REVIEW OF WATER LOSSES IN DRINKING WATER REGULATION IN COLOMBIA

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ABSTRACT

Before 2014, Colombian water utilities charges to users were regulated by a different rate scheme, where lost water was measured in terms of the Unaccounted-for-Water (Non-Revenue Water) index. However, this methodology had several problems, as it was not a technical index, but a financial index. The UFW index was not comparable between different water utilities, and it did not allow to assess the impact of leakage reduction programs developed by water utilities. For this reason, the methodology to measure lost water was changed to a different one based in the volume of lost water, normalized by the number of billed users. This paper is a review that describes, analyzes and criticizes several aspects of this new scheme for leakage regulation, which is important for rate definition, as it presents a summary on how losses has been accounted in water supply rate schemes in Colombia.

Keywords*: Drinking Water Regulation, Rates, Water Losses.*

INTRODUCTION

Drinking water regulation in Colombia is divided amongst different institutions; the responsible for rate regulation is the Drinking Water and Sanitation Commission (*Comisión de Regulación de Agua Potable y Saneamiento Básico* – CRA, in Spanish). They are responsible for the economic regulation for the operation of drinking water systems, whether if they are public or privately owned, or whether if they are monopolies or not. This commission makes suggestions to the Vice Ministry of Water, a dependency of the Ministry of Housing (*Ministerio de Vivienda, Ciudad y Territorio* in Spanish), about regulatory aspects of the service. A third institution is the Superintendency of Domiciliary Public Utilities (*Superintendencia de Servicios Públicos Domiciliarios* - SSPD, in Spanish), who is responsible of surveillance and control of water utilities, and thus, for the enforcement of CRA's regulations. However, these are not the only institutions that affect water regulation in Colombia.

For rate regulation, water utilities are classified in two groups according to the number of users they serve: large utilities are those with more than 5000 subscribers, and small providers are those with up to 5000 subscribers. Because of this distinction, there are different technical and service goals for each provider category. This article focuses on large providers, which currently are regulated by CRA Resolutions 688/2014 and 735/2015. These resolutions state how drinking water and wastewater utilities must assess the rates they can charge to consumers. This rate is assessed in terms of the amount of water they produce, the volume of lost water, administrative and operational costs, user's growth, current and future investment costs (e.g. expansion, rehabilitation or reposition costs) and environmental costs (in terms of fees for the use of water or pay rates for wastewater final disposure).

Water losses are unavoidable, since every Water Distribution System (WDS) in the world must have any losses. In developed economies, it is usual to find that these losses present lower values than those found in developing countries. Nevertheless, losses will be found in all networks. According to estimations of the World Bank, currently there are losses of more than 48 billion m^3 every year in the world (Kingdom, Liemberger, and Marin 2006). This number is large enough to satisfy water needs of more than 200 million people that currently does not have access to water (Kingdom, Liemberger, and Marin 2006).

It must be a goal for all water utilities in the world to reduce their water losses, not only to preserve this natural resource, but also to make a reasonable use of it and use it to provide people's growing needs. In addition, when a water utility lowers its water losses, they can perceive more benefits for their commercial activity, which itself can be a good reason to achieve these reductions in leakage and water losses.

In an optimal scenario, all water utilities would reduce the losses in their WDS; however, there are several economic and technical limitations for water loss reductions. For these reasons, it is accepted that a zero-loss level is impossible to achieve for any WDS in the world. The workaround solution is to set an acceptable loss level, where this level can be controlled and managed by water utilities. There are plenty of alternatives for water utilities to achieve water loss reductions, like Active Leakage Control strategies (ALC), pressure management strategies, network sectorization, pipe rehabilitations, etc.

BACKGROUND

CRA's Resolution #17 of 1995

Colombia had defined policies for water loss regulation since 1995, when the CRA's Resolution 17/1995 was introduced. In this resolution it was established that the Unaccounted-for-Water (UFW) (or Non-Revenue Water) index was a good indicator to account for water losses, considering the current development and problems of Colombia's water industry (CRA 2004a). The UFW index has been used since 1995, however it was not until 2005 when the CRA's Resolution 315 established that the UFW must be assessed as it is presented below in equation 1. Thus, this was the equation considered for subsequent resolutions (CRA 2011).

$$UFW = \frac{Water\ Produced + Water\ Imported - Water\ Billed}{Water\ Produced + Water\ Imported} \qquad (1)$$

This index has been used for rate adjustment to include an accepted level of water losses since 1995 in Colombia. In this section of the paper, a short summary of how water rates have been calculated for Colombian water utilities will be presented. This summary will include definitions from CRA's Resolutions 151/2001 and 287/2004, as well as it will include preliminary work from the regulatory commission of 2004 and 2009.

As it was stated before, the first policies where from 1995. Before 1995 water rates for each water utility were directly established by the National Board of Tariffs. Thus, before the first resolution it did not existed a general-purpose rate regulation in Colombia. For this reason, this resolution did considered an equation to assess rates that was simple enough to be useful for Colombian water utilities considering that most of them had financial and measuring problems (i.e. an equation that did not considered complex items that were not measured in WDS at that time) (CRA 2004a).

For this first attempt to regulate rates, water costs were assessed considering capital, operational and administrative expenditures for both drinking water and wastewater systems. For this paper, only drinking water costs will be considered, since wastewater systems are out of the limits of this paper. Since 1995, the basic formulation considers an average cost for those three items, although in recent years more elements have been included. Thus, the rate comprises a fixed charge cost component and a variable charge cost component (CRA 2001).

