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The Deficient Harvesting Rainwater System in Kuala Lumpur and the Human-made Water Pollution Conditions

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Abstract: Rainwater harvesting is a method to collect water from rain, in forms such as direct from the roof, tanks deposits, ponds or artificial lakes. In the city of Kuala Lumpur (1.7 million inhabitants) the process has in consideration flash flood, river pollution, soil erosion. With an annual rainfall of 2486 mm, and build-up area reaching 1663.23 km^2 in 2014 while forest area has suffered reductions of 8.3% in 2014.
The paper examines the conditions that exert pressure in the infrastructure of Kuala Lumpur whose center has experienced an increase in the number of violent flooding yet at the same time prevent an effective harvesting of stormwater.
The primary methodology used is consultation of the available literature, journals, published reports, interview with experts and survey at impacted neighbourhoods. A secondary source of information is the observation in situ with a sample case, to help to support the validation of the conclusions.
The deficiency in the control of the flooding system in a negative correlation to the city's development. This fact is related to the insufficient drainage system, narrowed stretches in rivers, low prices of water, and the lack of an adequate incentive policies and low volume of information to the population.

Keywords: harvesting, stormwater, flooding, drainage, pollution.

Conference topic: Water engineering.

Introduction

Two geographical enclaves the federal territories of Kuala Lumpur and Putrajaya compound the region of Malaysia known as the state of Selangor. Kuala Lumpur is a fastest growing metropolitan area of the country, it covers a 243 km squared area with a population of approximately 1.6 million in the central federal territory and 5.5 million in the suburbs, which combined have an urban concentration of 7.2 million inhabitants, growing explained when the non-urbanized suburbs become occupied with residents and/or peripheral small towns making the whole area merge into one massive urbanized area, sometimes called a super city (Weebly 2016).

Topographically the great Kuala Lumpur, it is known as well as Klang Valley, named like that for the Klang River that has its origins in the highlands, 25 kilometres northeast and flows to the strait of Melacca in the west coast, after bisecting the concave shaped valley. The bowl-shaped form is a critical factor of incidence in the numerous environmental challenges and issues presented by a combination of natural and human forces.
Total area of forest decreased by only 5.47% during this period, from 300,271 ha in 1989 to 283,850 ha in 2011, mangrove area basically increased in part due to the intervention of conservation practices, while the first two decreased product of the urban expansion, palm oil plantation and illegal logging (Aisyah *et al.* 2015).

The deforestation process in Malaysia has been recorded since 1970, when the process of cleaning rainforest areas started by replacing them by rubber and palm oil. From 1990 to 2000, a big urban expansion started and the deforestation ratio increased to a 77% (FAO 2010).

All these facts combined are crucial components in the process of soil erosion and help to understand from a different perspective the situation of Kuala Lumpur and the direct positive correlation in the flooding occurrence. This incidence is supported by many studies conducted by the DID, the Department of Statistics, FAO and the Energy commission (Vincent 2014).
The methodology adopted is to carry out the scope of works of the updated conditions of Selangor Federal State, related to the correlation between the Harvesting rain water system and the situation of the flooding occurrence. Bibliography will be revised in paper and through internet. An Interview as a substantial complement of the literature with Dr. Shahridan Faiez (PhD in Sustainability, University of Cambridge) developing deeper analysis of the flooding causality and the current situation of the harvesting stormwater in the city based on his experience as a Former Senior Sustainable Development Specialist of the World Bank. A survey conducted taking as a sample to a Chinese-based neighborhood about the harvesting process and water usage and waste conditions.

Facts and figures if Selangor rainfall and flooding

In terms of weather conditions, Kuala Lumpur has a tropical wet climate with a year round rainfall with an average of 2366.2 mm (93.2 in) per year, or 197.2 mm (7.8 in) per month and at least 3 months with 20–25 out of 30 days of rain, and the lowest being February with 14 days (Shown in Figure 1).

