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ASSESSING DEEP SEEPAGE IN SMALL RESERVOIRS

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ABSTRACT: The increasing demands for surface water supplies for agriculture have emphasized the need for more information on the storage of water in small reservoirs. The storage provided by these infrastructures depends upon the interrelationship between supply, losses, demand, and their respective distributions throughout the year. A great part of the small reservoirs in the world are not adequately built and/or are being poorly maintained. Seepage, in those cases, represents a significant component of the water balance of small reservoirs. It is important to extend our knowledge of seepage behavior of this type of infrastructure. The main objective of this work was to test a simple methodology to measure seepage losses through the bottom of small reservoirs. To study the seepage spatial variability, seepage barrels were built and installed in six places inside a small reservoir. The results showed that seepage varies spatially and temporally over the reservoir. The difference in seepage between the highest and lowest average seepage value is a factor of 143.
KEYWORDS: water resources, water storage infrastructures, water infiltration.

INTRODUCTION: Water availability during the dry season in the Cerrado Biome is uncertain, especially for irrigation. Hence water retention and storage is the only alternative to supply the diverse water demands over time (RODRIGUES, 2007). Among the many ways to store water, reservoirs are the most used. Reservoirs or dams are barriers built transversally to the flow direction of rivers. They are useful infrastructures where the available water flow is less than the requirements for water supply or irrigation, as water can be stored from times when there is surplus. They supply water for domestic use, livestock watering, irrigation, and other beneficial uses. In the last years, hundreds of small reservoirs were built in the Preto River Basin, a sub-basin of the São Francisco basin, contributing to the improvement of irrigated agriculture in the region. The increasing demands of water supply for agriculture have emphasized the need for better understanding of water storage in small reservoirs. The storage provided by these infrastructures depends upon the relationships between supply, losses, and demand over time. Evaporation and seepage are the main types of losses, of which the first is easier to estimate. In a number of situations, seepage is not considered in the calculation of the reservoir water balance, because there is not a simple method to estimate or measure it (DEKKER, 2007). Many small reservoirs in the world are not adequately built, and seepage represents a significant component of the water balance. Thus, to manage the reservoir in a proper way, it is fundamental to get an extensive knowledge of the seepage behavior. The main objective of this work was to test a simple methodology to measure seepage losses through the bottom of small reservoirs.

METHODOLOGY:
- Local: The reservoir of interest lies in a subcatchment of the São Francisco Basin. This subcatchment is called the Buriti Vermelho catchment. The reservoir under investigation is a typical type of small reservoir in high part of the São Francisco Basin. It has a surface area of about 0.25 ha and storage capacity of 3178.7 m^3. Its water is used by a small community of farmers for irrigation.

- Seepage barrel construction: Seepage rate was measured in six places inside that reservoir, Figure 1. For this, six seepage barrels, made of PVC pipe with a diameter of about 25 cm, were constructed. The pipe was closed on the top end and was open at the bottom. About 10 cm below the closed side a small hole was made. An infusion bag was connected to the hole by a rubber tube. We used a medical infusion bag. The infusion bag can be taken off when needed. In the tube, a valve was placed to close of the infusion bag when it to be disconnected from the tank. A hole was drilled in the closed part of the pipe. A rubber stopper was used to close this hole after the barrel has been immersed in the reservoir water and all the trapped air released.

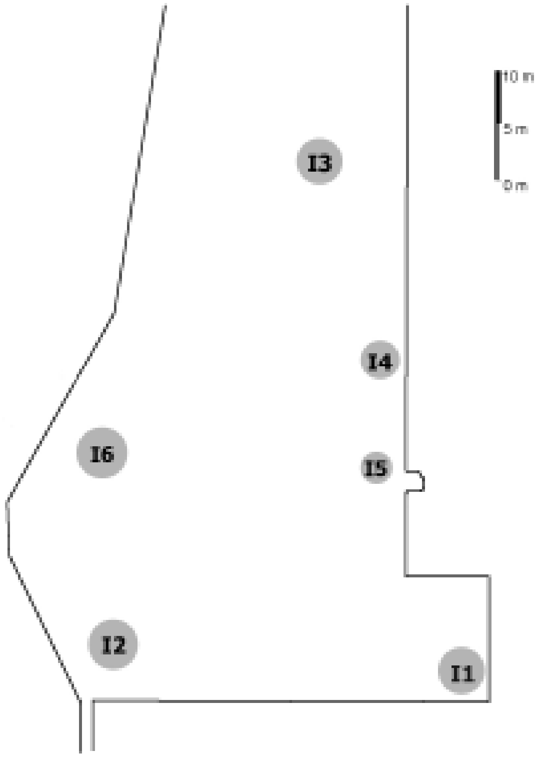

FIGURE 1. Locations of the direct seepage measurements.

