Insight: Cambodia Journal of Basic and Applied Research, Volume 1 No. 1 (2019)

An economic assessment of urban flooding in Cambodia: A case study of Phnom Penh

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In development discourse, 'sustainability' is defined as a balance between the environmental, economic and social aspects of a scenario. Economic assessments of the value of natural environments within and surrounding cities, in terms of the ecosystem services they provide, are important for understanding the nature of sustainable development in emerging economies. Ecosystem services play a vital role, providing resources for economic development, regulating environmental flows, supporting livelihoods and well-being, and representing of cultural values such as spiritual or recreational benefits. However, to date, ecosystem services have generally been overlooked in terms of planning and policy decisions in Cambodia. More specifically, in Phnom Penh, the role of wetland ecosystems in retaining stormwater flows for flood protection has not been sufficiently recognized. However, determining the value of urban wetlands in mitigating the impacts of flood events in heavily populated urban areas is complex and difficult to conceptualize. This study assesses this value in terms of the regulating ecosystem services they provide. It achieves this by placing a value on the economic losses experienced in three study areas in Phnom Penh that experience regular rainy season flooding. A mixed methods approach was used to collect the required data for this analysis from 300 questionnaire respondents, as well as through interviews with key informants. The results show that urban flooding is primarily caused by heavy storm events during the rainy season. Economic losses related to these flood events include: vehicle lubricant and other vehicle maintenance, disruption to business activities, and flood recovery costs. Notwithstanding this, the level of flood preparedness by Phnom Penh citizens was found to be very low. These findings suggest that development planners and policymakers should consider urban planning

approaches that place a value on the degradation of urban wetlands to mitigate future economic losses from unsustainable development.
Keywords: urban flooding, storm events, economic losses, public perceptions.

To cite this article: Khan, L. (2019) An economic assessment of urban flooding in Cambodia: A case study of Phnom Penh. *Cambodia Journal of Basic and Applied Research (CJBAR*), 1:1, 125–149.

Introduction

Phnom Penh was once known as the 'pearl' of Asia, endowed with natural water resources such as streams, lakes, and rivers throughout the city. From a landscape architecture perspective, these resources represented strong aesthetic, social, and ecological values related to sustainability (Englund and Ryttar, 2008). Urban wetlands provide a wide range of ecosystem services to the city. For example, they support a variety of flora and fauna, which contributes to food security and economic development. They also regulate of water flows through the city after rain events, filtering them to improving water quality (Sar et al., 2010). Choeung Ek is the largest urban wetland in Phnom Penh, located five kilometers south of the urban centre of Phnom Penh. It borders the districts of Dangkor and Meanchey, as well as Takmao City, which is the capital and largest city of Kandal Province. Choeung Ek provides Phnom Penh with a broad variety of wild aquatic foods, such as fish, snails, and vegetables (Chea et al., 2010; Sar et al., 2010) and supports the livelihood of many local residents through providing supplementary income. However, the ecosystem functions of Choeung Ek have become degraded over time, affecting these outcomes. Rapid urbanization has caused Phnom Penh to become more vulnerable to the impacts of flooding and

caused economic losses (Englund and Ryttar, 2008). Over the last two decades, it has also caused a decline in water quality as a result of the capacity of the sewage system being exceeded (Fortnam & Flower, 2015).

Urban flooding is a common issue in South East Asia and is often overlooked by planners and decision makers (Qin et al., 2013). The problem results largely from unplanned urban development linked to rapid population growth. Master plans developed for sewage and drainage systems are often not sufficient to address increasing infrastructure demands. This problem becomes worse when urban wetlands and natural drainage systems are replaced with impervious surfaces. This increases the intensity of surface runoff and the demand on drainage infrastructure (Ward et al., 2017). Urban flooding also has other negative social, environmental, and economic impacts. This includes traffic disruptions when roads become flooded, pollution of surrounding water bodies, increased public health risks, and economic losses. Rapid urban development in Phnom Penh has led to many wetlands to be filled in and replaced with built infrastructure. The loss of urban wetlands has led to more intense peak stormwater flows, which have exceeded the capacity of drainage systems causing higher flood levels (Qin et al., 2013). This has also led to a need for increased public expenditure on infrastructure for urban flood management.

