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The influence of rainwater drainage related to legislation in the configuration of the urban landscape in Belo Horizonte, Brazil

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Abstract

Master plans and land use, occupation and subdivision laws are some of the main instruments responsible for shaping and directing urban development. In relation to this, legislation has a fundamental role in consolidating effective rainwater drainage strategies, such as the establishment of minimum permeability rates, environmental protection zones and tax incentives over the installation of compensatory storage and drainage systems. In the city of Belo Horizonte, Brazil, the expansion of urban occupation has taken place inappropriately with regards to the existing hydric resources, with little consideration for natural water courses and reflecting developmentalist and unsustainable thinking, which has resulted in the occupation of the river sides and the rectification of water courses in a counterproductive manner. In addition, the city has been late in addressing the issues and legislation regarding rainwater management. This has led to a series of problems in dealing with urban drainage, resulting in recurring and damaging floods throughout the periods of high rainfall over the hydrographic basin of the River Arrudas, and at the expense of extensive social, economic and structural damage to the city. This paper seeks, through a critical review and analysis of the evolution of the municipal urban drainage laws from 1930 to the present, to evaluate the applicability of urban planning instruments adopted in the central area of the city and their effectiveness as mechanisms of landscape transformation and environmental improvement.

Keyword: *rainwater drainage, urban legislation, urban planning instruments, basin of the River Arrudas, Belo Horizonte*

Introduction

The article presents research carried out on the urbanist Radamés Teixeira da Silva and focuses on drainage issues in Belo Horizonte, a city designed to be the state capital of Minas Gerais, in the Southeast of Brazil. As such, a brief outline has been mapped out which provides a history of municipal occupation and shows how legislation has addressed rainwater drainage throughout time, given the growing needs for mitigating urban floods created by anthropic action.

Belo Horizonte is located across two hydrographic basins that contribute to the upper Rio das Velhas, one of which is the River Arrudas basin, responsible for draining the city centre area. The basin's main streams are located to the South of the *Serra do Curral* ridge, an important topographical landmark of the Metropolitan Region. Allied to the characteristics of the site, the occupation that has taken place has made the area vulnerable to flooding at lower elevations.

The original city plan established three distinct zones: the Urban, delimited by *Avenida do Contorno* (the inner ring road), the Suburban and the Rural Zone. The geometric layout of the streets within the Urban Zone failed to take into consideration the configuration of topography and watercourses by placing streets above the newly canalised streams, in addition to projecting streets on steeply sloping hills, perpendicular to the contour lines. This has resulted in recurrent flash floods in the central area and at lower elevations.

The study area, where urban expansion began, is known as the Hypercenter. Densely populated and accommodating high rise buildings and most of the city's services and commerce, it attracts a high transient population from the whole metropolitan region.

In the course of time, municipal legislation has failed to provide effective guidelines designed to reduce the possible adverse impacts related to rainwater drainage and has allowed significant soil impermeability. Consequently, flooding still regularly occurs across the lower areas of the Hypercenter.

This article aims to investigate to what extent, if any, urban legislation has contributed to the effectiveness of rainwater drainage in the city. The study of plots, within a generic block in the area examined, reveals the most evident consequences over different periods and provides verification of how urban legislation has influenced the configuration of the landscape and, as a result, rainwater drainage.

Urban occupation and its consequences on rainwater drainage

The presence of water resources was one of the most important factors taken into consideration when selecting the site of the new capital. The reflections of positivist 19th century thinking and the related sanitary considerations, appropriate for embellishing the urban space, can be easily observed in the original city plans which manifested and prioritised an orthogonal grid at the expense of natural site characteristics, such as the many water courses.

