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PRINCIPLES OF SUSTAINABILITY AS GUIDELINES OF ACTIONS FOR THE SOLUTION OF STORMWATER MANAGEMENT RELATED PROBLEMS

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Abstract: The objective of this work was to establish specific principles qualified of guiding administrators in making decisions related to stormwater problems, and, specifically guide them to continue this work and the development of sustainability indicators for stormwater management. As methodology, in order to establish specific principles for stormwater management, the goal was to search for general principles about sustainability, disparately present in literature, which, most times, present generic and open characters, being qualified of application in any situation or place. From the search results, there was a re-reading and interpretation of the generic principles, searching its adequacy to problems related to urban stormwater. We can see the same methodology for raising issues. As a result, we could issue thirty-six related problems and thirteen principles, which are specific to stormwater management and from the results obtained in the survey; we were able to make correlations of the principles, which were able to lead actions related to the respective problems. This way, we could conclude that it is possible to use these specific principles in different situations, as orientation in the elaboration of public policies and in the development of sustainability indicators, aiming at enhancing the planning and support of decision-making. They will also be useful for orientation to the next phases in the project, in the elaboration of sustainability indicators, targeted to stormwater management.

Keywords: Urban Problems, Sustainability Principles, Stormwater Management, Sustainable Urban Draining.

1. INTRODUCTION

The urbanization process has been happening in an intense way and it will most probably be irreversible. According to the United Nations Settlements Program (UN-Habitat), the urban population has increased five times between 1950 and 2011 worldwide. Only in 2007, for the first time in human history, the number of people living in cities outnumbered the cipher of those based on the countryside.

We can directly relate the urban problems connected to stormwater management to the urban expansion and to the high level of soil sealing due to the occupation model. In the last centuries, the urban occupation has occurred chaotically, without appropriate integrated planning, mainly when it comes to diversified infrastructures, necessary to urban development and to the well-being of the population, such as transportation, sanitation, public health, education (mainly to what concerns environmental education and public participation).

The urban growth of Brazilian cities has caused significant impacts on the population and on the environment. The development of cities is what mainly triggers off these problems: absent or mistaken planning, lack of control mechanisms for soil usage and occupation of risk areas and inadequate or inefficient draining systems. Problems such as floods, public health and national and human habitation security. Nowadays, most projects transfer, through a fast draining process, the stormwater forwards, and, at the same time, the problems in time and space.

It is not possible to reach the equation and solution to these problems with palliative or immediate measures, under the penalty of aggravation or dislocation of such problems in terms of time or space. This way, it is necessary to execute the management of stormwaters under the paradigm of sustainability, guaranteeing the assistance of the current needs, not compromising its future assistance.

2. CONCEPTS AND ASPECTS OF SUSTAINABILITY

According to Barllett (2012), the publication *Limits to Growth,* from 1972, presents the results of global economy simulations accomplished by a group of system analysis in MIT (*Massachusetts Institute of Technology*), indicating the usage limits of diversified natural resources. The central subjacent idea to the concept of sustainability is the notion that economy, society and environment integrate intensively to the local, regional, national and world scale, composing a solid plot of causes and effects. This thought, formally expressed in 1987, in the report "*Our Common Future"*, or Brundtland Report, where the official concept of Sustainable Development appears for the first time.

ECO- 92- Conference on Environment and Development- taking place in 1992, in Rio de Janeiro, consolidated the concept of sustainability presented in the Brundtland Report, which means "development which assists the needs of the present without compromising the possibility of future generations to assist their own needs."- Another important achievement of the conference was the *Agenda 21,* a broad and large action program, aiming at the global sustainability in the XXI century.

In 2002, the Earth Summit on Sustainable Development of Johannesburg restated the commitment of the Agenda 21, proposing the greater integration of the three main dimensions of sustainable development (economic, social and environmental) through programs and policies focused on social issues an on the environmental protection systems.

The definition for urban sustainability is, in parts, the capacity that urban policies have to adapt to service offers, to quality and to quantity of social demands, searching balance between the urban services demands and investments in structure (Acselrad, 1999). Nevertheless, it is also indispensable for urban sustainability, the responsible use of natural resources, and the good condition of the urban environment, based on the interaction of these resources, in addition to the answers to urban needs with the minimum deject and reject transference to other present and future ecosystems.

