Research Article

Water Management in Housing Developments on Wetlands: A Case Study of Chbar Ampov District, Phnom Penh, Cambodia

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Abstract

Phnom Penh's rapid urban expansion has led to the large-scale conversion of wetlands into residential areas, undermining natural flood protection and accelerating environmental degradation. While previous studies have examined wetland loss and urban governance challenges in Cambodia, few have compared water management practices between Borey (gated communities) and non-Borey (non-gated) on both wetland and non-wetland. This study addresses that gap through a mixed-methods approach combining GIS mapping, field surveys, and semi-structured interviews with 27 stakeholders. Results show that while Borey developments feature planned layouts and green areas, these are predominantly decorative and provide limited flood mitigation. Non-Borey projects, particularly on wetlands, face severe flood risks due to inadequate drainage and minimal green space. Weak enforcement of wetland protection laws, fragmented governance, and the absence of water-sensitive design standards exacerbate these problems. Policy recommendations include mandating nature-based solutions, integrating Water Sensitive Urban Design principles into all housing developments, and strengthening enforcement of environmental regulations. By reframing wetlands as essential urban infrastructure, Phnom Penh can balance housing growth with climate resilience.

Keywords:

Urban housing, Development on Wetland, Water management, Urban planning policies

1. Introduction

Phnom Penh's rapid urban expansion has come at a significant environmental cost. Vital wetlands natural buffers that absorb stormwater and reduce flood risk are being filled for residential development (Figure 1). While housing demand continues to rise, the consequences of wetland loss, including increased flood vulnerability, water pollution, and ecological degradation, remain underexamined in the Cambodian context (Chandran, 2020).

Urban development and residential project design have a direct influence on environmental sustainability and quality of life. Key factors affecting the performance of housing developments include drainage systems, public space configuration, vegetation use, and sustainable infrastructure planning (Tochaiwat et al., 2018). These considerations are especially critical when construction occurs in environmentally sensitive areas such as wetlands. Effective drainage design can significantly reduce flood risks, while well-planned green spaces can enhance both ecological resilience and livability. As Tochaiwat et al. (2018) and Hui et al. (2023) note, incorporating features such as waste management facilities, recreational spaces, and renewable energy systems into master plans can improve community well-being and environmental outcomes. The design quality of these elements strongly shapes residents' satisfaction, perceptions, and long-term decision making.

Despite these insights, little research has compared how different housing development models in Phnom Penh address water management particularly when built on contrasting land types. Borey developments, defined as master planned gated communities aimed at middle to high income residents, typically include formal infrastructure such as drainage systems and shared amenities. In contrast, non-Borey developments of non-gated areas with mixed housing forms, including flats, villas, and traditional houses often emerge without comprehensive infrastructure planning. While Borey projects may priorities aesthetic landscaping over functional water management, non-Borey areas face heightened flood risks due to inadequate drainage and minimal green space. At the same time, Cambodia's urban policies struggle to balance housing growth with wetland conservation, leading to weak enforcement and inconsistent application of environmental regulations (Beckwith, 2020; Marks & Baird, 2025; Sahmakum Teang Tnaut, 2019).

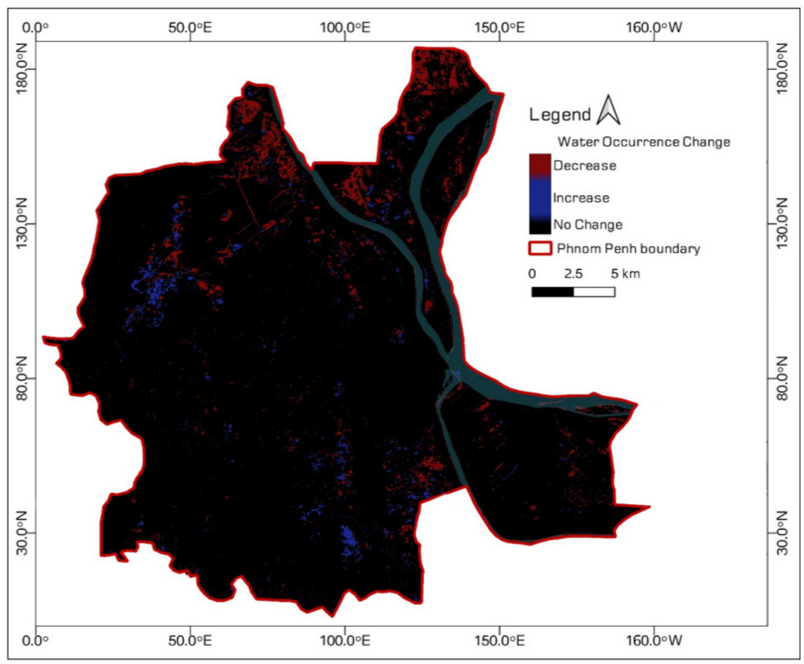

Figure 1. Phnom Penh flood map (2019-2020)
Source: Researcher, 2024 (Adapted from Google Earth Engine, 2019-2020)