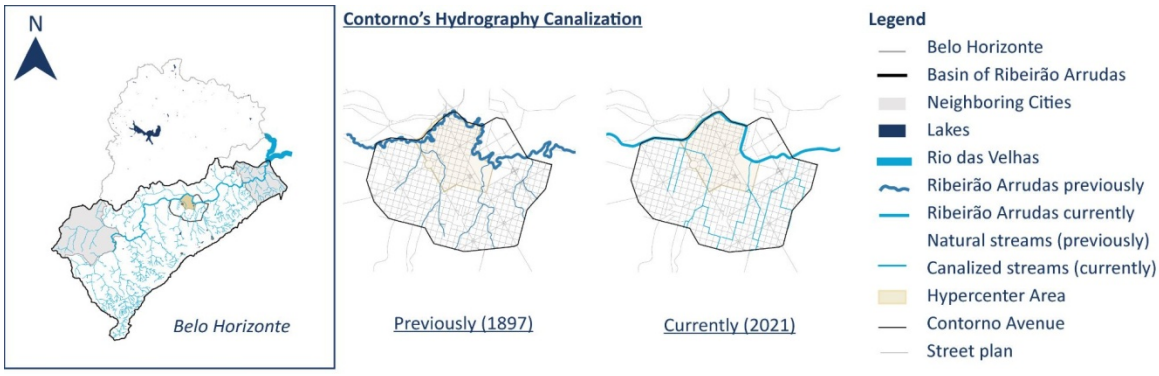

Figure 1. *The canalization of Contorno's hydrography. The maps show, respectively, the limits of Belo Horizonte and the River Arrudas basin, as well as the difference between the water courses located within Avenida do Contorno in the previous (1897) and current map (2021). Source: BHMaps. Adapted by the authors. 2021.*

Such thinking contributed to the canalization and buffering of several basin water courses, including parts of River Arrudas, which was covered by streets and avenues (Cavalcante, 2011). During the period, the contradictions of this urban development, in other words, between natural sites and the process of occupation were already visible. Several interventions were made which changed the configuration of the central area, especially the Hypercenter, and further reinforced the prevalent highway-driven practices of the time (Figure 1).

The original city occupation took place along the river banks which had a flatter topography. This was common practice considering that rivers have played an important role in the consolidation of population centres, providing water and food supplies, irrigation and transport (Borsagli and Bernardes, 2015).

However, from the beginning of the 19th century, water resources ceased to be seen merely as an inductor of elements of the urban formation and became viewed as obstacles to urban development, being sources of unpleasant odours (due to the wastewater discharge), limited urban mobility and flooding. This situation was not different in Belo Horizonte. In the River Arrudas basin, the increasing soil impermeability occurred together with the city's urban expansion which initially took place over flat areas but which later reached the hillier regions (Ferreira, 1997).

The problems related to flooding in Belo Horizonte are the result of a confluence of factors and interventions which have been further exacerbated by wastewater deposits. With the foundation of the neighbouring Industrial City of Contagem, the Arrudas river basin also began to receive industrial sewage, resulting in the siltation of rivers and streams. In addition, the canalization, rectification and buffering of such watercourses have further increased soil impermeability, favouring the occurrence of large flash floods that the conventional rainwater drainage system is unable to handle.

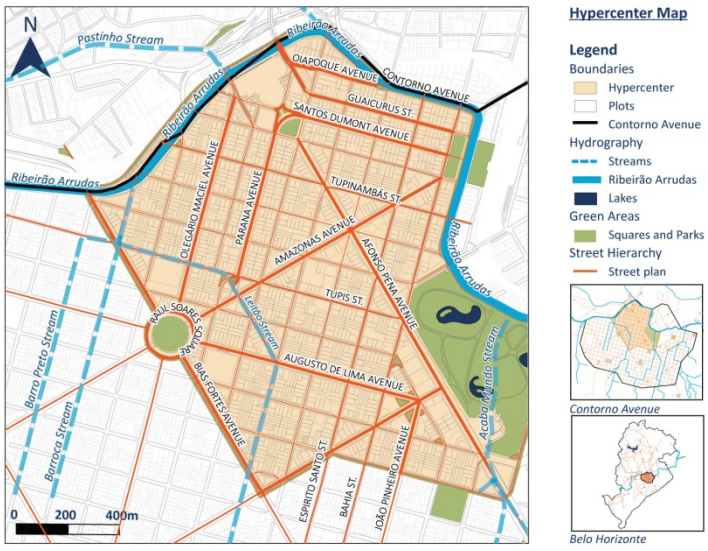

Figure 2. *A Map of the Hypercenter: the study area and its insertion within Avenida do Contorno and Belo Horizonte. Source: BHMaps. Adapted by the authors. 2021.*