The capital expenditure costs include long-term investments for the WDS, considering the lifespan of infrastructure assets and a discount rate. The equation used to assess this cost is presented below in equation 2, where CMI stands for *Costo Medio de Inversión* (Spanish for Average Investment Cost).

$$CMI\ (\$/m^3) = \frac{Asset\ Value + Investment\ Plan}{Demand\ Present\ Value} \tag{2}$$

The Demand Present Value (or VPD in Spanish), expressed in cubic meters, is assessed considering the Water Production in a long-term horizon (VPP, in Spanish). Then, corrected by an acceptable water loss level (*P*) defined by the Water Commission (CRA 2001). The VPD is presented in equation 3.

$$VPD = VPP \cdot (1 - P) \tag{3}$$

This value of *P* is the first way to consider water losses in the rate assessment in Colombia. This value was also considered for the Average Operational Cost (*Costo Medio Operacional* – CMO, in Spanish), which accounts for the operational expenses of the water utility. The CMO included energy, operational, maintenance, equipment, and workforce costs; as well as it included raw water costs and environmental use costs (CRA 2001). The equation for the CMO is presented below.

$$CMO\ (\$/m^3) = \frac{\sum Operational\ Expenses}{Water\ Production \cdot (1 - P)} \tag{4}$$

The other main component considered in the rate were the administration costs, or CMA (which stands for *Costo Medio de Administración* in Spanish). The CMA is a fixed cost; this means that it is the same for every user in the network disregarding their monthly consumption levels. The CMA includes the administrative expenses and it is divided between the numbers of billed users. At the end, the final 1995 rate scheme comprises two main components, as it was stated before, a fixed cost and a variable cost. For the fixed charge the CMA is considered, whilst for the variable charge the CMO and the CMI were considered. This means that the acceptable water loss level *P* only affects the variable charge cost component of the rate. A simplified version of the rate considering 2001 Resolution is presented in equation 5.

$$Tariff_{1995}\ (\$) = CMA + (CMO + CMI) \cdot Metered\ Volume\ (m^3) \tag{5}$$

Thus, the most important component regarding water losses in this rate scheme was the value of P, which was the only parameter, related to water losses, in this Resolution. The regulator defined that the maximum level of acceptable water losses was 30%, assessed with the Unaccounted-for-Water index presented before.

This scheme assured that water utilities could cover the expenses incurred in the daily operation of the WDS (CMO) and covered the costs for the maintenance, rehabilitation and future expansions of the network required to meet future demands (CMI). Thus, the plan defined by the CRA was to allow water utilities to be stable and financially self-sufficient. Then, in a second stage, water utilities could be encouraged to reduce their costs, to improve the quality of the service they provide, and reduce their water losses.

CRA's Resolution #287 of 2004

In 2004, for the CRA's Resolution 287/2004, the main rate scheme presented in equation 5 was maintained. However, several changes were made to consider more cost components into the assessment. This updated rate scheme also introduced valuable innovations like a model for comparative efficiency and more detailed cost components. For instance, it introduced an environmental cost component in the variable charges (*Costo Medio de Tasas Ambientales* – CMT, in Spanish). In addition, there were changes in the formulation of the CMA; however, as this component is not affected by the water losses parameter, these changes to CMA are not relevant for this paper.

The CMO component also had several changes. The commission decided to use the behavior of the best utilities to define an efficient standard for the rest of the water utilities. This strategy is Regulation by Comparative Efficiency and it can be used to establish floor or cap prices (CRA 2004a). For this reason, since 2004 the CMO has two components, the first one is particular to every water utility and the second one is defined by comparison between the costs of several water utilities. This formulation allows to consider that some operational-related variables cannot be compared between different water utilities (i.e. energy required for pumping, water treatment components, etc.). This CMO cost is presented in equation 6.

$$CMO = \frac{\sum Operational\ Expenses}{Water\ Production \cdot (1 - p^*)} + \frac{\sum Operational\ Taxes\ and\ Rates}{WB + \left(\frac{WB}{1 - UFW} \cdot 0.57 \cdot (UFW - p^*)\right)} \quad (6)$$

In this equation, WB stands for Water Billed by the water utility. The operational taxes item comprises all taxes that water utilities must pay to make use of their water sources, as well as all particular costs for each water utility. It is worth to note that this component of the equation also should be divided by $Water\ Production \cdot (1 - p^*)$. However, the purpose is to recognize to the water utility just the real losses; thus, this value is replaced by the expression presented in equation 6, where the 0.57 represents an adjustment factor to the apparent losses assessed by the regulator (CRA 2004a). Therefore, the commission seeks to recognize real losses that are below the established limit, excluding apparent losses. This adjustment factor was obtained considering a sample of 30 water utilities, which had discriminated real and apparent losses.

On the other side, the component on the CMO defined by comparison between different water utilities keeps the same structure of the previous CRA's Resolution; this structure was presented in equation 4. Likewise, in general terms the main structure of the CMI was maintained as it was presented previously in equation 2. The only addition to this formula was to include a component that accounted for land investments, being the new formulation for the CMI as it is presented below in equation 7 (CRA 2004b).

$$CMI\ (\$m^3) = \frac{Asset\ Value + Investment\ Plan}{Demand\ Present\ Value} + Land\ Investments \qquad (7)$$

The investment plan may include those actions that the water utility must execute to reduce the UFW index as long as the proposed actions attack real losses. These actions must be included in the investment plan and must be formulated according with the plans for loss reductions defined by the utility.

