

Climate Change and Climate Variability Effects on Stormwater Management

"Most climate change scientists agree on one thing: we're going to see more frequent and intense storm and rainfall events along with increased flooding, stormwater runoff, and soil erosion."¹

SUMMARY

STORMWATER RUN-OFF IS GENERATED WHEN THE CAPACITY OF THE ENVIRONMENT TO ABSORB RAINFALL IS EXCEEDED. THIS IN TURN IS AFFECTED BY RAINFALL INTENSITY AND DURATION AS WELL AS BY NATURE OF THE LAND SURFACES. CLIMATE CHANGE IS LIKELY TO RESULT IN MORE FREQUENT EXTREME EVENTS WHICH WILL AFFECT BOTH INTENSITY AND DURATION. CURRENT STORMWATER INFRASTRUCTURE WILL BE INADEQUATE TO COPE WITH THE CHANGES WHICH WILL RESULT IN GREATER IMPACTS ON THE MARINE ENVIRONMENT AND ADVERSELY AFFECT ECONOMIC ACTIVITY IN CARIBBEAN STATES. IN ORDER TO ADDRESS THIS MORE SUSTAINABLE AND RESILIENT STORMWATER MANAGEMENT PRACTICES WILL HAVE TO BE ADOPTED. THIS WILL INVOLVE MORE ROBUST ENGINEERING SOLUTIONS AS WELL SOURCE CONTROL APPROACHES THAT TAKE INTO ACCOUNT RISK AND VULNERABILITY AS WELL AS CONTINGENCY PLANNING. LASTLY, THERE NEEDS TO BE A CHANGE IN ATTITUDE TO ONE THAT SEES STORMWATER NOT AS A NUISANCE BUT AS A SOURCE OF NEW WATER.

KEY POINTS

- CHANGES IN LAND USE AS WELL AS CLIMATE CHANGE WILL LIKELY INCREASE STORMWATER RUN-OFF
- THE CARIBBEAN'S CLIMATE WILL BECOME MORE VARIABLE
- EXISTING APPROACHES TO STORMWATER MANAGEMENT ARE NOT ADEQUATE TO HANDLE FUTURE EXTREME PRECIPITATION EVENTS
- ADOPTION OF HOLISTIC APPROACHES WILL IMPROVE PERFORMANCE OF EXISTING SYSTEMS UNDER CLIMATE CHANGE & VARIABILITY
- THERE IS NEED FOR BETTER URBAN DESIGN TO IMPROVE SOURCE CONTROL AND TO ADOPT INTEGRATED URBAN STORMWATER MANAGEMENT

STORMWATER GENERATION

Stormwater runoff is generated when the intensity of rainfall exceeds the infiltration capacity of the ground and excess rainwater runs off the surface. Runoff can accumulate and transport pollutants and sediments, depending on its speed and volume and the nature of land surfaces. In urban areas much of the land surface consists of impervious surfaces. The duration and intensity of a rainfall event, as well as antecedent conditions, affect the amount of stormwater runoff generated. So, both climate and land use have controlling influences, and thus changes in land use, climate and climate variability impact stormwater runoff and its management.

CLIMATE CHANGE AND CLIMATE VARIABILITY

According to projected climate change,⁴ the Caribbean will be affected by:

- a decrease in the length of the rainy season and increase in the length of the dry season;
- an increase in the frequency of intense rainfall events as basic physics indicates that a warming atmosphere with higher humidity leads to more intense precipitation;
- an increased frequency of the strongest hurricanes; and
- sea level rise of 30 to 50 cm by 2080.

However, there is still high uncertainty in the rainfall projections as well as gaps in the knowledge of how climate drivers at the sub-regional level will be altered under climate change.

STORMWATER STRUCTURE AND DESIGN

Stormwater systems handle “excess water” during precipitation events. They consist of minor and major stormwater systems and use gutters, small ditches, culverts and storm drains, detention ponds and channels.