Baptista, Nascimento and Barraud (2015) state that structural and non-structural compensatory measures can be adopted as a solution for drainage problems. Structural measures may include direct interventions, such as construction work on the drainage system. Non-structural measures, on the other hand, may encompass environmental education, treatment of valley floors, rationalization of urban land use and the legislation formulated to engender more efficient urban rainwater drainage - from the individual plot up to the wider urban area. Thus, urban instruments and parameters related to soil permeability are those mostly responsible for allowing water to return to its natural cycle without overloading conventional drainage systems and generating floods over the valley floors. Such combined interventions can mitigate the effects caused by conventional rainwater drainage overflows.

Legislative measures regarding rainwater drainage in the Belo Horizonte Hypercenter

The study presents the effects of legislation on the plot configuration and the consequences regarding rainwater drainage in the Belo Horizonte Hypercenter. The analysis will consider legislation from each period as applied to the plot as part of a generic block and will examine how each law has established parameters that can influence spatial configuration and rainwater drainage. Five time periods were defined, each corresponding to the different evolutionary phases of the city. The parameters have changed throughout each period and include: yards**,** occupancy rates/permeability rates, *non aedificandi* areas and the mandatory implementation of regulatory controls.

The 1st period - The foundation of the new capital (1897-1930)

This period commenced with the city's 1897 inauguration, in which it was planned to be the administrative headquarters of the Minas Gerais government, up until the 1930s. The main normative document outlining the city's morphology was the New Capital Report drawn up by the Commission for Construction (CCNC).

Construction took place in alignment with the streets and with a maximum of two-storeyed residential and four-storeyed public buildings, thus generating a predominantly horizontal city. Open spaces at the side and rear of the plot created backyards and gardens with permeable areas. The grouping of rear yards resulted in expressive intrablock relations that allowed rainwater drainage and thus avoided greater water concentrations in the channels and public spaces.

Despite the regulation's lack of specific parameters, building design granted permeable open spaces at the block's core, resulting in adequate rainwater drainage.

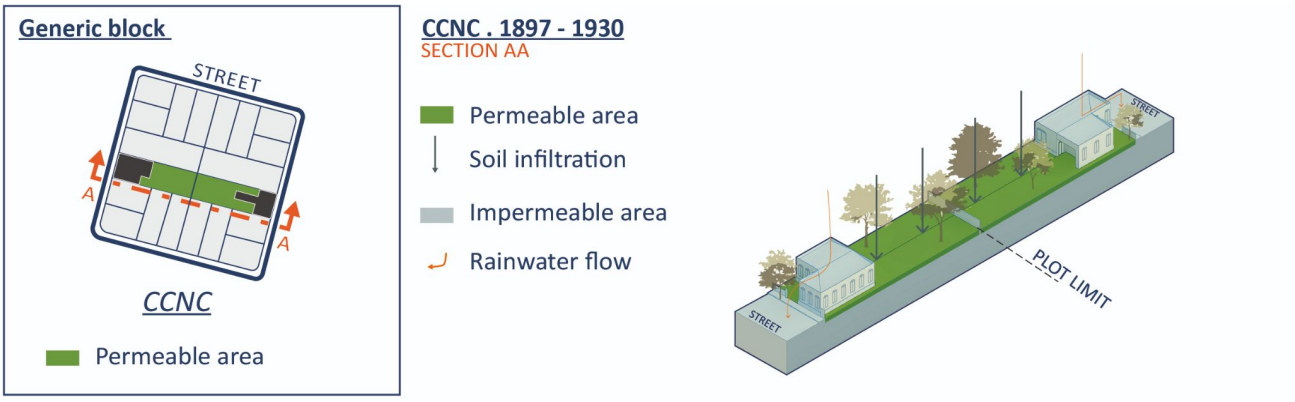

Figure 3. *CCNC block plan and section. Source: Authors, 2021.*

The 2nd period - Brazilian urbanization (1930 - 1970)

In this period, the city still had several vacant plots, despite undergoing an intense process of verticalization.

