meet this requirement. Only one reach (orange segment in Figure 9) has a sum of the Q_{dt} between 60 and 100% of the Q_{lt}, exceeding even the limit of 80% of the Q_{lt} recommended by Tucci (2012). Therefore, this segment represents the most concerning scenario.

Considering aspects of water quality, literature references highlight the versatile influences of water reservoirs on an environment, as changes in flow's hydrological regime, hydrogeological conditions of adjacent areas, transformations of local aquatic and land ecosystems. Some authors indicate that some influences depend on the reservoir size. In agricultural catchments, for example, small dug and dam reservoirs were used to improve the quality of water originated from overland flow and groundwater outflow, and waters used for economic purposes (ZUBALA, 2009).

Generally, with the individual dam's geographic setting, aspects of the position and accumulation of dam impacts in the river network are a key issue in assessment (POFF; HART, 2002).

CONCLUSIONS

The results obtained in this study allow us to conclude that

- for natural conditions, 49.3% of the reaches with water withdrawal permits presented demands that exceeded the maximum allowable streamflow, reflecting the need for streamflow regularization measures;

- the construction of reservoirs enables the increase in water availability because of the effects of the distribution of the demand over time and from using the allowable streamflow value for stored water conditions;

- the substitution of the superimposed streamflows (Q_s) by streamflows distributed over time (Q_{dt}) accounted for a demand reduction of up to 60%,which is equivalent to an increase of up to 60% in the potential for using water resources;

- when the criterion for stored water permits was considered, water availability increases were in the range between 1,390 and 1,610%; and

- when the potential of both effects of the construction of reservoirs on mitigating water use conflicts were assessed, even for a theoretical regulation of 100% of the Q_{lt}, the demands were not satisfied in 5.9% of the reaches in which streamflow regulation was necessary.

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