3. PROBLEMS RELATED TO STORMWATER MANAGEMENT

According to Pompêo (2000), in a general way, the floods are natural phenomena that occur periodically in water flows due to high magnitude rains. The floods in urban areas may be due to these intense rains, to large period of return or due to overflowing rivers, provoked by balance chances in the hydrologic cycle in regions backwards of the urban areas, or even, due to urbanization itself. The volume of stormwater draining generated during an event depends on the relation between the total amount of rain and on what is lost with infiltration, evapotranspiration and the storage on surface. These losses depend on soil, climate and geology, vegetal cover and, mainly, on the soil usage.

Alterations in the soil usage affect the hydrology, as it follows - changes in the volume of superficial draining, changes in superficial draining flow peak, changes in water quality, and changes in hydrologic "services" (Paul Meyer, 2001, Mango etal.2011; Garg et al, 2012; Yan e Edwards, 2013).

In addition to floods, some problems currently faced by stormwater management include (Silveira, 2002): the access of rainwater into the sanitary sewer system and vice-versa, compromising the adequate

functioning of the respective systems. Dilution of pollutants, such as heavy metals and oils derived from roofs, streets and parking lots, besides nutrients, pesticides and herbicides from gardens, parks and lots into the superficial draining to water flow receptors. The sealing of surfaces wears out the aquifers by reducing its natural recharge. High speed flows cause erosion and, consequently, silting of rivers, streams and estuaries. The fast removal of stormwater in urban areas prevent its use in, for instance, for non-potable means and for landscaping.

The urban growth of cities in developing countries has provoked significant impacts on the population and on the environment, absence of control mechanisms in soil usage and the occupation of risk areas and draining systems, which are inadequate or inefficient. The urban territorial occupation, without adequate integrated planning of diversified infrastructures, which are necessary for the harmonic development of the city, triggered off the appearance of draining problems due to hydrologic events of high intensity (Righetto et al, 2009). The traditional model of stormwater management has as its philosophy *to drain the precipitated water downwards as fast as possible.*

These systems projects have basis on historical series of meteorological data and predictions of patterns for urban development. The main objective is to reduce the risk of specific floods, although the implantation of these systems frequently appear with little consideration on impacts backwards. One more issue on draining systems projects, which are not present in Brazil yet, is the one referent to the canalization with sealing of river channels and urban streams, solution adopted to extract the unwanted water from the urban area quickly.

For Tucci et al, 2005, it is necessary to alter this tendency through the immediate removal of stormwaters, adopting flood control principles that consider; the increase of flow due to urbanization must not go backwards. Prioritize the reestablishment of natural infiltration in the watershed, aiming at the reduction of environmental impact. The river watershed must be the physical domain of evaluation of the impacts resultant from new enterprises, since the water does not respect any political limits; the evaluation horizon must contemplate future urban occupations; there will only be occupation of the coastal areas according to a zoning system, which contemplates the flood conditions; the control measures must be non-structural, preferably.

Yet, according to Tucci (2005), the problems relate to infrastructure and urbanization, the appearance of the *informal* city (uncontrolled increase of the outskirts) and the occupation of flood risk areas or land sliding. Mistaken urban space control legislations, municipal inability of planning and anticipating urbanization and investing in secure and adequate space planning, based on urban development. Discharge of effluents in the net of pluvial exhaustion, which is drained through the urban rivers, occupation of the coastal flood bed, sealing and canalization of the urban rivers with an increase in the flood flow (up to seven times) and its frequency. Increase of the solid waste load and the quantity of stormwater on the rivers next to the urban areas, limited vision of what is the integrated management of the urban soil. Its infrastructure and in great part of its problems, lack of knowledge from the population and the professionals,(inadequate conception from the engineering professionals for systems control and planning, sectored vision of urban planning ,lack of management capacity), from different areas which do not possess adequate information on the problems and their causes. For instance, the use of canalization for draining is a generalized practice, even representing very high costs and generally tend to increase the problem it meant to solve. The population themselves, when having any flooding problem, require the construction of a canal to control the flood. With the canal, the flood goes backwards, affecting another part of the population. These constructions may reach the magnitude order of ten times superior to more sustainable measures.