Standards for stormwater systems are not uniform and are set by governments. Local standards revolve around how frequently storms of different durations and intensity occur (referred to as design storms). The design storm varies in the range of 2 to 25 years (i.e., a 1:2 to 1:25 year returning period) for many drainage systems. Major systems, such as culverts and bridges, are generally planned for the 100-year event.

CLIMATE CHANGE AND VARIABILITY IMPACTS TO URBAN STORMWATER STRUCTURE AND MANAGEMENT

Stormwater infrastructure is designed based on existing Intensity Duration Frequency graphs (IDF Curves). In the Caribbean, these have been derived from a limited data set, and their use in designing for the future assumes stationarity in future climate – which climate modelling indicates will not be the case. Under projected climate change and variability, frequency of intense rainfall events and the strongest hurricanes or storms is expected to increase, which means that the return period of



design storms may decrease (e.g., a 1-in-100-year storm may now become a 1-in-50-year storm). Recent work suggests a reduction in frequent short duration events (i.e. lasting a few hours) and increases in long duration extreme events (i.e. lasting a few days). Higher intensity of longer duration events will have major implications for urban drainage infrastructure. Thus in coping with future events it will be more costly to avoid damage to urban infrastructure.

Other potential impacts include sea level rise, loss of biodiversity and loss of marine and coastal ecosystem to coastal communities. Sea level rise and storm surges may exacerbate storm-related flooding on urban infrastructure and drainage systems near the coast.

MANAGING STORMWATER UNDER CLIMATE CHANGE AND VARIABILITY

In adapting to the potential impacts of climate change and climate variability stormwater managers should seek to carry out:

- **Risk assessments.** Systemically using information to identify potential hazards and to estimate the likelihood and costs associated with their occurrence
- **Vulnerability analyses.** Determining consequences of hazards affecting the facility or operations of concern.
- **Contingency planning.** Incorporating disaster scenarios, estimating demands, identifying measures for meeting minimum needs and isolating critical components or systems that may cause system failures.

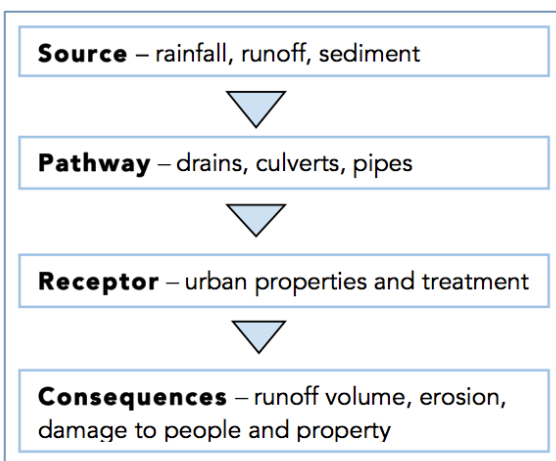


Figure 1: Flow diagram of Source-Pathway-Receptor-Consequence conceptual model.

DISCUSSION BRIEF

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Given the inherent uncertainty in climate change projections and the gaps in knowledge relating to how climate drivers will impact climate variability, a range of climate scenarios must be considered for system design. The over-arching goal should be to reduce risks to levels as low as practicable.

An effective means of visualising the risk of climate change and variability impacts on urban stormwater management infrastructure is the Source – Pathway – Receptor – Consequence (SPRC) conceptual model.⁵ SPRC models represent systems and processes that lead to a particular consequence within the management system (see Figure 1).