The persistent degradation of these natural urban assets has not been paid adequate attention by urban planners and policymakers. In the Mekong region, the value of ecosystem services has not been well integrated into urban development policies. This is true in Cambodia, where significant policy gaps exist with respect to ecosystem services (Lebel et al., 2014). Urban

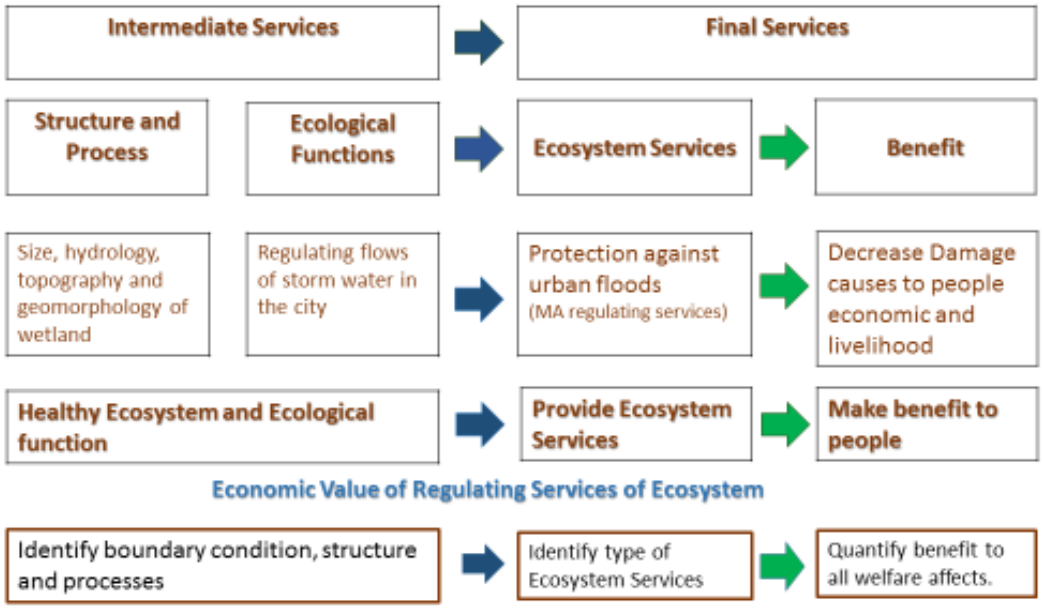
planning practices are highly influenced by the need for economic growth and linking the city to the global economy; however, unsustainable urban growth is a significant environmental concern. For example, Choeung Ek currently faces many constraints in terms of its capacity to regulate of peak stormwater flows. High-density urban development is encroaching on areas surrounding urban wetlands causing a degradation of its ecosystem function and negative impacts on public health (Kok et al., 2012);(Wang et al., 2008). Thus, an assessment of the economic loss associated with this degradation through its impact on urban flooding in Phnom Penh is timely. It is anticipated that this research will support urban planners and policymakers to become more informed of both the positive and negative economic impacts of urban infrastructure projects.

This research explores the close association between a loss of capacity of wetland ecosystems in Phnom Penh to regulate stormwater flows and urban flooding. The first objective is to conceptualize the connectivity between the urban flood events and the ecosystem services provided by urban wetlands. This is achieved by defining the characteristics of stormwater flows through the city, how they are connected to infrastructure such as the sewage and drainage systems and major urban wetlands.

This is defined in a conceptual model of how ecological processes and functions are structured in Phnom Penh, as a foundation for the provision of ecosystem services (Figure 1). The second objective is to draw upon local perceptions about flood preparedness and stormwater management to mitigate economic losses from flooding. To be able to characterize the ecosystem benefits of urban wetlands and what is lost when they become

degraded, it was important to define the structure of a healthy, functioning urban wetland ecosystem. This was to be achieved by defining a set of boundary conditions such as the size of the wetlands; their physical location, geology, and water balance; pH and dissolved oxygen; as well as seasonal and annual variation in rainfall. Then, the function of the wetland ecosystem services were to be classified by the intermediate services they provided, such as the regulation of stormwater flows; the final services that are supplied such as flood protection; and the direct benefits experienced such as the mitigation of economic losses due to flooding (Turner et al., 2008) (Figure 1).

Figure 1. A conceptual model of the regulation of stormwater flows in Phnom Penh by the ecosystem services provided major urban wetlands.