For Baptista and Nascimento (2012), some institutional and financial aspects cause several problems. From the institutional view, it is necessary to have political and financial strength as well as administrative restructuring in the urban sanitation sectors and adoption of a regional policy that takes care of the problems. A correlation between the potentially problematic conditions related to stormwater management and their causes are in chart 1.

Chart 1. Relation between potentially problematic conditions related to stormwater management and their respective causes.

POTENTIALLY PROBLEMATIC CONDITIONS RELATED TO STORMWATER MANAGEMENT	CAUSES
1. Water shortage	**Absence of rainwater use policy; lack of adequate and sufficient reservoirs for use.**
2. Increase of superficial draining	**Excessive sealing of the soil; Absence of draining control mechanisms.**
3. Increase of flood flows (maximal)	**Increase of the draining capacity through ducts, canals and streams.**
4. Incidence of diseases due to contact with stormwater and disease vectors	**Increase of the flooding areas; Problems in solid waste management.**
5. Floods	**Clogging of canals and ducts by solid wastes; lack of flood control mechanisms in the source; sealing of natural areas.**
6. Inadequate functioning of the system	**Illegal sewer connections in the draining system; Clogging of ducts;**
7. Occupation of risk areas	**Absence of habitat policies; Lack of studies and legislation of occupation control of the watershed.**
8. Disordered occupation of the watershed	**Absence of plans and studies on the occupation of the watershed; or in the presence of the same, lack of application.**
9. Contact of stormwaters with solid wastes/contamination (diffuse pollution)	**Problems in management and collection of solid wastes**
10. Inefficient /inexistent technical teams	**Lack of interest from the public organs to set up teams and qualified agents; lack of adequate training; lack of investment in technical background of technical team.**
11. Watercourse contamination	**Loading of heavy metals, oils and grease, from streets, roofs; loading of pesticides, herbicides and nutrients from parks and squares.**
12. Decrease in infiltration and recharge capacity	**Sealing of rivers and riverbeds; sealing of natural areas.**
13. Decrease in hydraulic capacity of the system	**Lack of cleaning and maintenance in the draining system; clandestine sewer connections**
14. Overcharge from the channels downwards	**Increase of velocity and superficial draining volume**

15. Population´s exposal to vulnerability situations	**Occupation of risk areas; Absence of social inclusion policies and habitat policies which assist low income population**
16. Lack of environmental education	**Absence of guidance canals and problem related campaigns**
17. Lack of control and monitoring of the rain effects	**Absence of equipment and qualified technical team**
18. Economic damages caused by rain or by inadequate management of stormwaters	**Public and private patrimony loss (furniture, property and natural)**
19. Flooded areas and risk to public health caused by the proliferation of vectors	**Sealing of natural areas; system clogging; silting of canals and streams; absence of lot control mechanisms.**
20. Lack of public investment in urban draining	**Absence of specific budget to urban waters**
21. Management and planning problems	**Absence of management integrated view.**
22. Erosion and land sliding of embankments	**Suppression of woods and forests for habitation construction**
23. Lack of knowledge of the system due to lack of registration in the system	**Inadequacy of investments in patrimonial management and registration**
24. Inadequacy of financial resource flow	**Absence of investment or adequate distribution of public money**
25. Lack of knowledge of physical processes involved	**Inadequacy of investments in hydrologic and environmental monitoring; inadequate technical background.**
26. Fragility of the draining responsible sector	**Absence of autonomy and administrative continuity; Inadequacy of financial resource flow.**
27. Fragmentation and replication of draining related actions	**Inadequate information flow and multiplicity of involved agents**
28. Inadequacy in the treatment of intermunicipal and/or metropolitan issues	**Strictly municipal approach to problems**
29. Deficiency in juridic structure	**Normatization deficiency**
30. Interruption of natural draining	**Allotment project dismisses natural draining**
31. Inadequate and problematic implanted systems	**Fragmented draining implantation**
32. Isolation of aquifer	**Canalization of rivers and streams; Sealing of natural areas**

33. Favoring of clandestine sewer connections.	**Inadequacy of investments in registration and patrimonial management**
34. Clogging of galleries and canals.	**Solid wastes in streets and empty lots (Plastics, PET bottles, etc.); irregular and inadequate disposition of solid wastes.**
35. Small or inexistent participation of society in processes of making decisions related to management	**Absence of public means of discussion and absence of information for the population; Difficulty of public access to discussion means and debates, when any.**
36. Increase in sediment production due to lack of protection in surfaces and silting of canals and receptor bodies.	**Deforestation of riparian areas and suppression of woods for habitation construction.**