Another item that was changed with the new CRA's Resolution was the equation to assess the value of the Demand Present Value (VPD). This equation was previously explained in 2001; however, it was not until 2004 that it was included in the Resolution. The term VPP (Water Production Estimate) of equation 3 was clarified, thus, the resulting form to assess the VPD is presented in equation 8.

$$VPD = \sum_{z=0}^{HDF} \left(\frac{BPV_z}{(1 - UFW_z)} \cdot (1 - p^*) \right) \qquad (8)$$

In this equation, *BPV* stands for the water Billed Present Value in the year z of the forecast, *HDF* represents the Horizon for the Demand Forecast, p^* is the maximum level of loss accepted by the regulator and *UFW* is the Unaccounted for Water index. Equation 8 considers that billed water in a year must be equal to the amount of water produced discounting the amount of water lost (which is represented by the UFW). The objective for the incorporation of the new VPP is to give a clear signal from the regulator to water utilities for the assessment of the forecasted production present value (CRA 2004a). Nevertheless, this approach to production volume must be corrected by the maximum acceptable loss level p^*.

Finally, the last change introduced by the last component presented by the 2004 Resolution was the environmental cost as a variable charge (*Costo Medio de Tasas Ambientales* – CMT, in Spanish). This item was included taking into account that the degradation of natural resources has led to look for policies and instruments to encourage water utilities to make a rational use of natural resources and modify its behavior to less contaminant processes (CRA 2004a). Traditional approaches include economic instruments (market-based stimulus), and contaminant control policies and restrictions. Equation 9 presents the way to assess the CMT. Water rates to be considered in this equation must be given by the environmental control agencies. This equation also considers the maximum level of accepted losses defined by the regulator.

$$CMT = \frac{Water\ use\ rates}{(1 - p^*)} \qquad (9)$$

$$Tariff_{2004}\ (\$) = CMA + (CMO + CMI + CMT) \cdot Metered\ Volume\ (m^3) \qquad (10)$$

Acceptable Water Losses

The CRA's Regulations presented previously from 1995, 2001 and 2004 both considered a maximum acceptable loss level of 30% (measured by the UFW index). For this reason, with the aim of integrating additional efficiency elements to improve the assessment of loss reduction programs, a new approach had to be proposed (CRA 2009). For the regulator it was pertinent to analyze the acceptable loss level recognized to water utilities, as it was relevant to analyze its estimation.

This acceptable water loss level must consider the cost-benefit relationship of loss reductions up to a level p^* that it is considered an economic optimum for regulatory effects. According to the regulator, this level must have several effects like the delay of investments in new water sources and the improvement in data records management (i.e. users and network database update). In addition, this economic optimum may also motivate water utilities to make better use of water resources, both in environmental and financial terms (CRA 2009).

It is worth to note that water utilities are not enforced to get a p^* value, water utilities must perform their technical, economic and financial evaluations to find their optimum loss level. If this value is different from p^*, each water utility has to decide if they will try to move to more efficient levels or if they will stay at their current levels. However, water utilities can only recover p^* from users billing.

The 30% loss level was defined considering the UFW index, which is affected by the amount of water produced, the amount of exported/imported water (since Resolution 315/2015) and the amount of billed water. However, as data-measuring devices availability increases and its costs decreases, it would be more feasible to reconsider the use of UFW as loss index (CRA 2009). At first, it must be stated that this 30% value accounts for both real and apparent losses, which could represent a problem to evaluate water utilities' performance in loss reduction.

Real and Apparent Losses

According to the World Bank, the average UFW index was 15% for developed countries and 35% for developing countries (Kingdom, Liemberger, and Marin 2006). In addition, they estimated that real losses account for 80% of losses in developed economies and for 60% in developing economies. This is important considering that to establish better loss reduction programs water utilities must know what problems they need to address, and this is possible only if real and apparent losses are correctly differentiated. The results presented in a research funded by the United States Trade and Development Agency, a consulting company stated that there was not a good relationship between the UFW index and apparent losses, as well as it is very complex to assess apparent losses since most Colombian water utilities do not have such information (International Consulting Corporation – ICC 2007).

In the same research, there were several conclusions about losses in Colombian utilities. If the amount of available water is greater than the demanded water, then it could be expected the marginal value of water to be low. The reverse situation is also true, if water availability is near the capacity of the system, marginal value would tend to be higher (International Consulting Corporation – ICC 2007). This research found that it is difficult to assess the exact amount of real and apparent losses in Colombia, since most water utilities do not have enough information.

For this reason, it was necessary to consider several international approaches to solve the problem and estimate the distribution of losses in WDS. For instance, the World Bank Institute proposed a Banding System methodology to establish real losses reduction goals considering the number of connections, the average pressure and the technical performance of water utilities (Kingdom, Liemberger, and Marin 2006). This methodology is based on the research made by Liemberger and

McKenzie and was accepted by the IWA (Liemberger and McKenzie 2005; A. Lambert et al. 2014). The Banding System methodology focuses loss reduction mainly by changing the average pressure in the network. Regarding apparent losses, it was found that there was not sufficient available research to be used by Colombian water utilities (CRA 2009).

Most regulation agencies throughout the world recognize that it is not necessary to include financial incentives for water utilities to reduce its apparent losses. This reasoning because for water utilities the financial benefits of charging for water that has been already produced, transported, treated and distributed is high enough to be an incentive to improve their apparent losses. Considering that, apparent losses may include legitimate demand that do not represent revenue (i.e. water delivered to state-owned buildings, parks and firefighters) some regulation agencies accept an small level of apparent losses of about 1.5-3.5% to be included in the rate calculation (CRA 2009).