Adopted from Wood et al. (2010)

This model may have been used to characterize the regulation of stormwater flows by urban wetlands and determine their total economic value. Once the structure and processes of urban wetlands were defined, their

ecosystem function could have been clearly specified. Then, the benefits of the ecosystem serviced provided by urban wetlands could have been determined based on whether the benefits are direct, indirect, or non-use values (Turner et al., 2008). Economic losses associated with urban flooding are a result or stormwater runoff exceeding the capacity of the existing sewage and drainage systems. Additional pressures can increase the magnitude of these losses. For example: increased land-use density associated with urbanization places greater stress on existing sewage and drainage systems, which are already insufficient; poor solid waste management, which is a growing problem in Cambodia, causes blockages and damage to existing drainage infrastructure and sharply decreases drainage capacity (Lamond et al. , 2012); and an increasing frequency and intensity of rainfall events associated with climate change makes urban flooding a more significant problem (Miller and Hutchins, 2017). The increasing pressure on the drainage capacity of urban infrastructure in Phnom Penh makes the natural stormwater flow regulation services provided by urban wetlands even more valuable.

Methodology

A desk review was conducted of the existing available literature on the economic assessment of stormwater flow regulation. This was conducted to obtain a broader insight into the ecosystem function of Choeung Ek and other major urban wetlands in Phnom Penh and their connectivity with different flood-prone areas. The conceptual framework outlined in Figure 1 was used to identify the main structural elements of the urban wetland system in Phnom Penh and how they are linked to ecological functions. A review of grey literature obtained from relevant Cambodian institutions was used to become

more familiar with the hybrid topography of natural catchments and sewage and drainage systems in Phnom Penh. This led to the selection of three study areas in Toul Kork district for collecting primary data including 1) Kampuchea Krom in Teuk Laak I Sangkat; 2) Depot Market, in Phsar Depo II Sangkat; and 3) the Mondial Commercial Center in Teuk Laak III Sangkat. These locations are all located in the centre of Phnom Penh, regularly experience flood events in the rainy season, and have ecological connectivity to Choeung Ek through the other urban wetlands.

The sites were also selected on the basis of covering different types of urban environments. This included different topographies, as well as both commercial and residential land use. The aim was to be able to compare a range of different perceptions about urban flooding. The first study area was a zone along a major road (Kampuchea Krom), where there is a high density of commercial office buildings. This area includes a campus of the Asia Europe University and Chea Sim Santhormork High School, as well as small businesses and restaurants operating at the street level. The second study area is a zone surrounding Phsar Depot market. The area includes a dense range of small businesses and open markets. By night, there are many temporary stalls selling food, drinks, and clothes. The third study area in Teuk Laak III Sangkat is primarily residential. However, it does include the Mondial Commercial Center, which comprises Klaing Romsav and Neak Meas markets. These are open-air markets selling electronic equipment and other products.

In total, 300 research participants were recruited to complete questionnaires using purposive sampling and a systematic selection of respondents. Every third person was selected to response to questionnaire in

the three study areas to avoid encountering previous respondents. In total, 100 respondents completed the questionnaire in each study area: Kampuchea Krom, Depot Market, and Mondial Commercial Center. All respondents lived and worked in the study area including: sellers, police, passengers on public transport, and residents. The aim of the questionnaire was to collect data for determining the economic value of losses associated with urban flooding in Phnom Penh based on these three representative areas with connectivity to major urban wetlands. The basis for determining this value was an average damage function taking into account the value of commercial and industrial activities, buildings, and other infrastructure (Huizinga et al 2017). This approach has been used globally, with indicative data available for many countries worldwide (Huizinga, Moel, & Szewczyk, 2017). Interviews with key informants, such as experts from the Royal University of Phnom Penh were also used to obtain a more complete understanding of the impacts of urban flooding in these areas.

The questionnaire comprised three main parts. The first part focused on general demographic information to understand the context in each study area. The second part focused on collecting information required to determine how stormwater flows are regulated by urban wetlands. This was to be estimated on the basis of an economic damage function, which defines the value of urban wetlands by a comparison with a situation where they don't exist. Actual economic losses experienced by people in each study area from flood events were used to estimate the value of urban wetlands in protecting citizens from these losses. The third part was focused on public perceptions towards flood preparedness and stormwater management to

mitigate these economic losses. The methodology was adapted over the course of the study to account for differences in the planned purposive sampling and the willingness and availability of respondents to participate.