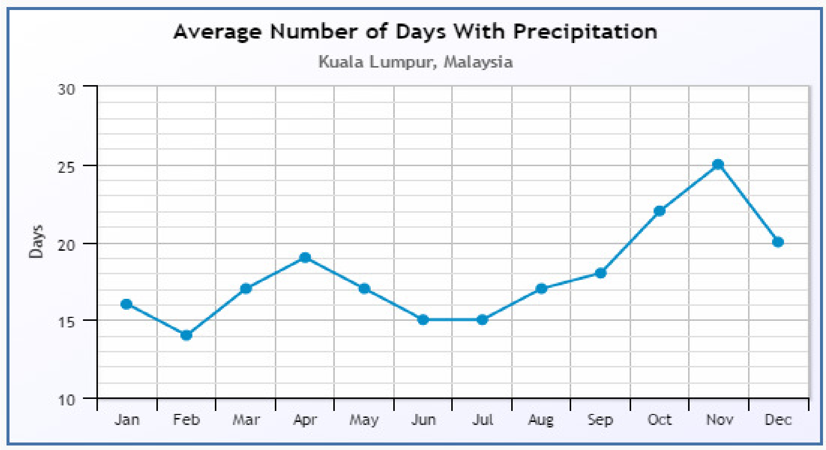

Fig. 1. Average number of days with precipitation (source: Weatherbase 2016)

On average there are 202 days per year with more than 0.1 mm (0.004 in) of rainfall. The driest weather is in June when an average of 126.8 mm (5 in) of rainfall occurs. The wettest weather occurs in November with an average of 284.8 mm (11.2 in) of rainfall and the lowest in June–July with 130 mm (seen in Figure 2).

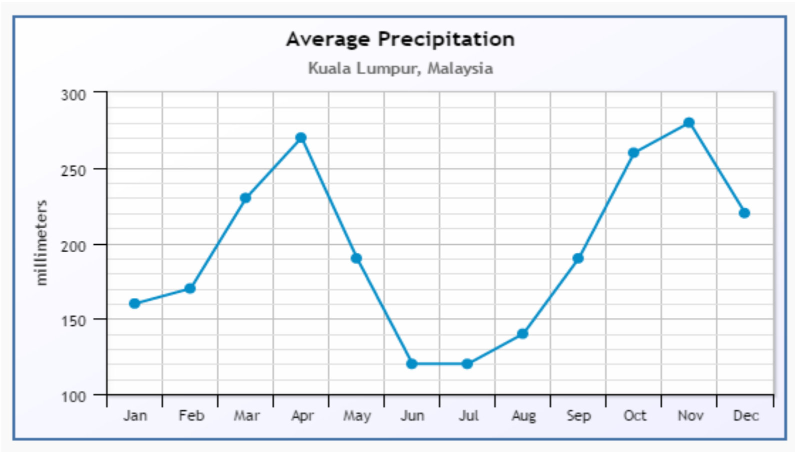

Fig. 2. Average precipitation (source: Weatherbase 2016)

It is significant, in order to understand the flooding occurrence, to know in fact that April is regularly the month with the majority amount of rain, and it has a strong negative correlation to the average of days with precipitation (see Figure 3).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Precipitation mm (in)	162.8 (6.41)	144.7 (5.7)	218.4 (8.6)	284.8 (11.2)	183.9 (7.2)	126.8 (5)	129.2 (5.1)	145.5 (5.7)	192 (7.6)	272.3 (10.7)	275.4 (10.8)	230.4 (9.1)	2366.2 (93.2)
Precipitation Litres/m² (Gallons/ft²)	162.8 (3.99)	144.7 (3.55)	218.4 (5.36)	284.8 (6.99)	183.9 (4.51)	126.8 (3.11)	129.2 (3.17)	145.5 (3.57)	192 (4.71)	272.3 (6.68)	275.4 (6.75)	230.4 (5.65)	2366.2 (58.04)
Number of Wet Days (probability of rain on a day)	16 (52%)	15 (53%)	17 (55%)	21 (70%)	17 (55%)	13 (43%)	11 (35%)	14 (45%)	17 (57%)	21 (68%)	22 (73%)	18 (58%)	202 (55%)
Percentage of Sunny (Cloudy) Daylight Hours	52 (48)	57 (43)	54 (46)	51 (49)	52 (48)	52 (48)	54 (46)	52 (48)	45 (55)	44 (56)	40 (60)	46 (54)	51 (49)

Fig. 3. Precipitation data in Malaysia (source: ClimaTemps 2016)

Holdridge life zones system of bioclimatic classification would situate Kuala Lumpur in or near the tropical moist forest biome type and according to the Köppen-Geiger climate classification it would be considered to be Af in the map (Kottek *et al*. 2006).