Cruz et al. (2007); Butler and Parkinson (1997), consider the draining systems to be sustainable, if they minimize the damage to natural and social processes and the onus to entrepreneurs and municipalities for maintenance and extension of their infrastructure. This way, the degree of the draining system integration to other activities and to the environment, works as a parameter to identify its level of sustainability. The perspective of sustainability, associated to the urban draining introduces a new way of directing actions, based on the recognition of complexity in relations between the natural ecosystems, the artificial urban system and the society (Pompêo, 2000). This posture demands that draining and flood control in urban areas are reconceptualized in technical and managerial terms. Sustainability points to reintegration of water in urban areas, working together with the hydrological cycle, observing ecological, environmental and landscaping aspects and leisure opportunities.

1. GENERIC SUSTAINABILITY PRINCIPLES

The selection, the development and the use of measurement and evaluation actions of sustainability at any level, must take into account some principles or characteristics. They are guidelines for the evaluation of the whole process, since the choice and the project of the indicators and its interpretation to the communication of the results, being interrelated principles, which must have a shared application. They aim at initiating processes of sustainable development evaluation, to evaluate processes already existent in any institution, from local communities and enterprises, to international organs (Hardi, 1997).

Along the discussions produced by different world conferences, some sustainability principles have been presented; among them: Bellagio Principles, Agenda 21 and *Aalborg Commitments*. A good way to doing so, for example, executed by some communities in the USA, consists in establishing objectives, principles and indicators; and, from this point, elaborate and implement activities (Lachman, 1997). In a similar way, these principles also collaborate with the guidance of legislators and decision-makers, once they are able to picture the objective of elaborated public policies.

General principles appear in disperse way in literature about sustainability, having, in its majority, generic and open characters, being able to be applied to any situation, anywhere.

1. Humanistic- the human beings are integrating part of the concerns for sustainable development. They are entitled to have a healthy and productive life, in harmony with nature. Adapted from UN, 1992.

2. Prevention – instead of evaluating the damage and trying to repair them, we should avoid its occurrence, controlling the respective causes. It is also necessary to integrate control methodologies in the activities of the local community, allowing the identification of negative impact activities on the community life quality. UN, 1992, CUE, 2006.

3. Precaution- where there is the possibility of very significant negative impact occurrence, or significant and irreversible impact, the absence of scientific certainty must not have its use to justify advances or relegate preventive measures to second plan. UN, 1992, CUE, 2006.

4. **Polluter-payer**- the polluters will pay for all the damage caused to the environment, in order to maintain the required quality standards. Such principle is found in the article 225, § 3, of the Brazilian Constitution of 1988, which disposes that " the conducts and activities considered harmful to the environment, will subject the offenders, natural persons or legal entities, to penal and administrative sanctions, in addition to the obligation of repairing the damage caused." Adapted from UN, 1992, CUE, 2006.

5. Cooperation – determines the search for concentrated solutions for environmental and managerial problems in natural resources with other local actors, national or international. The initial cooperation among all interested parts, in the planning process and implementation of policies, plans and projects may attenuate some obstacles in the way. UN, 1992, CUE 2006.

6. Ecological integrity – the introduction of the urban ecosystems concept happened in the seventies. This concept leads to evaluation of artificially constructed environments, similar to natural ecosystems. Sustainability means it is not possible to increase the necessities indefinitely; there must be policies to secure adequate protection of biodiversity and maintenance of the main ecological processes of the life-supporting systems. UN, 1992, CUE, 2006.

7. Continuous improvement- determines the necessity of policy development, flexible and dynamic plans and projects, acknowledging the necessity of adaptations and alterations at any point, following the logics of continuous progression, towards sustainability. This principle is associated to concepts of evaluation and constant monitoring. CUE, 2006.

8. Intra and intergeneration equity- determines the necessity of ensuring the improvement of life quality of the population in general, as well as present and future generations. UN, 1992, CUE, 2006.

9. Integration- provision of adequate means, in order to ensure the integration of the economic and social growth policies, as well as nature conservation policies, aiming at the integrated, harmonic and sustainable development. UN, 1992, CUE, 2006.