Figure 2. A map of the three selected study areas.

The study initially planned to conduct an economic assessment of regulating services of the Choeung Ek wetland, located to the south of Phnom Penh. However, this scope was revised down to an assessment of the economic losses experienced due to flood events in the three study areas due to budget constraints and the capacity to collect sufficient data. The will be used as a starting point for future studies on the value flood regulation services provided by urban wetlands. Flood depth data in the study areas are presented as simple descriptive statistics (maximum, mean (average), and minimum). However, data collected about the scale of economic losses were assessed using an analysis of variance (ANOVA) to determine whether a significant relationship between time of a flood event and the scale of

economic losses existed. Additionally, data on public perceptions of urban flooding was analyzed using a Weight Averaged Index (WAI) to gain insight into the impact of local perceptions of urban flood risks and risk reduction activities on the mitigation of economic losses.

Findings and Results

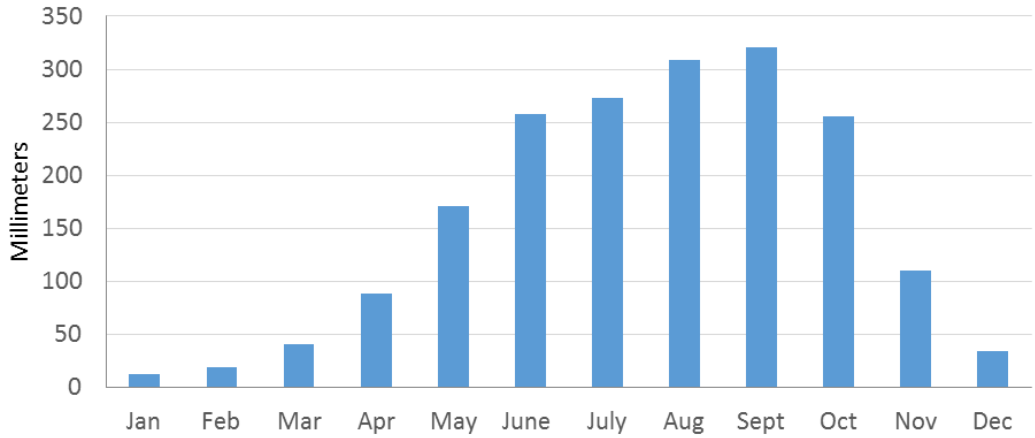
Severity of flood impacts in Phnom Penh

In Cambodia, a rainy season is usually experienced between May and November. Heavier rainfall events usually occur in August and September, in middle of the rainy season; as well as in November, at the end of rainy season. Average rainfall trends in Cambodia for the period between 1991 and 2015 are presented in Figure 3 (World Bank, 2018). While the total rainfall in between August and September is relatively higher than at the end of the rainy season, flood events in November usually are of longer duration and higher intensity. This results in a higher incidence of flood events with a high flood peak at the end of the rainy season. Observations of flood events in Phnom Penh between September and November reflect this scenario.

A period of higher rainfall intensity usually begins in September (annual average rainfall = 320 mm) and continues into October (annual average rainfall = 255 mm). Generally, flood events occurring in October tend to have a less significant impact on commercial activities. Survey results show that businesses still operate, albeit with less customers. Flood events with a higher peak and duration occur in both September and November. During these months, there are frequent rainfall events, where the capacity of the sewage and drainage systems is exceeded. This strongly influences the level of economic loss experienced. When this capacity is exceeded, the value of

urban wetlands (sub-basins), such as Boueng Trabek and Boeung Tumpun; and Choeung Ek (a major drainage basin) becomes more significant. Without their ecosystem function, stormwater would be spread across a larger area of the city, with an increased depth in flood prone areas (Figure 4). This depth varies in each study area depending on topography, localized rainfall characteristics, and the quality of drainage infrastructure.

Figure 3. Average rainfall in Cambodia from 1970-2015.