For these reasons, the Colombian regulator has proposed that the maximum acceptable loss level (p^*) should include different components for real and apparent losses (CRA 2009). Equation 11 represents this behavior. Although this equation was never implemented in any CRA's Resolution, since it did not passed the socialization process.

$$p^* = {p^*}_{real} + {p^*}_{apparent} \tag{11}$$

Thus, it was clear that a 30% loss level could be improved after 20+ years of using it as maximum loss level. It was found that maintaining the same regulatory signal for all water utilities was not appropriate to assess particular efforts made by utilities in losses management (CRA 2009). For instance, it is not the same a 1% loss reduction for a 25,000 users system that for a 2,500 users system. For this reason, it was proposed that in the future water losses maximum level should be defined using a real-losses-per-person index. This is, an amount of water lost per person or household that would be recognized as costs of water supply. For instance, if the WBI's Banding System were considered as reference values, the acceptable losses-per-person value would have been 54 $m^3/subscriber/year$ (a subscriber is not a person, but an account per household). Therefore, acceptable real losses were to be assessed as presented in equation 12 (CRA 2009).

$${p^*}_{real} = \frac{54 \cdot \#Subscribers}{Water\ Production} \tag{12}$$

Concerning apparent losses, the regulator proposed a general efficiency signal. Thus, the same maximum level would apply to all water utilities, disregarding any particular condition. Considering that Colombian utilities, in general, have problems in measuring and billing activities, the regulator proposed to establish acceptable apparent losses as ${p^*}_{apparent} = 7\%$ (CRA 2009). However, this proposal was never implemented in any of CRA's Resolution.

CURRENT POLICY

All water real losses reduction research has been centered in the definition of performance indicators that can account for the actions in leakage control made by water utilities. Thus, the objective has been to identify how the improvements on management can affect loss reduction programs. In the 1st Water Loss Task Force in 1999, the IWA proposed a performance indicator for WDS, the Infrastructure Leakage Index (ILI) which measured real losses. This index seemed as a good replacement for less robust indicators like the UFW, as has a more profound conception than percentage indicators, allowed the comparison between different WDS, and thus allowed the definition of performance goals. However, on the downside, this index must be used with an economic evaluation of loss reduction costs, and requires a big effort of water utilities on measuring campaigns (CRA 2009).

Nevertheless, it was necessary to define a new methodology to encourage water utilities to improve its losses reduction programs. Losses reduction could achieve improvements in environmental costs, could extend water sources lifespan and could represent economic benefits for water utilities. However, the main purpose of rate regulation is to recognize particular situations that may affect water utilities, and avoid all losses costs to be charged to the billed users of the WDS (CRA 2011).

As a first step, the use of the UFW index was reconsidered. It was concluded that the robustness of this index was greatly affected by variation in water demands, the imported and exported amount of water and the volume of billed water (CRA 2011). Furthermore, as it will be demonstrated in the next chapter of this paper, it was found that water utilities were not achieving perceivable reductions in its UFW index, even after more than 10 years of loss reduction programs. For these reasons, the regulator implemented a new methodology to include water losses in rates. This new methodology is based in an operational performance indicator, instead of a financial indicator. Thus, the objective is to quantify lost water volume, instead of the costs of a loss level (CRA 2011). This indicator should account both for real and apparent losses.

Although there were several options like the Unavoidable Annual Real Losses (UARL) (A. O. Lambert and Fantozzi 2005), the Economic Recoverable Real Losses (ERRL) or the Infrastructure Leakage Index (ILI) (A. O. Lambert and Fantozzi 2005), these performance indicators required more information that Colombian water utilities did not collected at that time (CRA 2011). Thus, the regulator decided to use the IPUF (*Índice de Pérdidas de agua por Usuario Facturado*, which is the Spanish form to Lost water by Billed User Index). This index is measured in m^3/subscriber/month, thus, it accounted for the volume of lost water, normalized by the number of subscribers (assumed the same as the number of connections).

For these reasons, several changes had to be made to the equations to assess the different components of the rate calculation methodology. To include the IPUF index, it was also necessary to define the ISUF and the ICUF, which accounted for Supplied water by Billed User and for Consumed Water by Billed User, respectively. Equations 13 and 14 present ISUF and ICUF, also in m^3/subscriber/month.

$$ISUF = \frac{Produced\ Water}{\#Subscribers \cdot 12} \tag{13}$$

$$ICUF = \frac{Billed\ Water}{\#Subscribers \cdot 12} \tag{14}$$

Then, the IPUF could be assessed as it will be presented in equations 15 and 16.

$$IPUF = ISUF - ICUF \tag{15}$$

$$IPUF = \frac{Produced\ Water - Billed\ Water}{\#Subscribers \cdot 12} \tag{16}$$

The ISUF represents the volume of water per subscriber that a water utility has to produce in their water treatment plants to supply the network. The ICUF represents the volume of water billed per subscriber by the water utility (CRA 2014a). This framework assumes that there are limits in the billing gains, as well as there are limits in losses reductions. The first limit is established by the consumption level per subscriber, and the second one is given by the infeasibility of reducing losses up to zero (CRA 2014a). These elements were included in CRA's Resolution 688/2014 (CRA 2014b). The inclusion of this new formulation required the modification of the former equations defined in 2004.