10. Democracy (participation) – there must be sustainability fomentation through participative processes and these processes should allow the community as a whole, to have the same involvement in the decision-making process. UN, 1992, CUE, 2006.

11. Subsidiarity (decentralization) – this principle implies that there must be decisions to the closest decision level of a citizen. UN, 1992, CUE, 2006.

12. Involvement with the society and transparence – acknowledges that we can reach neither sustainability, nor significant progress towards it, without the support and involvement of the whole community. The decision-making process must be clear, explicit and public. UN, 1992, CUE, 2006.

13. Accountability- points to the assumption by agents of the consequences for third parts of their actions, direct or indirectly, on natural resources. UN, 1992, CUE, 2006.

14. Evaluation of social and environmental impacts- the evaluation of environmental impact, as a tool, must be performed for proposed activities, which have significantly adverse impacts on the environment, and must be subject to the decision of competent national authorities. UN, 1992, CUE, 2006.

15. Equality of individuals towards public duties- consists of sharing the onuses equally, with those who benefit from the service. Cavalieri Filho, 2005.

5. SPECIFIC PRINCIPLES OF SUSTAINABILITY FOR STORMWATER MANAGEMENT

As a method to establish the specific principles for stormwater management**,** we tried to identify, among the generic principles, which aspects would have some relation to such management. We have carried out a review and an interpretation of the generic principles, aiming at the adequacy of the problems related to urban stormwaters.

These are the specific sustainability principles for stormwater management obtained:

I. **Principle of systemic management of stormwater-** insertion of the management of urban stormwater in Director Plans, in land zoning and subdivision laws, in sanitation, road and transportation planning, thus, interdisciplinary in the diagnosis and in the solution of problems.

II. Principle of spatial planning in stormwater management- the management of stormwater must be planned for occupation within the scope of the river watershed, from the sustainable management of the hydric resources, from the municipal stormwater, and from the watershed in which the same is inserted. Impacts cannot be transferred to other watersheds without control and mitigation measures.

III. Principle of accountability for soil sealing – all new urban enterprises are responsible for possible impacts caused by the increase of sealed areas, thus, they must implant control measures in their own area so the high-water mark does not trespass the acceptable limit.

IV. Principle of solid wastes management connected to stormwater management- solid wastes cause direct impacts on stormwater, and, consequently, in hydric resources; so, integration between stormwater management plans and solid waste management is necessary, in order to reduce the pollutant load of stormwaters, starting at the control of throwing solid waste in streets and sidewalks.

V. Legal regulation and land subdivision –there must be specific legislation and control mechanisms of expansion areas, which consider the effects on stormwaters, for the subdivision and occupation of the land.

VI. Principle of limit occupation based on river watersheds- the impacts derived from soil occupation over stormwaters must be evaluated considering the river watershed as a whole and not only isolated areas internal to it.

VII. Principle of constant evaluation of the stormwater management process- stormwater management plans are dynamic processes, which do not cease after their implantation, and they must be in permanent adequacy in order to embrace extensions and changes, and correct possible distortions and violations.

VIII. Principle of public participation and transparence in stormwater management- stormwater management planning must have public participation and transparence in its discussions and actions.

IX. Principle of social capacitation in stormwater management- the consolidation of the community participation will happen from broadening environmental education works, so that the same embraces the phenomena, plan working, and take part in an active way.

X. Principle of technical capacitation of stormwater management professionals- responsible technicians must take part in continuous and targeted capacitation for sustainable management of urban stormwater.

XI. Principle of temporality of actions in stormwater management- the land occupation and stormwater management plans must take into account the water distribution along time and the investments must be planned and executed in short, medium or long term and associated to produced benefits.

XII. Principle of risk prevention in stormwater management- there must be identification and regulation of risk areas (flooding, land sliding, etc.), so there will be no occupation, or, when it is inevitable or irreversible, the planning and regulation are preventive.

XIII. Principle of economic accountability for impacts associated to stormwater management- the generator of impacts must pay for the costs of prevention/mitigation/compensation of the same. For instance, in case of soil sealing, additions or deductions in the Land and Urban tax (IPTU), according to higher or lower soil sealing.

In chart 1, we can see a correlation between both the considered generic principles and the proposed specific principles. There is no unique correspondence between both sets.