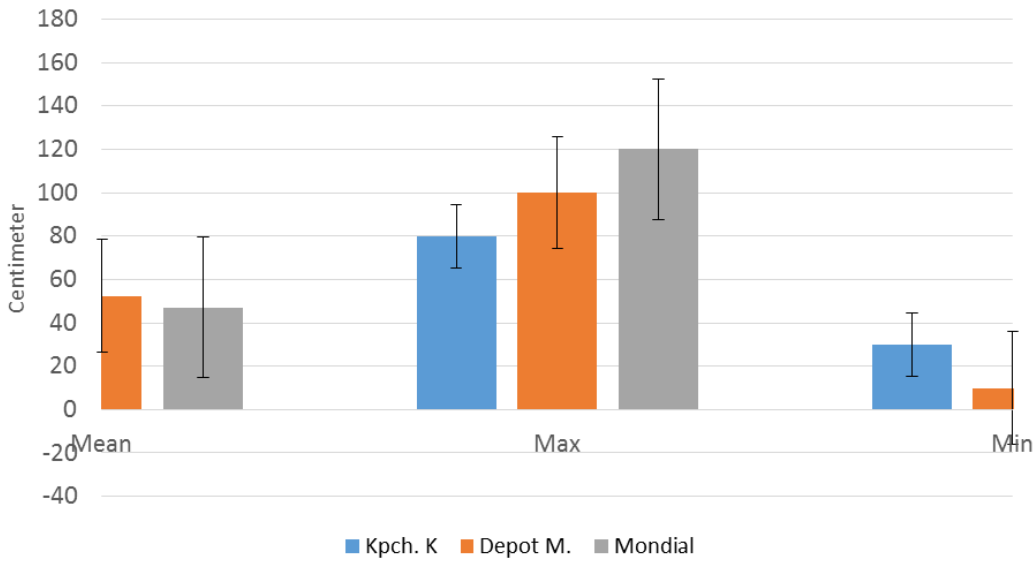
Source: Climate Knowledge Portal World Bank, 2018

Figure 4 shows the descriptive statistics for flood depth in the three areas studied. It also shows that flooding at Kampuchea Krom, while being more widespread than in other areas, only reaches a maximum depth of 80 cm. This is due to being located near Russian Federation Boulevard, a major road, which is sloped and enables water to drain away more rapidly. This reduces the impact on traffic flow in this area. However, the drainage and sewer system at Kampuchea Krom is of a lower standard, resulting in a longer period of time where restaurants and other business are impacted. In

addition, the impact of the flood event is transferred to smaller roads and intersections in the area.

The flood levels experienced at Mondial Commercial Center reach a higher level than other locations. Flood levels in this area vary depending on rainfall volume. Heavier rainfall events cause floods to cover main streets and pathways, with of the entire surface of the locality under water. Flooding after medium and heavy rainfall events is attributed to the capacity of the sewage system being exceeded by stormwater runoff. This is made worse by the presence of plastic waste in the sewage system, which increases the duration of flooding and results in higher flood levels than would otherwise be expected. The area has a low topography and water from other areas flows to this location rapidly.

Figure 4. Flood depths reported in each of the three study areas.



Notwithstanding this, flood levels also recede quickly. The area includes Doeum Kor market, which is one of the largest distribution points for

agricultural produce in Phnom Penh. It was recently prioritized for drainage infrastructure improvements. Floods here now recede within a few hours of a major rainfall event. One key informant described how this area is one of the lowest in the city, having previously been a wetland. Previously, water naturally accumulating in this area would flow into Boueng Tumpun, which acted as a sub-reservoir to regulate flows to Choeung Ek.

Flood levels at Depot market are not as high as the Mondial Commercial Center but have a more significant impact due to problems with the sewage and drainage system in the area. Floods cover the road at a major intersection near the market reach a level of 100 cm, two or three times per year. This is much higher than regular flood levels of between 10 and 47 cm. Residential areas near Depot market are located on higher ground. However, because of limitations in sewage infrastructure, they flood more frequently than the other study areas.

Table 6. Economic losses related to urban flooding.

Attribute	**Kampuchea Krom**	**Mondial Center**	**Depo Market**	**Overall**
Lubricant replacement	3.34	2.38	4.45	3.50***
Vehicle maintenance	2.59	4.12	5.07	3.97
Trading losses	0.72	0.63	0.51	0.62
Flood damage recovery (businesses)	32.20	31.57	22.81	29.24

In each of the study areas, commercial activities are suspended or cancelled when floods cover the road. This may last for a period of between 20 minutes or a few hours depending on the intensity of the rainfall event. These are direct impacts from flooding. Other economic losses are experienced due to vehicle maintenance costs and traffic congestion. These are indirect impacts from flooding. When major roads are flooded, motorists tend to commute using other roads to avoid potential damage to vehicles. This transfers traffic problems to other areas not directly affected by floods. Flooding has an impact on traffic movement and travel times across the entire city. Residents who live in flood-prone areas also suffer vehicle damage if they do not have a safe place to park their vehicle. The economic loss profiles due to urban floods are differentiated for each of the three study areas.