To include losses in the rate calculation it is necessary to differentiate between the efficient values and the current values, since both of them will be used in the rate equations. For instance, there must be an efficient value of water supplied ISUF*, which must be related to an acceptable loss level IPUF* that may represent the control an loss reduction potential of water utilities (CRA 2009). On the other side, the regulator accepts that a low ICUF value may represent that there are inefficiencies in billing management (CRA 2014a). Therefore, the ISUF will be a regulation signal that seeks to discourage water production from water utilities. The relationship between these components in its acceptable values is presented in equation 17 (CRA 2014a).

$$ISUF = IPUF^{*} + ICUF \tag{17}$$

The regulator demands that water utilities define a detailed losses reduction program for the indicators IPUF, ICUF and ISUF. These programs will be a 5-year horizon plan, with annual loss reduction goals, and must differentiate between residential and non-residential demands (CRA 2014a). Thus, the CRA's objective is to limit the acceptable IPUF* value. Then, water utilities will reduce its water production levels, considering the effects of improving its billing management and reducing water losses (CRA 2014a). It is worth noting that the ICUF does not fully represent the real consumption because it represents the consumption billed to customers. These two values will become closer as apparent losses are reduced.

After a research considering the performance of several water utilities in Colombia and Latin America (93 Colombian and 79 Latin American water utilities), the CRA found that the IPUF variation of the best 25 utilities in the sample was in the range 2.2-7.6 m^3/subscriber/month. Similarly, considering the largest water utilities, the average IPUF of the best five was 5.9 m^3/subscriber/month. While, for the best five small-sized utilities its average IPUF was 5.0 m^3/subscriber/month (CRA 2009).

Considering a sample of 107 Colombian water utilities, it was found that the average IPUF for the best 10 utilities in 2008 was 4.6 m^3/subscriber/month (CRA 2009). Then, in 2011 it was assessed the IPUF for a 32-utilities sample with water meters for at least 80% of subscribers in the WDS; results found an average IPUF for the best 15 utilities of 6.26 m^3/subscriber/month (CRA 2014a). Additionally, the regulator considered appropriate to take into account the proposals that were not implemented, presented previously in equations 11 and 12. Following these proposals, the acceptable losses would have been 6.6 m^3/subscriber/month (CRA 2009). At the end, after all these considerations, the regulator defined an acceptable value of 6 m^3/subscriber/month to be included in rate calculation (CRA 2014a). However, water utilities can use a different value if they justify that value to the regulator that their optimal loss level (CRA 2014b).

Therefore, as formula for CMO, CMI and CMT (equations 6, 7 and 9) had water losses in the denominator, it was necessary to include the ISUF and the IPUF* to assess the losses-corrected consumption (CCP for the Spanish *Consumo Corregido por Pérdidas*), instead of using the UFW (CRA 2014a). The equation for the CCP in a year *i* is presented below in equation 18.

$$CCP_i = (ISUF_i - IPUF^*) \cdot \#Subscribers_i \cdot 12 \tag{18}$$

Then, for the CRA's Resolution 688/2014 the CMO was defined as presented below in equation 19. Similarly, the new formula for the CMI is presented in equation 20 and the CMT in equation 21 (CRA 2014b). In these equations, PV stands for the Present Value function.

$$CMO = \frac{\sum Operational\ Expenses}{CCP} \tag{19}$$

$$CMI = \frac{PV(Investment\ Costs)}{PV(CCP)} \tag{20}$$

$$CMT = \frac{Water\ use\ rates}{CCP} \tag{21}$$

Finally, a simplified version of the rate considering the 2014 Resolution, to update what was presented previously in equation 5, is presented below in equation 22. This formula contains all three analyzed components: CMO, CMI and CMT as the variable charge items in rate. It also includes a fixed charge component, based on the CMA cost (CRA 2014b).

$$Tariff_{2014} = CMA + (CMO + CMI + CMT) \cdot Metered\ Volume\ (m^3) \tag{22}$$

REASONS TO CHANGE: CASE STUDIES

As it was mentioned previously, the UFW index was used to account for water losses in water supply rate schemes in Colombia from 1995 to 2016, since it was until 2014 that CRA's Resolution 688 made mandatory to change the rate scheme to the new one that included the IPUF instead of the UFW index. The 2014 Resolution established a two-year grace period for the utilities to make the adjustments they considered necessary. Since 2016, CRA's Resolution 688/2014 is fully implemented, and it became mandatory for large water utilities (i.e. utilities that serve more than 5000 subscribers).

Therefore, it is now relevant to state why it was considered necessary to make all the changes proposed in 2009 and revised in 2011. As it was mentioned previously, the main objective of the regulator was to encourage water utilities to reduce the amount of water produced. Thus, water utilities were stimulated to implement several losses reduction programs for both real and apparent losses. However, it was unfeasible to see the results of these losses reduction programs with percentage indicators like the UFW index, reducing the impact of what water utilities made and reducing their motivation to continue with those projects. With this index, it was also possible that utilities with high losses levels were forced to attain unmanageable billing goals.

Figures 1, 2 and 3 highlight the water production, water billed and number of subscribers of three different cities in Colombia in the period 2007-2011. All cities have growing trends regarding the number of subscribers of the network, and have almost constant water billing values. However, there are several differences in the behavior of the amount of water produced. These three cities were chosen because they are relevant capital cities and allow to present several issues on the UFW index: Bogotá is the largest city in the country; Santa Marta was the city with highest UFW in the sample and Bucaramanga the city with the lowest UFW in the sample (CRA 2014a).

It is worth noting that these figures present data of a period before the IPUF was implemented. In Bogotá and Bucaramanga, it can be seen that water production levels remain almost constant, while the number of subscribers is increasing, thus, it could be expected that water losses were reduced and the UFW index should be lowering in this period. However, data shows the opposite, as the UFW index becomes higher in the three cities. On the other side, if the IPUF is evaluated, it shows a slightly decreasing trend in Bucaramanga and it remains almost constant in Bogotá.