The first Building Code of Belo Horizonte, Ordinance n. 84 of 1940, promoted population density, which would soon become expressive due to the industrialization process taking place across the whole country (Castriota and Passos, 1998). Plans that allowed higher than four-storey buildings changed the initial urban landscape configuration and its use by prioritising commercial development.

Within the Hypercenter, the pertinent parameters in Decree n. 84 allowed greater constructive density and only regulated the plot's space (front, lateral and rear), albeit with a focus on sanitary concerns which ensured adequate lighting and ventilation. Block occupation was permitted across most of the plot and there was no obligation to maintain the soil's permeability in the open spaces. As such, these already scarce areas started to become impermeable with the result that rainwater was directed into overloaded drainage systems which, in turn, flooded the urban valleys.

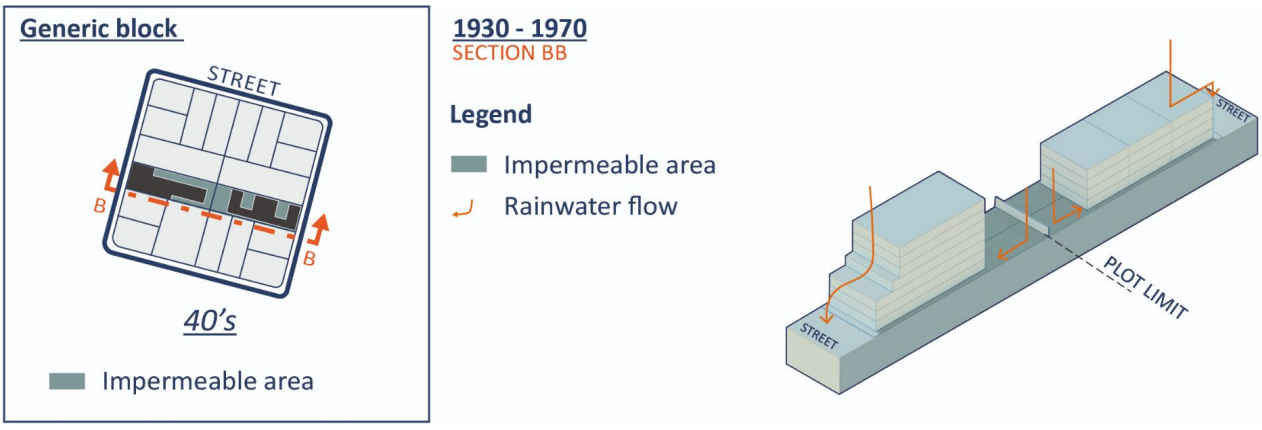

Figure 4. *1940s block plan and section. Source: Authors, 2021.*

The 3rd period – The emergence of a Metropolis (1970 - 1990)

This period reflects the population growth resulting from rural exodus with the process of industrialization demanding labour in the new urban centres. The city centres and their outskirts experienced significant population growth which further intensified the verticalization process.

The Belo Horizonte Land Use and Occupation Law, published in 1976 and modified in 1985, incorporated more specific parameters for commercial use in the central area. The city was divided into sections categorized according to the legislation and aligned to the main road axes. Urban regulation was based on settlement models which determined occupancy rate established according to construction potential across each section (the percentage of the plot which can be occupied by a building).

The Hypercenter settlement models allowed greater construction density and mixed uses, in which commerce was located at street level and residential confined to the upper floors. Total plot occupation (100%) was permitted on the first alongside partial occupation (30%) on the upper floors, thus configuring a tower typology. The occupancy rate failed to take into consideration the necessity for permeable areas and, as such, the overloading of the conventional drainage systems continued to cause severe floods.