The economic impact of urban flooding in each of the three study areas is significant (*P-value = 0.005*). During flood events, economic activities were halted for few hours due to the duration and intensity of storm events. Most businesses are affected, however, these activities continue after floods recede. Damage occurs to vehicles traveling through the area during flood events. The survey results show that economic losses relate to replacing lubricant and vehicle maintenance. The value of these losses is shown in Table 6, which provides amounts scaled in terms of US dollars. Other losses associated with transportation include traffic as commuters choose routes with no flooding and the number of vehicles on these roads increases sharply increasing travel time and causing traffic congestion. This causes commuters to feel stressed and significantly impacts commercial activities due to lost trading time.

For example, a bakery located near the Mondial Commercial Center intersection shown while flooding in Figure 5 indicated in their questionnaire response that their business declined dramatically during flood events as customers are not able to access the bakery. Flood events such as this cause business disruptions lasting more than four hours. However, high rainfall events that occur during the evening or at night have a lower impact. Other economic losses reported included damage to items sold by businesses. For example, a second-hand computer shop in a flood zone at Mondial Commercial Center reported losses from water entering their premises and damaging equipment, which is more significant in this study area, where flood levels are higher than others. Majority of the economic losses in the study are associated with business recovery from this type of situation.

Figure 5. A flood event observed at the intersection neat the Mondial Commercial Center.

According to results of the questionnaire, urban flood events experienced in Phnom Penh usually last for a maximum of three hours and occur during the middle and at the end of each rainy season. Questions were asked about each respondent's perception about the risks associated with urban floods across a number of different categories including disaster management, public hygiene risk, the loss of urban wetlands, and the provision of public information about flooding. These perceptions were recorded as a weight averaged index (WAI) measured on a five-point scale from considerably less (0.00 - 0.20) to less (0.21 – 0.40) to moderate (0.41 – 0.60) to high (0.61 – 0.80) and to very high (0.81 – 1.00). The results of the WAI are presented in Table 7.

Table 7. Perception of people in study area on flood preparedness and stormwater management.

Attributes	**Kampuchea Krom**		**Mondial Center**		**Depot Market**		**Overall**	
	(n=80)		(n=129)		(n=91)		(n=300)	
	WAI	OA	WAI	OA	WAI	OA	WAI	OA
Disaster management	0.23	L	0.22	L	0.21	CL	0.13*	CL
Hygiene during flood	0.16	CL	0.22	L	0.25	L	0.22*	L
Flood related to wetland loss	0.17	CL	0.17	CL	0.14	CL	0.16*	CL
Information about flood	0.09	CL	0.08	CL	0.35	L	0.23*	L

Note: The WAI was measured on a five point scale [Considerably Less (CL) =0.00 - 0.20, Less (L) = 0.21 – 0.40, Moderate (M) = 0.41 – 0.60, High (H) = 0.61 – 0.80, Very High (VH) = 0.81 – 1.00; OA = Overall Assessment; *Significance at the 0.05 Level; **Significance at the 0.01 level.

Disaster management was perceived as "less" in each of the three study locations and "considerably less" overall. All other WAI responses in the three locations related to public hygiene, the loss of urban wetlands, and public information regarding floods were ranked as "considerably less" on the WAI, except for public information in Depot market which was rated as "less". This shows that most people in Phnom Penh get little information and about disaster preparation, disaster management, public hygiene during flood events. In addition, citizens in Phnom Penh do not perceive that the intensity of flooding in the city is caused by the loss of urban wetlands, as indicated by a WAI score of less than 0.20. The WAI suggests that most households in the study area have little knowledge of stormwater management or flood preparation practices. For example, most respondents indicated that they had not received any training in flood preparation or stormwater management.

Discussion

The three main research objectives of this study were to: 1) determine the characteristics and depth of urban flood events in the three study areas, 2) explore the economic losses associated with flood events, and 3) measure citizen perceptions of preparedness for urban floods in the study areas.