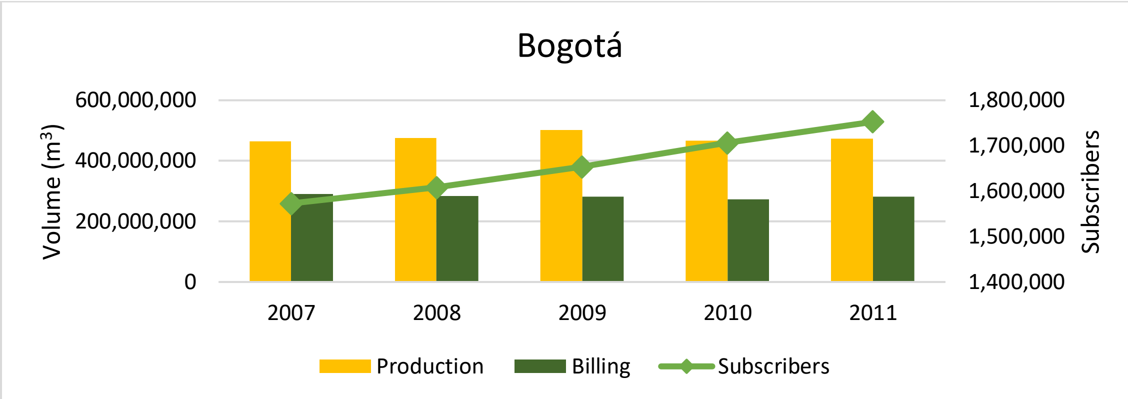

Figure 1. Volume produced and billed (m^3) and number of subscribers in Bogotá (2007-2011)(CRA 2014a).

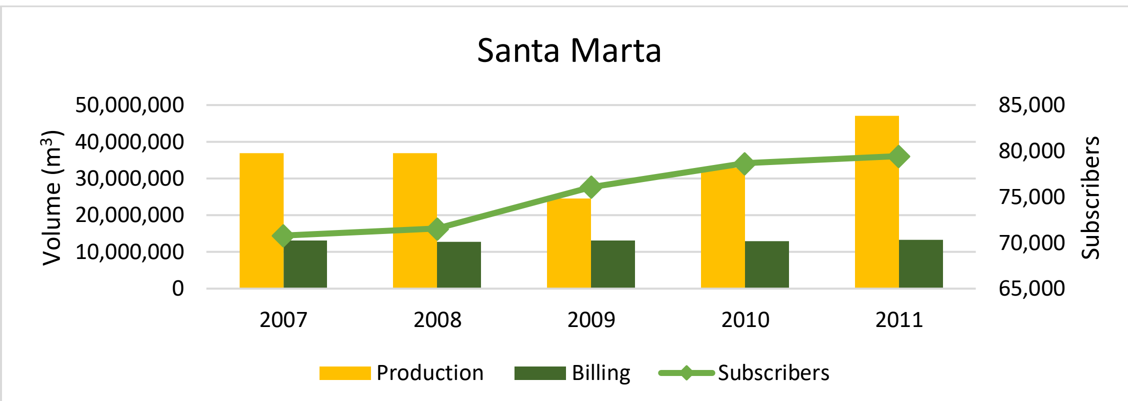

Figure 2. Volume produced and billed (m^3) and number of subscribers in Santa Marta (2007-2011)(CRA 2014a).

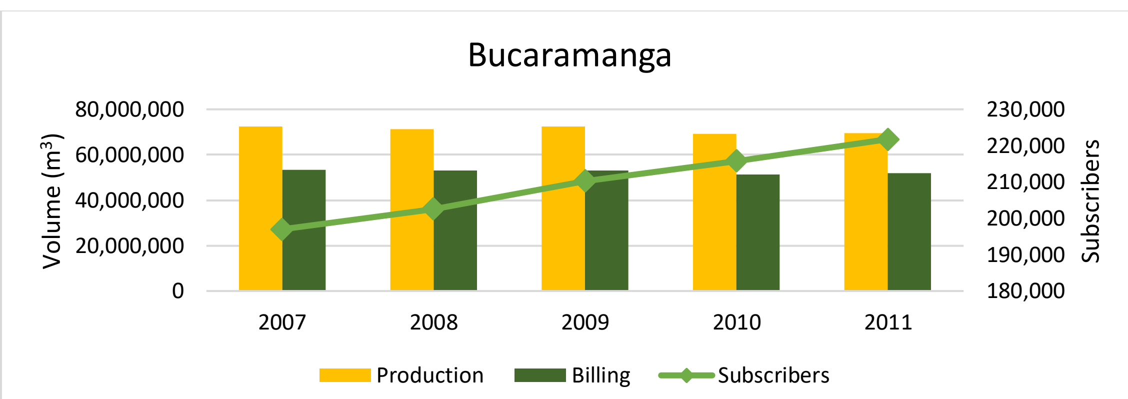

Figure 3. Volume produced and billed (m^3) and number of subscribers in Bucaramanga (2007-2011)(CRA 2014a).

As it will be presented, it was found that in the 20 years that the UFW index was considered as the loss performance indicator for rate calculations, this index remained almost constant for most water utilities, justifying the change for a new index. This trend can be seen in Figures 4 and 5 for a 10-year period. In these 10 years, the general trend shows that the UFW is decreasing, however this decrease is almost negligible, and for individual cities, it remains almost constant in this period. It is worth noting that for 2012 there were not individual values reported and for 2013 the values where completed from a different source.