This study addresses this gap by adopting a comparative approach to analyze four housing typologies in Chbar Ampov District (1) Borey on former wetlands, (2) non-Borey on former wetlands, (3) Borey on non-wetland, and (4) non-Borey on non-wetland. Using spatial analysis, field surveys, and stakeholder interviews, it examines water management strategies, flood resilience, and compliance with planning regulations. The central argument is that flood vulnerability in Phnom Penh is shaped not only by infrastructure quality but also by the interaction between development type, historical land condition, and governance capacity. The findings aim to inform policymakers, planners, and developers on how to integrate water-sensitive urban design principles into both formal and informal housing developments, ensuring that Phnom Penh can continue to grow without sacrificing its natural flood protection systems.

2. Literature Review

Urban development and residential project design have a significant impact on environmental sustainability and living quality. According to Tochaiwat et al. (2018), key factors influencing the success of residential developments include drainage systems, public space configuration, plant material use, and sustainable infrastructure planning. These elements are particularly important in the context of rapid urban expansion into environmentally sensitive areas, such as wetlands. Effective drainage design, for example, plays a crucial role in mitigating flood risks, while well planned green spaces enhance ecological resilience and livability. Tochaiwat et al. (2018), highlights the necessity of integrating infrastructure elements such as garbage disposal areas, playgrounds, sports fields, and alternative energy systems into urban design to support both community wellbeing and environmental management. Tochaiwat et al. (2018) also notes that the design of master plans and the quality of environmental features strongly influence residents' perceptions, satisfaction, and decision making.

2.1 Theoretical Frameworks for Urban Water Management

Urban water management involves the planning, design, and operation of systems that supply safe water, manage stormwater, and treat wastewater. Its goal is to create urban environments that are sustainable, resilient, and adaptable to challenges such as climate change and population growth (Sharma & Ayuba, 2024). In rapidly expanding cities, the replacement of permeable landscapes with impermeable surfaces such as roads and buildings has increased runoff and overwhelmed conventional drainage systems. These systems, often composed of concrete channels, cannot absorb stormwater or integrate with green spaces, leading to frequent urban flooding (Jia et al.,2013).

To address these challenges, various concepts and practices, including Sustainable Urban Drainage Systems (SUDS), Nature-Based Solutions (NBS), Low Impact Development (LID), and Water Sensitive Urban Design (WSUD), are proposed. These practical solutions have some similarities and differences. The SUDS is essential for reducing stormwater peak flows, improving water quality, and supporting biodiversity. The application can take multiple forms, including green roofs, rain gardens, permeable pavements, and constructed wetlands (Susilo et al., 2009). These systems are adaptable to a range of scales, from small individual properties to large urban catchments (Chen & Chui, 2025).

Popularized by the European Union in the 2010s, Nature-Based Solutions (NBS) utilize natural processes, such as urban forests, green roofs, and restored wetlands, to tackle environmental challenges and improve resilience. NBS incorporates living systems into the built environment through features like constructed wetlands, green corridors, and riparian buffers (European Commission, 2020). Constructed wetlands effectively store and treat stormwater using plants and soil to eliminate pollutants and promote biodiversity (Santos, 2025).

LID is a sustainable stormwater management approach that replicates natural hydrological processes by managing runoff close to its source (United States Environmental Protection Agency New England, 2009). It was introduced by the US Environmental Protection Agency. LID techniques are integrated into site and building design to reduce peak stormwater flows, improve water quality, and enhance infiltration. Key elements of LID include bioretention systems, such as rain gardens and bioswales, which filter and absorb stormwater. Other elements include permeable pavements, which reduce runoff and help recharge groundwater, and green roofs, which delay roof runoff while providing cooling and insulation. Additionally, vegetated swales can replace traditional gutters to convey and treat stormwater. Rainwater harvesting systems are designed to collect and store roof runoff for reuse. Infiltration trenches or basins facilitate the gradual infiltration of water into the ground (Dietz, 2007).

Water Sensitive Urban Design (WSUD) emerged in Australia in the early 1990s, first mentioned by Mouritz (1992) and later detailed in a report for the Western Australian Government by Whelans et al. (1994). Its objectives included managing the water balance, protecting and enhancing water quality, promoting water conservation, and maintaining water-related environmental and recreational values. Wong and colleagues later expanded the concepts, describing WSUD as an urban planning and design philosophy aimed at reducing the hydrological impacts of urbanization through strategies such as flood control, flow management, water quality improvements, and stormwater harvesting (Lloyd, 2001; Wong, 2000, 2001, 2002). In practice WSUD integrates multi-functional landscapes, stormwater treatment wetlands, green streets, and water recycling systems to achieve balance between water supply, flood resilience, and ecosystem health (Fletcher et al., 2015).