Table 1. Some important impediments and solutions to sustainable stormwater management⁷

IMPEDIMENT TO SUSTAINABLE STORMWATER MANAGEMENT	SOLUTION TO IMPEDIMENT
Performance and cost uncertainties	Conduct research on costs and watershed-scale performance
Insufficient engineering standards and guidelines	Develop a model ordinance and encourage guidance documents
Fragmented responsibilities	Integrate management across levels of government and the water cycle
Absence of institutional capacity	Develop targeted workshops to educate professionals
Absence of legislative mandate	Use grassroot efforts to gain support for ordinances and regulations
Absence of funding and effective market incentives	Address challenges in market approaches to provide funding mechanisms

One of the ways in which stormwater could be better managed is through a combination of “soft” and “hard” engineering practices collectively known as Water Sensitive Urban Design (WSUD). The aims of WSUD are to reduce runoff at its source as much as practicable and to usefully harness as much of the runoff as possible. Some practical WSUD measures that can be considered for implementation in the Caribbean are:

Landscaping changes to urban design -- can be implemented to reduce stormwater runoff and help to prevent erosion.

Retrofit permeable surfaces and Sustainable Drainage Systems -- restoring permeability and adding more runoff treatment and storage reduces pollution and downstream flooding as well as improves urban ecology and amenity.

Large Scale Rainwater Harvesting -- rainwater from roofs and other facilities (i.e. car parks) in urban areas can be harvested and stored above or underground for use. Runoff from these sites would be greatly reduced.

Conjunctive water use -- recognises the connection between surface and groundwater and seeks to utilise for improving overall water supply efficiency.

A number of impediments to sustainable stormwater management exist (Table 1). Solutions to these impediments which could be incorporated into an iterative risk management process are shown in Figure 2.

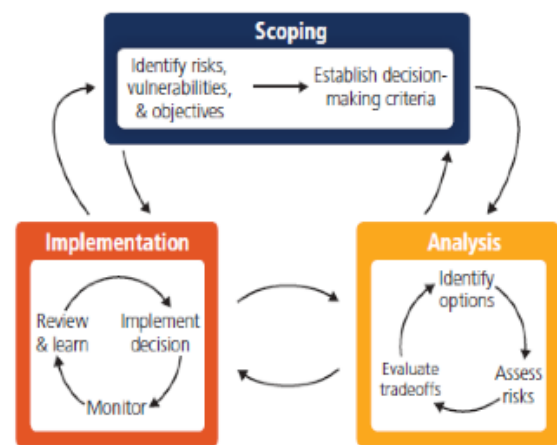


Figure 2: An iterative risk management process for climate change adaptation.⁶

STORMWATER AS A RESOURCE

The typical costs (US dollars) of specific stormwater management practices are illustrated in Table 2., but captured stormwater runoff can also be used as a resource. Urban stormwater harvesting can be a feasible means to supplement water supply in cities with high rainfall. Singapore, for example, effectively harvests stormwater from urban catchments to supplement its water supply. Treating and infiltrating stormwater for the purpose of recharge can be a way to maintain groundwater.

Table 2: Stormwater retrofit and approximate costs⁸

STORMWATER MANAGEMENT PRACTICE	COST RANGES (PER SQ. FT. OF IMPERVIOUS AREA MANAGED)
Basins or ponds	\$0.17-\$0.37
Created wetlands	\$0.25-\$0.60
Reducing impervious surfaces	\$0.62
Swales (broad shallow vegetated channels designed to convey, filter and infiltrate stormwater runoff)	\$1.08
Trees planted near pavements	\$1.09
Rain gardens	\$1.42-\$1.45
Underground projects (subsurface infiltration)	\$1.16-\$2.24
Rainwater harvest and reuse	\$2.95
Flow-through planters	\$5.30
Porous pavements	\$2.10-20.96
Green roofs	\$31.43

CONCLUSIONS

Climate change and climate variability are likely to increase the frequency and severity of extreme precipitation events. Urban stormwater drainage systems will not have the capacity to cope with the resulting greater volumes of run-off and there would be increased frequency of flooding and associated economic damages. In order to mitigate these effects design standards will have to be revised to account for the increased frequency of extreme rainfall events. Greater use will have to be made of sustainable stormwater management solutions that retain and absorb run-off through more innovative approaches to the design of the urban landscape.

References

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