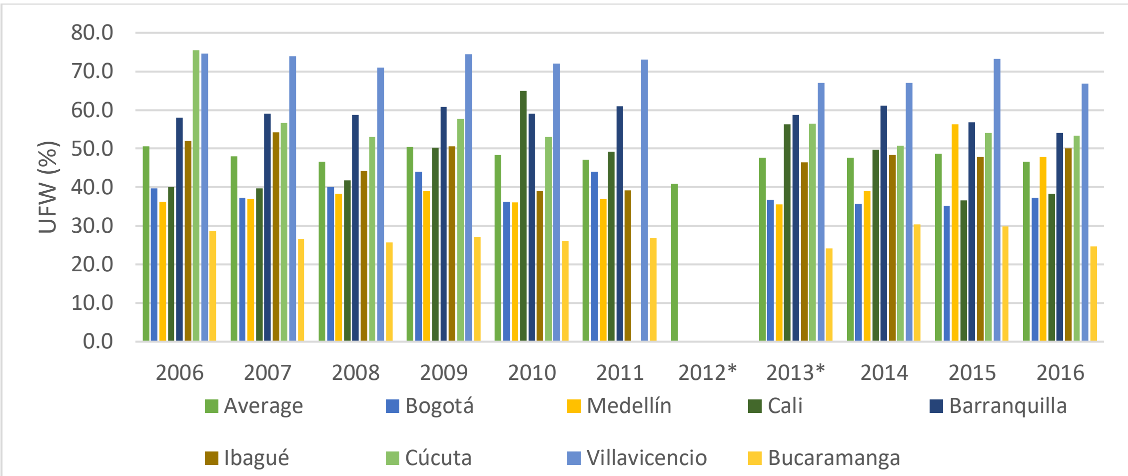

Figure 4. Evolution of the UFW index in several cities between 2006 and 2016 (SSPD 2015, 2017).

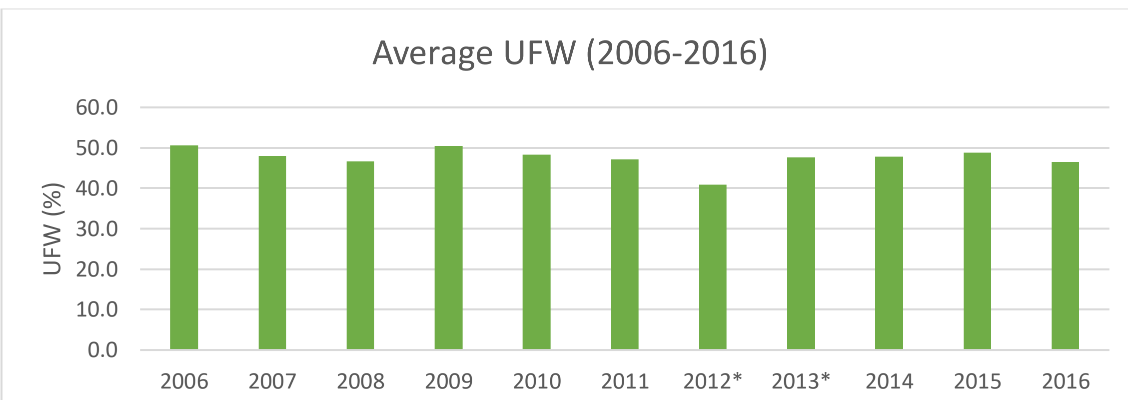

Figure 5. Average UFW index for Colombia between 2006 and 2016 (SSPD 2015, 2017).

Figure 6 presents the average IPUF and UFW values for a 13-cities sample (Bucaramanga, Popayán, Cartagena, Manizales, Cúcuta , Santa Marta, Bogotá, Pereira, Cali, Armenia, Montería, Tunja and Barranquilla), where it can be seen that in general, the UWF is unstable, while the IPUF is more stable. The latter presents a general decreasing trend, while the UFW increases and decreases greatly year-over-year for this sample.

At last, Figure 7 presents the total amount of water produced, billed and consumed in the period between 2014 and 2016, which is the grace period that utilities had to prepare for the implementation of the new IPUF. It is interesting to note that the amount of treated water greatly dropped from 2014 to 2015, while water consumption increased in 2015 serving more subscribers than in 2014. Thus, it would be possible to think that this is a positive effect of the new regulation scheme. However, as this is the first year of application of this new scheme, currently there is no information available to public of the IPUF because the SSPD has not released yet the analysis for 2017. Thus, it is reasonable to state that currently there is not enough information to compare and see the effects of CRA's Resolution 688.

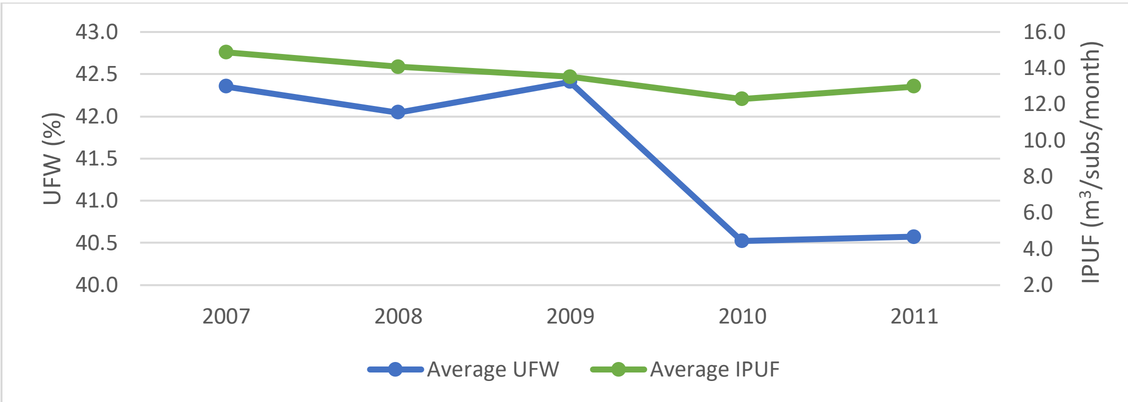

Figure 6. Comparison between the UFW index and the IPUF index for the average of 13 large cities (CRA 2014a).