While these four frameworks provide a conceptual foundation, this review gives particular emphasis to China's Sponge City and Singapore's Active, Beautiful, Clean Waters (ABC Waters) programs. The reason for this focused attention is that both initiatives not only embody the theoretical principles of SUDS, NBS, LID, and WSUD, but also provide detailed, project-level design applications tailored for tropical and monsoon climate conditions very similar to those in Phnom Penh (PUB Singapore, 2017).

China Sponge City, also inspired by SUDS and WSUD, was launched the in the end of 2014 to address urban flooding and water scarcity (Li et al., 2017). This approach is applied in multiple scales as neighborhood, city, and regional by integration measures such as green roofs, permeable pavements, urban wetlands, and underground water storage tanks to reduce flooding and enhance water reuse (Li et al., 2017; Yin et al., 2022; Zhang, 2016). Implementation involves public private partnerships, with private firms funding, designing, and maintaining sponge infrastructure in exchange for phased government compensation. While the programme combines stormwater retention, pollution control, and climate adaptation, it faces challenges such as high costs, difficulties in retrofitting older districts, and balancing rapid urban growth with environmental protection.

Similarly, Singapore's Active, Beautiful, Clean Waters (ABC Waters) program, launched in 2006, also adapts WSUD and NBS principles to tropical urban contexts (Cui et al., 2021). This initiative converts conventional drains and canals into green-blue corridors with vegetation-lined banks, rainwater gardens, and recreational spaces (PUB Singapore, 2017). Flagship projects such as Bishan Ang Mo Kio Park and Kolam Ayer demonstrate how water sensitive design can be combined with community engagement. The programme's success is supported by strong governance, dedicated funding, and a certification scheme encouraging private sector participation (PUB Singapore, 2017). Overall ABC Water seeks to reframe stormwater management, with the purpose of enhancing flood resilience and creating sustainable urban environments. Its key features include the following:

1. **Natural Stormwater Treatment** is achieved through elements such as rain gardens, bioretention swales, wetlands, and cleansing biotopes help to filter the rainwater. These systems use plants and soil to take out dirt, oil, and other pollution from the water and also help improve water quality before the water flows into rivers or reservoirs.
2. **Detention and Retention** are applied to temporary stores and treatment rainwater on-site rather than letting it flow away immediately. This helps reduce peak runoff, urban flooding and allow water to be reused. A well-known example is a building called Kampung Admiralty in Singapore, where rainwater is collected from the roof and sequentially treated through planter boxes, stored in tanks for irrigation and excess water directed to ground level for further clean. This measure, water is managed better and can be reused safely.
3. **Green Blue Integration** is another important aspect which combines green infrastructure such as plants and parks with blue elements like rivers and ponds into urban design. This not only improves ecological and hydrological function but also contributes to cooler, attractive and better for nature and environment more livable. A notable case is parking space was retrofitting concrete drain to green swales filled with plants that slow down the rainwater and clean it naturally. These changes make the area more pleasant for people and better for the environment.
4. **Community Involvement** is also a central component as ABC Waters seeks to connect people with water by creating parks, walkways, learning areas and plazas into stormwater infrastructure. These spaces help recreation while fostering public awareness of water processes and conservation.
5. **Support for Sustainable Development** is another key feature to supports Singapore's goal to become a green and sustainable city. This is achieved through the incorporation of green roofs, rainwater reuse systems, and plant-based water filters that not only reduce water and energy but also improve thermal comfort in high rise buildings. These measures align with Green Mark certificates schemes, strengthening the role of ABC Water in advancing sustainable development across the city.

Table 1. Summary and comparison of urban water management concepts **Source:** Researcher, 2024

Concepts	Origin	Key Features	Main Objectives	Relevance to Flood Management
Sustainable Urban Drainage Systems (SUDS)	UK,1990s	Rain gardens, wetlands, permeable surfaces, mimic natural cycles	Manage stormwater sustainably, filter pollutant	Reduces runoff, improves water quality
Nature-Based Solutions (NBS)	EU, 2010s	Green roofs, urban forests, restored wetlands	Use nature to solve urban challenges, enhance resilience	Absorbs stormwater, supports ecosystems
Low Impact Development (LID)	USA, 1990s	Rain barrels, bioswales, permeable pavements, small-scale intervention	Local, decentralized rainwater management	Reduces localized flooding, promotes infiltration
Water Sensitive Urban Design (WSUD)	Australia, 2000s	Green streets, water recycling, multifunctional landscapes	Integrate water into urban planning	Controls stormwater, reuses water, supports biodiversity
ABC Waters	Singapore, 2006	Naturalized rivers, floating wetlands, rain gardens, public spaces	Blend water, environment, and community	Combines drainage with recreation and public engagement
Sponge City	China, 2014	Permeable pavements, green roofs, underground storage, urban wetlands	Reduce flooding, improve water reuse	Absorbs and stores rainwater, mimics sponge function