The adverse consequences of Law n. 2662 from 1976 which persisted in promoting construction with limited open spaces in the central area, especially on the ground and second storeys, has further aggravated rainwater accumulation in the city's lower areas.

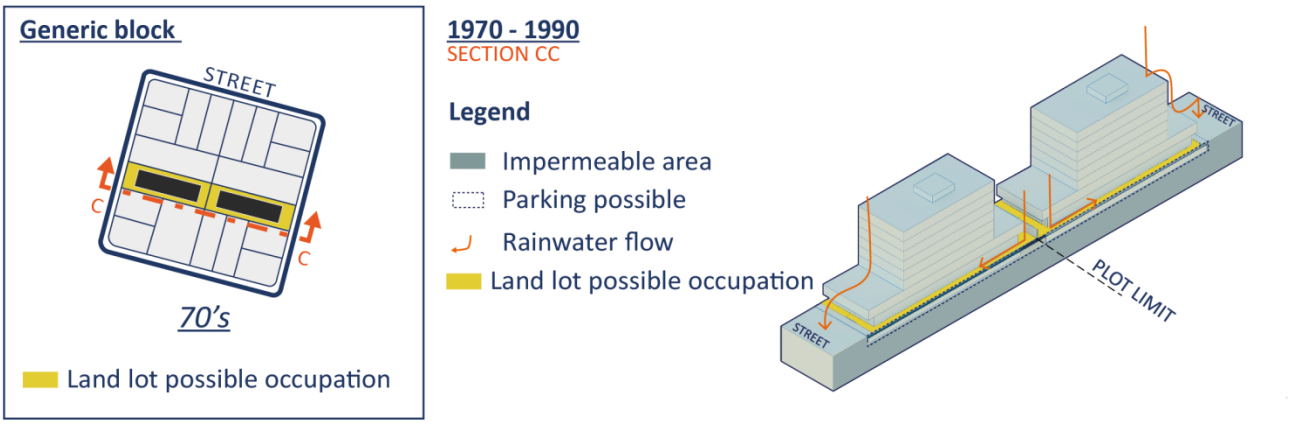

Figure 5. *1970s block plan and section. Source: Authors, 2021.*

The 4th period – The Metropolis of Belo Horizonte (1990 - 2019)

In this period, the legislation master plans should be highlighted: the first of them, published in 1996, divided the city into zones defined by their capability to absorb enduring population density.

Permeability rates appeared as a parameter, meaning that 20% of the plot area had to be maintained as open space within the Hypercenter. In the 2010 Master Plan, this changed to 10% for plots smaller than 360 m² and currently remains at 20% for larger plots throughout the whole city.

However, while defining a mandatory permeability rate, legislation allowed its replacement through the advocacy of catchment box installation[1]. Despite being a compensatory drainage device, in practice, many entrepreneurs incorporated the solution only in presentations to the City Hall, whilst in practice such measures were quickly jettisoned with the resulting adverse consequences for urban drainage.

For the first time in the legislation, open areas to the rear of the plot were recognized as potential permeable spaces. Despite not being mandatory, the law also stated that, if a free, permeable and revegetated area was introduced to the open area to the front of the building, additional constructive potential would be permitted.

In this period, block transformation reflects the region's dense and vertical process of consolidation. The changes established in the legislation on rainwater drainage had little impact, mainly due to the intense development of much of area within the Hypercenter.