There is total of 189 river basins flowing directly to the South China Sea and 85 of them are susceptible of recurrent flooding (89 of them are in Peninsula Malaysia). The estimated vulnerable area to flood disaster is approximately 29,800 km^2 or the equivalent to a 9% of the total Malaysia area, affecting almost 4.82 million people which is equivalent to a 22% of the total population of the country.

In the last decade, 8 major floods occurred in the metropolitan area of Kuala Lumpur, these floods resulted in high property damages, loss of lives, heavy damage and disruption in traffic and in socio-economic activities.

The main causes of major floods were identified as the resultant of rapid and uncontrolled development in catchment areas, the obstructions in river flow system that reduce flow capacity and the limited available arteries to conduct the caudal due to the accelerated urbanization process There are three types of floods in Malaysia monsoonal, flash (the most destructive weather related phenomena) and tidal floods (last ones with the high occurrence at the East Coast).

Monsoon season has two faces, the Southwest occurs from May to September, and the Northeast Monsoon from October to March. Currently operatives there are 15 rubbish traps, about 350 kilometres of minor rivers and trunk/monsoon drains, 21 catchment systems conveying storm water runoff from individual roadside drains, where each catchment area covering a minimum of 40 hectares. The City's river and drainage system basically consist of a total of 2,400 kilometers of reticulated drains not fully connected to a centralized system (Shown in Figure 4)

Fig. 4. Rivers, drainage and retention pond system, 2000 (source: Kuala Lumpur City Hall 2014)

The DID (Department of Irrigation and Drainage) is the entity in charge of the flooding contingency, stormwater management, river Basin Management and Coastal Zone, Water Resources Management and Hydrology in Malaysia and Kuala Lumpur. The basin can be understood as the most urbanized area including rapidly urbanizing regions. These increase in urbanizing may result in increment of sedimentation and pollution. Even though there's a lot of mitigation projects have been done, the problem of flooding still remains as one of the most frequent and devastating nature related events in the country.

Currently the drainage is an obsolete separate network of underground drains, as a country with high rainfall, Malaysia (and specially Klang Valley) uses a sewer system with a segregated drainage and sewerage system. The drainage system is for stormwater (rainwater) and discharges while the sewerage system is for wastewater discharges and treatment. Combined sewer system is not suitable in Kuala Lumpur as the high rainfall can lead to sewerage overflow, as a resultant there is higher pollutants in the rivers.

A geographic information system (GIS) and remote Sensing had guided the several projects are in place to mitigate flooding effects, one of the major innovations was a large drainage tunnel, SMART, Stormwater Management and Road Tunnel, conducted by the Government of Malaysia to solve problems in the City Centre of Kuala Lumpur at Klang River. A 3 km double-deck motorway within the 9.7 km tunnel which starts in city center and ends at Kuala Lumpur-Seremban Highway (The Malay online 2016).

It emulates the capacity of a river channel with temporary storage facilities to keep the flow downstream, it is a fast (though insufficient) mitigation of the flash flooding in the center, but does not collect or harvest the stormwater that runs in it, basically its function is to be a bypass. Unfortunately, this project has not been able to solve the problem, source (DID; Department of Irrigation… 2012).

Harvesting Stormwater in Malaysia

According to the Department of Irrigation and Drainage in 2013 there was a total of 23 projects across the entire nation of Malaysia to deal with rainwater harvesting and minimize the impact of floods. Of these, only 6 of them focused on the Kuala Lumpur and Selangor areas. Clearly not enough to deal with the situation considering the amount of rainfall in the area (Department of Irrigation… 2013).

Other urban projects have been created to prevent the aftermath of the recurrent and the sudden violent rainfall, but actually only 23 of them have included the purpose of harvesting the stormwater. This process is still considered as a new phenomenon. As far as the Malaysian legal framework is concerned there is no single provision pertaining to rainwater harvesting being stated under local laws.

Severe draughts in 1998 and the pressure in the demand for water supply due to the rapid escalating urban growth forced the Malaysian government to take action in the matter, publishing the "Guidelines for Installing Rainwater Collection and Utilization System" as the first step towards a feasible and official policy on harvesting rainwater as a systematic process (Mohd. Shahwahid *et al.* 2016).