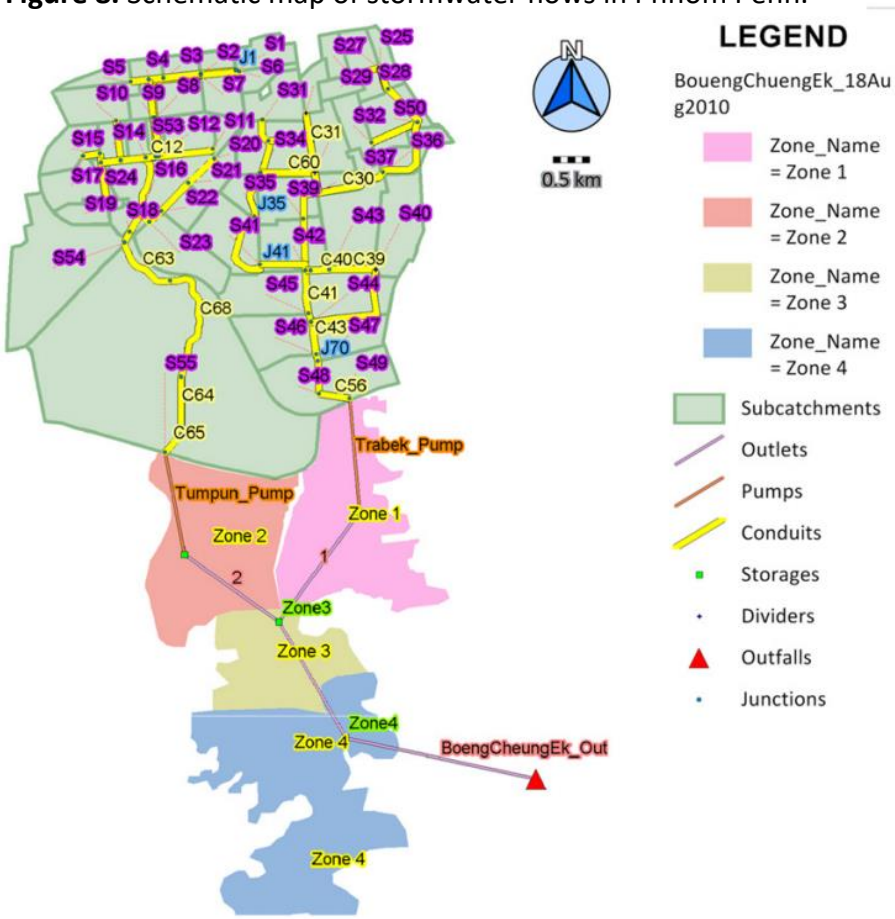
Stormwater generally flows to sewers and low lying surfaces in the city before it is transported by infrastructure or natural processes to reservoirs or wetlands. Figure 8 shows a schematic of stormwater flows in Phnom Penh (Irvine et al., 2015) and provides more detail. In the case of Phnom Penh, stormwater initially flows toward two sub-reservoirs (Boueng Tumpun and Boeung Trabek). Without these two wetlands, the volume of stormwater in the city would overload sewers and drainage systems to a higher degree and

flood a larger surface area. Thus, water from the sewage system would also be spread more widely. The wetlands enable more water to flow into sewers and drains, accelerating the rate at which urban floods recede. Once the flow of water in the sewer is reduced, the water held in the two wetlands is then able to flow to Choeung Ek, where the water is treated. Thus, Boeung Tumpun, Boueng Trabek, and Choeung Ek play a significant role, as urban wetlands, in reducing economic losses associated with flood events. If urban development encroaches upon these wetlands, they will lose their capacity to retain stormwater and the level of economic losses experienced in flood-prone areas of Phnom Penh will increase. Flow regulation services provided by these wetlands have a significant value. However, this value could not be detailed in this paper due to time and budget constraints. If these constraints did not exist, this information would be of significant public interest.