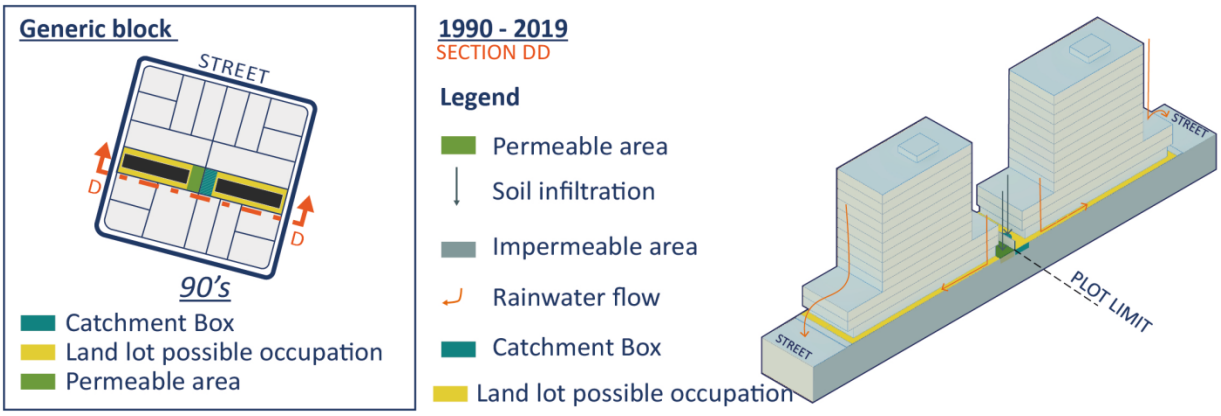

Figure 6. *90's block plan and section. Source: Authors, 2021.*

This period is marked by the Drainage Master Plan and DRENURBS (Drenurbs Programme/Springs and Valley Floors: the approved potentialities and challenges of Belo Horizonte's socio-environmental management of territory and water courses). Such programs have enabled insertion or reintegration of still occurring natural watercourses. Meanwhile, the further development of Boulevard Arrudas in the central area, designed to allow increased road connectivity, has demonstrated the still prevalent highway-driven thinking inherited from the previous century.

The 5th period - Prognosis (2019 to the present)

The 2019 master plan maintained the requirement for a 20% permeability rate for every plot, regardless of size or location. The frontal areas of plots within the Hypercenter were now obliged to be revegetated and, therefore, permeable. In addition, for those plots located along the valley floors, there was a requirement that 50% of the frontal areas had to be revegetated.

[1] Catchment boxes consist of small rainwater collection structures installed on the plots and may or may not be connected to the city's rainwater drainage system (Baptista, Nascimento and Barraud, 2015).

In this master plan, catchment boxes have been made mandatory throughout the whole city and it is prohibited to use them as a means of manipulating the 20% soil permeability rates anymore. Taken together, such parameters can contribute to the effectiveness of plot rainwater drainage.

With these stipulations and measures, plot intervention has tended to become more permeable, allowing part of the rainwater to filter through the soil and thus prevent flooding of the conventional rainwater drainage system and the adverse consequence for local streams.

The new master plan aims to create partnerships with large construction companies which, in return for relaxed planning regulation, obliges them to create green areas along the city's East-West axis and areas designated for low-income family accommodation. This initiative proposes several urban intervention programs along the River bank designed to foster a more sustainable dialogue between the city and nature.