The Department of Irrigation and Drainage, rainwater-harvesting system (RWH), define the process as a direct collection of rainwater from roof and other purpose built catchment, for a variety of usage. It can be categorized as small, medium and large scale, defining some of the most important advantages of harvesting water as an independent supply that can be used in non-drinkable benefits as flushing toilets, laundry, watering garden, wash cars, reduced water bill and other uses at a domestic scale. At a medium scale it is defined for industry, commerce, fire protection and emergency usage. At the large scale is the minimizing discharges into drainage systems preventing major floods, reduce soil erosion, improvement of river management and other environmental benefits (Department of Irrigation… 2012).

Through the Urban Stormwater Management Manual of Malaysia, 2000 (MSMA 2016) the provisions to harvesting rainwater are delivered along with the regulations in designing the retention tanks at a residential and commercial scale by the government. Among other specifications the rainwater harvesting system should be integrated with on-site detention facilities with the objective of serving in a minor storm event. This tank-shape harvesting system can be installed above-ground storages, below-ground storages, or it could also be a combination of both. Yet due to the composition of the soil in Kuala Lumpur, limestone which is extremely challenging as the erosion of the limestone mass created deep cavities and underground caverns, (I-Geology 2012) and in minor areas, a Kenny Hill formation, the more efficient and low cost installation would have to be done above the ground as it has the advantage of an easy incorporation to the residential system. Free land has been undertaken by buildings and infrastructure development where the space become overcrowded in a short period of time.
It is calculated that the usage per capita in Kuala Lumpur is 288 liters per day with a standard deviation of 73.9 (Bari *et al.* 2015). Out of the 288 liters used daily, only 30 percent are for cooking and drinking, while the rest of it is just for utilities like washing cars, washing pools and washing clothes every day.

This level of consumption puts Malaysia at the top of the table as the World Health Organization has as a recommended usage of 165 litres per person daily. Looking at the water consumption in the neighbouring countries such as Thailand with only about 160 to 170 litres per day per person, Singapore with 130–150 litres per day per person, and Indonesia with 140–160 litres per day per person reflect the excessive consumption done by the population of Malaysia (Astro Awani 2014).

Water consumption varies depending on the use of different water equipment's (mitigates such as low shower head, dual flush to mention a few) among the surveyed households. As expected there is a positive relationship between water consumption and household size. It is calculated that near two trillion of litres of piped water was lost only in 2012 through leaking and aging piped. In Selangor, out of 1578 billion of litres produced, 521.6 billion was lost due to a burst pipe, which meant losing 33% of their water production. In all Malaysia a breakage or leak is reported every 84 seconds, according to the National Water Services Commission (SPAN), which is the equivalent of 36.4% of the total piped water produced (Lee 2013).

It is significate that the rainwater harvesting process has recently gained attention in Malaysia considering that it is the country's most abundant and reliable natural resource with an average precipitation of about 3000 mm (rounding) per year. This is the equivalent of 990 billion cubic meters of water over the country.

Malaysia has a big potential considering that the river system delivers 25,000 cubic meters of renewable water per capita per year (25.000.000 litres per capita per year). Only in the last year's authorities have recommended to the population to consider utilizing harvesting system for both potable and non-potable usage (Bari *et al.* 2015).

DID has been working among various agencies in the subject and recently published –*"Rainwater Harvesting Guidebook – Planning and Design"*. It explains "in detail" an approach to be considered by planners, and all the parts involved in order to comply the requirements that will satisfy the water quantity and water demand. Malaysia hence has the resources, infrastructure such as water treatment plants, dams, inter-states water transfer, a long term plan to replace the asbestos pipes, artificial lakes, tunnels for captation of water and flood relief, and the implementation of new projects such as the new dam in the Langat River yet there is still water rationing and flooding (World Bank 2016).

But numbers are demonstrating that all the contingency put in place is not working properly or at least it does not meet the expectation, as flooding episodes are more violent and frequent. The SMART tunnel became insufficient and inefficient due to the poor drainage system which collapses whenever there is a major event of rainfall (Malaysian Digest 2016).

The expansion of the city and the consequent deforestation in the quest for space are exerting pressure in the water supply demand while at the same time the waste of huge quantities continues. What is the common denominator in all the numbers above?