- Seepage barrel installation procedure: Sites where to install the seepage barrels were chosen in such a way as to get a good representation of the spatial variability of seepage inside the reservoir and to avoid large cobbles, debris and vegetation, Figure 2. Infusion bag was filled up with water from the reservoir and weighed. Before the pipe was immersed in the water, the rubber stopper was taken out. The open end of the pipe was pressed into the bottom of the reservoir closing off a section with a known area. Ideally, the bag should not apply any pressure on the water contained in the PVC pipe. In such a case, the pressure in the bag will be the normal hydrostatic pressure of the place where the bag is located and the measurement does not change the seepage rate.
- Seepage calculation: The bag was connected to the tank, which is completely under the water table and completely filled with water. After some time, the bag was disconnected and weighed again. Seepage, in minutes, was calculated using equation 1:

$$S = 0.06 \frac{\Delta M}{A\, \Delta t} \qquad (1)$$

where: ΔM is the difference in mass over the measurement, g; A is the pipe cross section area, m^2; and Δt is the time over which the measurement is taken, min.

FIGURE 2. Photo showing the seepage barrels installed in the reservoir.

RESULTS AND DISCUSSION: Seepage barrels were built and installed as described above. Medical infuse bags were used to capture the volume of water seeping in or out of the tank. The results of the seepage measurements vary highly over the reservoir, Figure 3. In location I1, Figure 1, 14 measurements were performed. The duration of the measurements varied from 29 to 1,440 minutes and seepage varied from 0.0382 to 3.8892 mm h^{-1}. To calculate the average outliers were not considered. In this case, the three lowest values (0.0382, 0.0481, 0.0622 mm h^{-1}) and the highest one (3.8892 mm h^{-1}) were not used in the average calculation. The average value for this location was 0.2463 mm h^{-1}. For the location I2, Figure 1, 13 measurements were carried out. The duration of measurements varied from 36 to 1,203 minutes. All measurements were used in the average calculation, which was 0.3979 mm h^{-1}. Nine measurements were taken in location I3, with time varying from 161 to 1,446 mm h^{-1}. The average was 0.0375 mm h^{-1} and three measurements were discarded. Only one measurement was done in locations I4 and I5, with duration time of 30 and 31 minutes, respectively. The seepage values were 0.7741 and 1.0646 mm h^{-1}, for I4 and I5, respectively. The average for I6 was 5.3739 mm h^{-1} and two measurements were carried out, with duration time of 31 and 60 minutes. The mean seepage for this reservoir was 1.3157 mm h^{-1}. It can be noted that there is a factor of 143 between the lowest and the highest mean seepage in the reservoir, indicating that the spatial variation is significant.

CONCLUSIONS: Seepage is an important factor in the water balance. In the specific case of reservoir 2 in the Buriti Vermelho Catchment, during the time measurements were done, seepage was about the same order of magnitude as evaporation from the reservoir. The amount of measured seepage in this period was in the order of 1.3167 mm h^{-1}. Direct measurements are important as a first indication of the direction and magnitude of seepage. Due to large spatial and temporal variations, seepage should not only be measured directly, but extensive other measurements should be made to draw more reliable conclusions on the amount of seepage.

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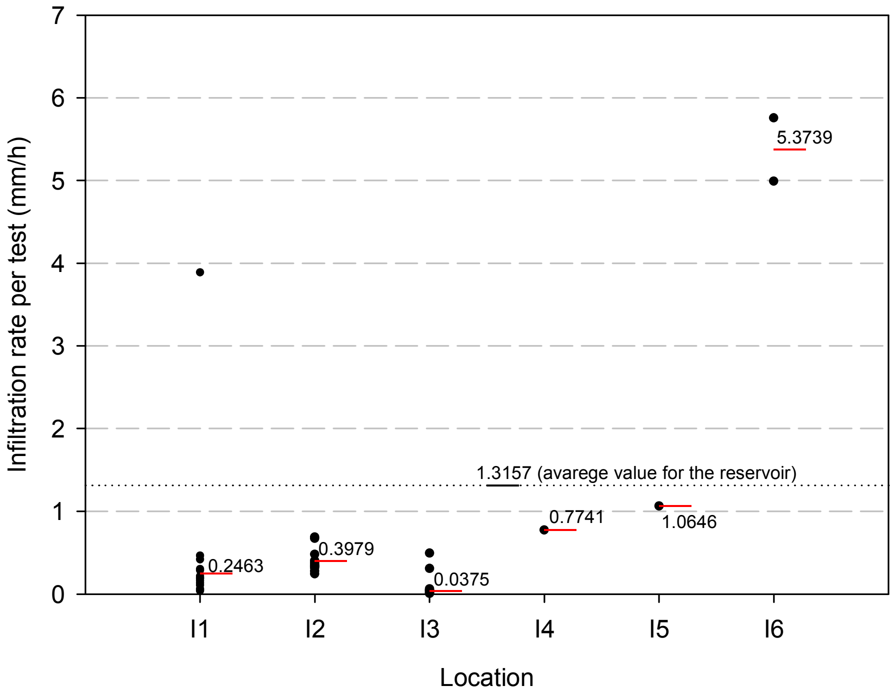

FIGURE 3. Seepage value per test performed and per location as well as the mean seepage per location and for the reservoir.