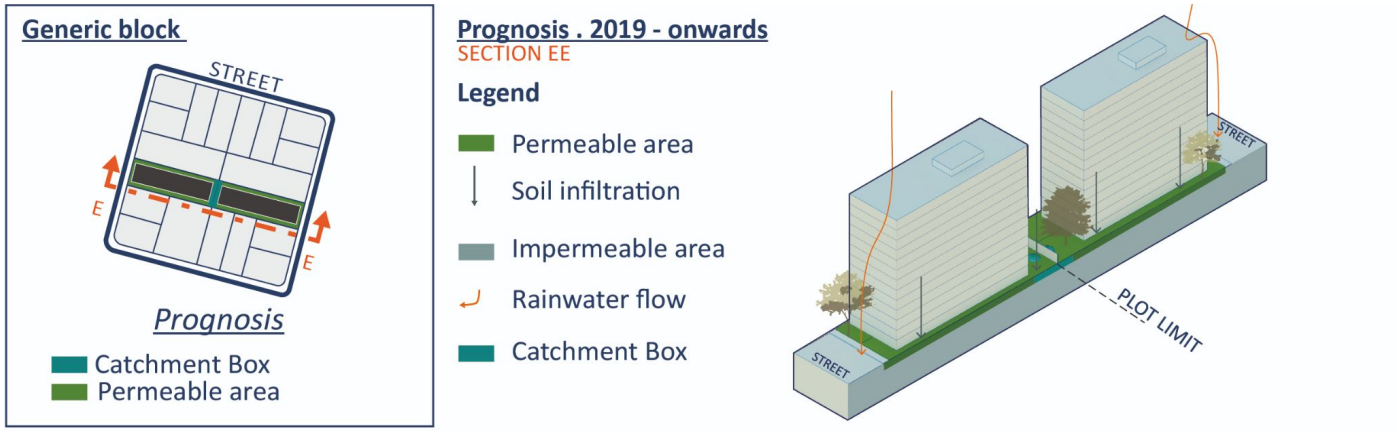

Figure 7. *Prognosis block plan and section. Source: Authors, 2021.*

Conclusions

Belo Horizonte's urban development has been characterised by the failure to preserve the area's rich green resources since the 1897 inaugural city plan: the strict observance of an excessively geometrical central area layout has compromised watercourses and has prevented the environmental conditions necessary for an efficient and green urban drainage system.

Municipal laws have created urban parameters which have, in turn, led to urban transformation with harmful consequences for the city's rainwater drainage system, particularly within the Hypercenter where services and commercial activities are concentrated. These parameters, over time, have increased block occupation, population density and verticalization, producing a new urban landscape and further compromising rainwater drainage from the plot to the conventional urban drainage system which flows into the river.

The requirement for designated permeable areas only appeared in the legislation of 1996, when specified permeability rates were made obligatory across the whole city. Previously, although the so-called occupancy rate was formulated according to some climatic conditions, its scope was limited to mainly sanitary considerations, rather than with concern for drainage.

Thus, frontal and lateral open areas were also recognized as potential permeable spaces only in 2010, with the application of incentives (these were designed to encourage additional constructive potential) for revegetated frontal areas. In the current Master Plan, the preservation of such areas is mandatory along the valley floors.

Environmental issues, related to rainwater drainage in the 1990s municipal urban legislation, have reflected the wider discussion taking place globally, namely the environmental agenda. Marked by events, such as the Eco-92 Conference, the general objectives of such summits have been to ally socioeconomic development with environmental preservation.

Discussions about the effects of climate change, caused by unsustainable development over the past decades, have intensified. Moreover, it has become apparent that increasing rainfall volume has been one of the consequences of global warming and has further aggravated urban rainwater drainage problems, requiring municipal and national governments to devise radical and innovative solutions.

Policy that aims to increase soil permeability has been recently incorporated into Belo Horizonte's legislation, and although limited, such measures have improved the city's rainwater drainage capacity and the quality of the landscape, as permeable areas are usually accompanied by green and wooded spaces that enhance the aesthetics of the urban experience.

References

1. Cavalcante, L. V. B (2011) '*A bacia do rio Arrudas: Análise das inundações entre 1930 a 2005 no município de Belo Horizonte/MG'* unpublished MSc dissertation, Universidade Federal de Minas Gerais, Brazil.
2. Baptista, M., Nascimento, N. and Barraud, S. (2011) *Técnicas compensatórias em drenagem urbana* (Associação Brasileira de Recursos Hídricos, Porto Alegre).
3. Borsagli, A. and Bernardes, B. (2015) *'O Ribeirão Arrudas em Belo Horizonte: de elemento integrador e indutor da ocupação urbana para obstáculo no desenvolvimento da urbe mineira', Cadernos PROARQ 25*, 86-101.
4. Ferreira, M. G. (1997) '*O sítio e a formação da paisagem urbana: um estudo do município de Belo Horizonte*', unpublished PhD thesis, Universidade Federal de Minas Gerais, Brazil.
5. Castriota, L. and Passos, L. (1998) 'O "estilo moderno": arquitetura em Belo Horizonte nos anos 30 e 40', in Castriota, l. B. (ed.) *Arquitetura da modernidade* (Editora UFMG, Belo Horizonte) 125-173.