The inhabitant, the unit base of all the cities, with all the indicators and the outcomes in the table should be considered. A closer study of the human factor as an individual component of the urban grid becomes fundamentally necessary. In a survey conducted in one of the neighbourhoods of Desa Parkcity Township, Safa (Desa ParkCity 2016) where the neighbours answered questions related to water consumption, habits and knowledge about general information on harvesting stormwater process, the common denominator was the economic criteria and the lack of information. The outcome showed the lack of interest of the housekeeper about the possible installation of a harvest water system, and this is easily explained (and a much repeated answer) because the tariff of the water bill is very inexpensive, according to SPAN the average (calculated in a family of 4) numbers are shown as follows:

- Minimum Payment for water bill = RM6.00 (1.3 euro)
- The first 0–20 m^3 = RM0.57/m^3 (0.12 euro)
- From 21–35 m^3 = RM1.03/m^3 (0.22 euro)
- Over 35 m^3 = RM2.00/m^3 (0.44 euro)

Average monthly water bill (22.5 m^3) = RM13.98 (3.07 euro) (Syabas 2016).

Following the methods described in the official site of the Centre for Science & Environment*, the numbers shown that in a hypothetical implementation of the required infrastructure in the same neighbourhood in order to harvest stormwater.

Data obtained from the calculations and shared with the neighbours as a part of an information process in a potential stormwater harvest per year per unit are as follow:

- Area of the catchment (Approx.) = 80 sq. m.
- Average annual rainfall = 2366 mm (2.366 m).
- Runoff coefficient = 0.85 (normal roof) Calculating the maximum amount of rainfall that can be harvested from the rooftop:

Annual water harvesting potential = 80 × 2.366 × 0.85 = 160.88 m^3 (160,880 liters). Calculating annual drinking water requirement of an average family of 4 as = 365 × 4 × 10 = 14,600 liters, 160,880 liters per unit, and the total condominium is composed by built-up Areas as follows:

- 2-storey Types (135 units) – from 2,254 –3,002 sf (209 m^2 –279 m^2);
- 3-storey Types (36 units) – from 2,715 –3,607 sf (252 m^2 –335 m^2).
- Total units 171 (Centre for Science and Environment 2016).

At the same neighbourhood of the survey, the total of potential stormwater harvested (Desa Parkcity, Safa terraces) 160,880 × 171 = (27.5 million liters approx.)

Taking the average of the yearly rainfall, a daily calculation would give: 6.48 × 80 × .85 = 440 liters per unit with a total of 75,240 liters in 171 units that are going daily to the sewage, directly to the center, as an average in only one of the condominiums out of 7 (plus two towers in construction process). If we had to average the entire township of Desa Parkcity it would give 526,680 liters running downtown, per day. Sometimes this amount can occur in one hour of heavy rainfall.

The cost of installation of a harvesting stormwater system is calculated to be in between 4,000 RM and 10,000 RM (882 Euro–2200 Euro) depending on size, type, and quality (Voda 2015). Taking in consideration the numbers, with an average of 1,540 Euro, without the proper incentive, the dwellers show no interest in considering this option of harvesting having a monthly bill in the range of 3 to 4 Euros. This means the return of the investment would take around 375 months or 31 years (NAHRIM 2016). In 2000 the approximate number of housing in Kuala Lumpur was calculated to be around 328,205 units (Kuala Lumpur City Hall 2016) this number multiplied by the 440, will give the approximate number of 144,410,200 liters to be harvested that would also help prevented to floods downtown KL. The number of houses is increasing since 2000, as of 2010 the number was in the values of 434,116 with a 32% increase (Asian-Pacific City Summit 2016) the calculation would give 191,011,040 liters.

Consulted about the more violent and sudden rainfall that is provoking severe flooding in KL center, if harvesting stormwater would help as a mitigation measure, Dr. Shahridan Faiez (PhD Cambridge, Former Senior Sustainable Development Specialist of the World Bank) answered: "Major cause of flooding is very high surface runoff due to urban land use change that cannot be adequately discharged due to heavy siltation of natural and artificial drainage system. It is uncertain how significant an impact stormwater harvesting can have – given that KL has severe space constraint for development especially housing. Where to store the excess water?"