The scale of economic losses related to urban flooding in Phnom Penh has not been addressed in the academic literature. Low level flooding in Phnom Penh imposes many opportunity cost on urban residents. This is a significant barrier to meeting urban sustainable development indicators in Phnom Penh. Urban planning to address regular flood events in the city is relevant to a broad range of these indicators related to sustainable transport, infrastructure development, energy efficiency, environment protection, green growth, public recreation areas, social equity, education, and equitable socio-economic development (Tanguay et al., 2010). Urban flooding affects progress toward urban sustainable development. It causes economic losses and disrupts connectivity between different parts of the city, resulting in greater opportunity costs for socio-economic development. However, results

from this study show that flood levels in Phnom Penh of around 50 cm are not considered to be considered a disaster with respect to the global flood damage function (Huizinga et al., 2017). This means that flood levels experienced regularly in the rainy season in Phnom Penh need to be managed differently to a disaster, as the scale and profile of damage is different. Table 8 presents information about the global flood damage index for Asia showing the relationship between flood depth and damage to transportation systems (Huizinga et al., 2017).

Figure 8. Schematic map of stormwater flows in Phnom Penh.



Source: Irvine et al (2015)

Figure 8 shows that flood levels most regularly experienced in Phnom Penh correlate to a flood damage function for transportation systems of less than 0.57. This means that assuming an income of 10 USD per day, the economic loss experienced by a citizen in Phnom Penh related to transportation system damage, would be less than 5.7 USD if flood impacts were experienced over an entire day.

Table 8. Damage of urban flood on transportation.

Flood Depth (Meter)	Damage function in Asia	Kampuchea Krom (Meter)	Depo Market	Mondial commercial center
0	0	0.3	0.1	0.1
0.5	0.36	0.5	0.54	0.47
1	0.57			
1.5	0.73			
2	0.85	0.8	1	1.2
3	1			
4	1			
5	1			
6	1			

Source (Huizinga, et al., 2017)

However, as flooding in Phnom Penh tends to last for a maximum of three hours, this loss needs to be adjusted to a value proportional to the amount of time lost in one day. For example, if the flood affected three of the five hours, usually spent generating income, then this is equivalent to an economic loss of 3.4 USD for the flood event. As the duration of a flood event

in Phnom Penh can range from twenty minutes to three hours, this has a significant impact on the value of economic losses experienced due to a flood and hence, the value of ecosystem services provided by an urban wetland.

Conclusion

Urban flooding caused by intense rainfall events results in economic losses due to various factors such as replacing lubricant in vehicles, other vehicle maintenance, time lost due to heavy traffic congestion and flooded roads, and disruption to commercial activities. After heavy rainfall events, the volume of surface water in Phnom Penh exceeds the capacity of sewers and drainage systems, as well as urban wetland systems. Land-use changes in Phnom Penh over the past ten years have seen most of the vacant land in the city transformed to impervious surfaces and roads, which do not allow water to penetrate into the soil. Runoff from hard surfaces causes short term flooding, however, high water levels usually recede within one to three hours of the rainfall event. This water eventually flows into Choeung Ek at the edge of the city. This wetland has a capacity to receive a large volume of water, which reduces the intensity of flood events and associated economic losses. Without urban wetlands such as Choeung Ek, stormwater would take longer to be transported through sewers and drainage systems. This would increase the duration and height of flood events, resulting in more significant economic losses. The majority of these losses are related to the disruption of commercial activities.

While economic losses caused by urban flood events are less significant than flooding that occurs in rural areas, they still require timely intervention. Flood levels in the study areas ranged from 10cm to 120 cm and

the time for them to recede ranged from 10 minutes to 3 hours. Questionnaire respondents in Phnom Penh demonstrated a low awareness of management approaches used to mitigate the impacts of these economic losses in flood-prone areas. Many citizens perceive that urban flooding is a natural phenomenon that cannot be avoided. They have limited experience in adapting to urban floods. A lack of capacity in preparing for floods reduces the resilience of the city making citizens more vulnerable to the impacts of flood events. This is significant as they are expected to have a longer duration and become more intense in the future due to climate change. This will in turn increase the vulnerability of urban residents of Phnom Penh, especially when considering other pressures on urban wetlands such as a rapidly growing urban population.

This study recommends that a greater focus be placed on urban planning to achieve sustainable development outcomes. To do this, it is important to better understand the ecological function of urban wetlands and their hydrological connectivity to engineered drainage and sewer systems. The effective management of urban flooding will require a cost-benefit analysis to be applied to the design of urban drainage infrastructure. This report has developed further insights into the requirements of estimating the total economic value of the ecosystem services that urban wetlands, such as Choeung Ek provide in terms of flood regulation. However, while this valuation would be highly useful for urban planners and decisions makers in Phnom Penh, it has not yet been completed due to budget limitations. It is recommended that a future study completes this work.

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