6. RELATION: PROBLEMS, CAUSES AND SPECIFIC PRINCIPLES.

From bibliographic consulting, connected to the theme "stormwater management", we were able to identify 36 problems and their respective causes. After that, there was a correlation between these problems and the 13 specific principles proposed to the management of stormwater. **Chart 2** depicts this correlation.

Chart 2. Relation between specific principles of sustainability and potentially problematic conditions related to stormwater management.

Specific principles applied to stormwater management / Potentially Problematic Conditions	Systemic management of stormwaters	Spatial planning of stormwater management	Accountability for soil Impermeabilization	Solid waste management connected to stormwater management	Legal Regulation and division of the soil	Occupation limit based on river watersheds	Constant evaluation of stormwater management	Public participation of transparence in stormwater management	Social Capacitation in stormwater management	Technical capacitation of professionals in stormwater management	Temporality of actions in stormwater management	Risk prevention in stormwater management	Economic accountability for impacts associated to stormwater management
1. Water shortage	■						■				■		
2. increase of superficial draining.			■			■							
3. increase of flood flows (maximal)		■	■								■		
4. Incidence of diseases in population due to contact with stormwaters and disease vectors.												■	
5. Floods	■	■	■		■								
6. Inadequate functioning of the system.	■	■		■							■		
7. Occupation of risk areas.	■				■							■	
8. Disordered occupation of the watershed.	■	■			■	■							
9. Contact of stormwaters with solid wastes/contamination (diffuse pollution)				■								■	

10. inefficient/inexistent technical teams.													
11. Contamination of water flows.													
12. Decrease of infiltration capacity and recharge of the aquifer.													
13. Reduction of hydraulic capacity of the system.													
14. overflowing from the channels downwards													
15. Exposition of the population to vulnerability situations.													
16. Absence of environmental education.													
17. lack of control and monitoring in rain effects													
18. Economic damage caused by rain or inadequate management of stormwaters.													
19. flooded areas and risk to public health by vectors proliferation.													
20. Lack of public investments in urban draining.													
21. Problems in management and planning.													
22. Erosions and embankments land sliding.													
23. lack of system knowledge due to absence of registration in the system													
24. Inadequacy of financial resources flow.													
25. Lack of knowledge in physical processes.													
26. Fragility in the draining responsible sector.													
27. Fragmentation and replication of actions related to draining.													
28. Inadequacy in dealing with intermunicipal and/or metropolitan issues.													
29. Deficiency in juridic structure.													
30. Interruption of natural draining.													
31. Inadequate and problematic implanted systems.													
32. Isolation of the aquifer.													
33. Favoring of clandestine sewer connections.													
34. Clogging of galleries and canals.													

35. small or inexistent participation of society in decision-making processes related to the management													
36. increase in sediment production due to lack of protection in surfaces and silting of canals and receptor bodies													

It is possible to notice several problems related to stormwater management, which start with the political/institutional aspect: changing the point of view over the urban planning. In addition, they embrace other sustainability dimensions, such as environmental issues, when it comes to degradation of aquatic habitats and suppression of vegetation. Social, with the participation of the population in making decisions; cultural, for the necessity of awareness and campaigns related to the residual discard and occupation of risk areas and; economic; related to the decrease of damage related to stormwaters. Both the specific and presented principles for stormwaters management may be useful as guidelines to policies and actions.

7. CONCLUSIONS

The present urban planning needs changes; it also has to be integrated, regional and must include effective public participation, since the population is the most affected part due to impacts caused by the rain. It is also necessary to have the implementation of technically prepared and economically independent teams, mainly in cities with constant flooding problems. The implantation of adequate legislation of soil usage and flood control is also required.

The present work tried to systematize generic principles of sustainability and, from this systematization, elaborate a list of specific principles for the stormwater management context. As a result, 13 specific principles were proposed. After that, correlate the principles to the specific problems of urban waters, 36 problems disperse in different related bibliographies.

We may use these specific principles in different situations, such as in the elaboration of public policies for guiding combat actions to stormwater management related problems, and the development of sustainability indicators, aiming at the improvement of planning and support to decision-making. These principles will be useful as guidelines of the next steps of the project in the elaboration of sustainability indicators, targeted to the stormwater management.

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