Also consulted about the most challenging issue to be solved in order to reduce the huge amount of water wasted in the Klang valley Dr. Faiez explains "Kuala Lumpur precise better infrastructure for water treatment, better designs, currently there are outnumbered of leakages at the supply side in the old pipes, mis-management, pricing – water is so cheap that people don't think twice about wastage as there are in place very weak sanctions for wastage and a very low awareness about water management".

With respect of the feasibility of the installation of harvest tanks by the dwellers Dr. Faiez answered: "A 20-year ROI (Return of Investment) is very unattractive as there is no incentive right now for consumers to harvest stormwater, the only particulars doing it are people with an ecological consciousness. In Malaysia, typically the burden of stormwater management is given to the housing developer and the relation cost-benefits doesn't make it a viable option".

On his appreciation about the lack of information among the population about the topic, Dr. Faiez indicates the best education process should come by a combination of awareness program integrated into education syllabus and economic measures that can reward and punish for good water management.

Discussion and Conclusion

The availability of an adequate water management infrastructure is essential, immediate, and constitutes a pressing matter in Kuala Lumpur. A metropolis whose population growth ratio is projected to increase around 25% by 2020 (2.2 million) with an annual rainfall calculated in 2366.2 mm, surrounded by an erosional soil as a direct outcome of the deforestation process.

The recurrence of more violent monsoon seasons every year, equipped with an aged and deficient drainage system that is indiscriminately and repeatedly clogged in human doing by the inhabitants that consider as a normal behavior the action of throwing rubbish and other type of detritus into the drain branches preventing the flow to reach the main relief flooding arteries like the SMART tunnel, which *per se* is becoming an obsolete engine if the feeding branches are not working efficiently.

The analysis shows as well a significant absence of public perception of the real positive impact at a big scale of harvesting stormwater, pertinent information about the importance of water as a vital element should be embedded in the educational curriculum. Water is wasted in trillions of liters in Malaysia, as the two main rivers that irrigate the valley are used as an open sewer and rubbish dumping site. The population needs to be aware that by harvesting stormwater they would also be helping to mitigate flooding as well as securing water to meet their basic needs. When the problem is global involving deforestation, economic policies, sociology, urban planning Environmental Engineering, sustainable management and others is when the problem needs to be addressed in a multidisciplinary approach and not by just one sector.

The findings of this paper are suggesting the following steps as a possible ways of mitigation towards the formulation of realistic and feasible solutions:

1. To effectively implement a deeper analysis, investigation, and understanding of the dwellers as individuals with their habits and traditions, their long-established way of living and the way they use their neighborhoods in order to take informed actions, like the enforcement of the usage of grease and rubbish traps that currently are running openly from all the restaurants, stalls and shops to the single concrete-based drainage system.
2. To encourage the use of water efficient equipment with a proper and suitable economic incentive, by presenting pertinent information and education to the public with an "all age" reader approach about the importance of water conservation and how to reduce its consumption and wastage. Only with that information it will be possible to outset the proper policy of incentives and education, the social question can only be effectively answered having a full comprehension of daily needs and usage.

At a large government based implementation scale:

1. To subsidize by using federal funds, the installation of the harvesting rainwater equipment and to compensate the effective harvesting process with a reduction of the territorial taxation as an incentive to the dwellers.
2. To implement a long-term program in stages that should include; a deep investigation and analysis of the current critical points by conducting a proper mapping of the flood-prone areas identifying key nodes in order to build up large-scale flood retention facilities to reduce the flash flooding occurrence. In addition to it, the plan should also include the eventuality of the implementation of flood bypass aqueducts to canalize floodwater from upstream avoiding the City Centre building more retention ponds to remove pollutants from sewage and waste water.
3. To assess methodically, adequately and exhaustively the impact of the rapid urbanization on the feeding branches that can cause a risk of flash floods in order to implement strict enforcement against irresponsible public, building contractors, future large real estate projects, developers and their environmental impact studies in regards of the readiness implemented to reduce flooding phenomena in order to force an effective annexation to the existing grid.
4. To improve maintenance of the individual roadside drains including the effective unclogged of them and bypassing the ones that are open and currently suffering the habitual usage as rubbish dumping sites. The bypassing has to lead the water to dams or collecting sites such as large scale ponds, preventing the

overflowing of the Smart Tunnel as its capacity is not coping with the arrival of excess of water from all the periphery.

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The author of the paper states that he doesn't have any competing financial, professional, or personal interests from other parties.

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