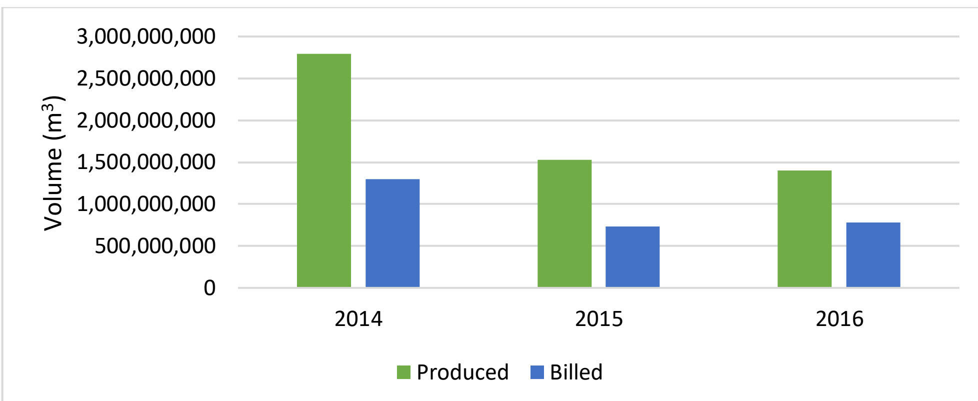

Figure 7. Total amount of water produced, and water billed in Colombia (SSPD 2017).

CONCLUSIONS

After all, it is possible to conclude that the UFW index never generated an effective signal regarding the reduction of water losses in WDS. Thus, its inclusion in rate equations may represent that some water utilities are not recovering their expenses because they are penalized by water losses. Besides, apparently the punishment for having higher losses is not enough for water utilities to decide to take actions to reduce water losses. This reason could explain that the IPUF is not a good index to account for the management and actions performed by water utilities.

The global trend, and CRA's intuition, allow thinking that volumetric losses indicators may account better for water utilities losses management. The UFW does not allow identifying the evolution in losses levels, and thus is not a good indicator to demand target goals to water utilities. However, it is still soon to know if this is true, as information is not available yet.

It is relevant to conclude that the regulator is moving in the right direction, since there have been several changes in rate equations to improve the way water losses are accounted in service rates.

At first, the regulator proposed the use of a *p** that represented a 30% loss, measured with the UFW index. Through the years, there has been some improvements to that formulation proposed in 1995. In 2004, the regulator made improvements to the assessment methodology, building on the original equations. However, those changes did not affect the way water losses were included in the equations, and thus these changes did not improve the behavior of water utilities concerning water loss reduction programs.

In addition, it is worth noting that despite regulation exists since 1995, most water utilities in Colombia did not achieved the 30% objective and most utilities had UFW values above that limit. Therefore, it is possible that the regulatory signal of 30% maximum losses level did not corresponded to an optimal signal regarding efficiency, and that may be a reason why water utilities did not reach that level. It is also probable that water utilities have not made the proper actions to reduce their water losses, or that they have assessed their optimum water loss levels and attained to reach that value, disregarding the 30% recognized by the regulation agency.

In Colombia, it is now accepted that regulation must move forward. Thus, management signals must be included in rate assessments, these signals should consider an efficient loss level and water production levels in the calculations. It is also a good idea to allow water utilities to adjust their operational and investment expenses to be included in the water rate, according to their own decrease goals in water production. Therefore, it is expected that utilities can define their particular reduction levels in production, considering their own loss and billing efficient levels.

It was found that it is still very difficult to assess the amount of apparent losses in WDS, even in developed countries where this value is expected to be lower than in developing countries. For that reason, it is possible to conclude that the Colombian regulator had made a good choice by deciding to define an acceptable loss level that accounted both for apparent and real losses. Even for international organisms it is still difficult to define an acceptable loss level for apparent losses, and thus it is not possible to force water utilities to reach a specific apparent loss level.

Because of the newness of the new acceptable loss level scheme, currently it is not possible to assess its effects on water rates and on water utilities behavior on production, treatment and loss reduction of water. However, it is worth noting that apparently water utilities present a natural trend to reduce their consumption levels, because the ISUF tends to lower values each year. This behavior made possible that the regulator did not established an efficient value ISUF*. This may be relevant as the produced water volume affects directly the operative costs of the WDS. Thus, the current regulation encourages water utilities to reduce real and apparent losses whenever it is possible, serving more customers while reducing water production.

The regulator has defined that each water utility has to set its own reduction goals for a 5-year period. Therefore, it is not possible to see if utilities have reached their goals today. For this reason, it is possible to state that rate schemes are long-term processes that must be carefully studied. Therefore, today it is worth noting that the Colombian regulator should be looking for the future acceptable losses schemes to modify or change the current one. For instance, as it was stated before, the regulator should look the possibility to use an internationally accepted index like the ILI, or other robust indicator. For this, it is necessary that the regulator demands water utilities to improve its data acquirement instruments and improve water metering both at household residential connections and at main pipes. All of this in order to be ready for the future, and thus to be prepared to a new regulatory scheme.

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