While these models differ in scale, governance, and financing, they share core principles such as ecological integration, decentralized drainage, and community participation. Table 1 summarizes and compares their objectives, key features, origins, and relevance to flood resilience, providing a foundation for evaluating Phnom Penh's housing developments.

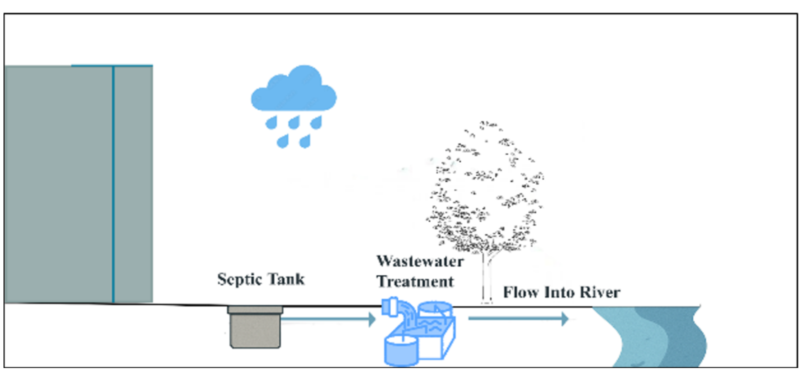

Figure 2. Conventional water system in housing development
Source: Researcher ,2024

2.2 Trend of Housing Development in Phnom Penh

Phnom Penh, the capital of Cambodia, has experienced rapid growth in recent decades, resulting in major transformations in its housing landscape (Mialhe et al., 2019). Historically, most residents lived in the city Centre in traditional wooden houses or French colonial era buildings. Today, housing development in Phnom Penh typically relies on a dual drainage system such as stormwater and household wastewater (Figure 2). The drained water is intended to pass through treatment facilities before entering roadside drains, which connect to the main sewer network and eventually discharge into major rivers such as the Tonle Sap or the Mekong. However, in practice, untreated sewage is often channeled directly into the river due to the absence or failure of wastewater treatment infrastructure.

Driven by rapid urbanization and rising private investment, the city's housing landscape has diversified. Large-scale, master-planned Borey estates are often marketed as self-contained satellite cities and have proliferated along the urban fringe, while informal, developer-led flat house clusters have filled smaller parcels of available land (Phnom Penh Municipality, 2019). This boom has been fueled by easy access to mortgage credit, significant foreign direct investment, and a growing middle class (Yin et al., 2017).

Between 2009 and 2014, projects such as Diamond City, Camko City, Grand Phnom Penh, and Platinum City added tens of thousands of residential units, office buildings, and commercial facilities. Borey developments are particularly popular among middle- and high-income households and often include schools, malls, and parks. However, despite attempts by the government to introduce urban planning regulations, enforcement remains inconsistent (Sahmakum Teang Tnaut, 2019). This weak governance has contributed to unchecked construction, including on wetlands and public lands, displacing lower-income communities and exacerbating housing affordability challenges.

One of the most serious consequences of this growth is the destruction of wetlands, which once acted as natural retention areas for rainwater. Their loss has intensified flooding, degraded water quality, and reduced biodiversity (Hails et al., 1996). Wetland removal also contributes to the urban heat island effect and disrupts hydrological processes, as new developments block natural water flow. Many projects lack adequate drainage, resulting in seasonal flooding (Beckwith, 2020; Doyle, 2012). For instance, the infilling of lakes and wetlands has led to flooding in both newly developed and long-established neighborhoods (Beckwith, 2020). However, physical designs of water management in these housing developments on wetlands are insufficiently researched and not well understood. While prior studies have examined governance challenges, land conversation and community displacement (Beckwith, 2020; Marks & Baird, 2025; Sahmakum Teang Tnaut [STT], 2019;), with limited attention to comparative housing projects level analysis. Few studies have compared the water management practices of non-Borey project across both wetland and non- wetland context and this study was addressed that gap.

2.3 Implications for Phnom Penh

The review of water management concepts and practices mentioned earlier offers valuable conceptual guidance, their implementation relies on governance, financial, and institutional capacities that differ from those in Phnom Penh. The city's urban governance is characterized by fragmented institutional responsibilities, limited regulatory enforcement, and rapid, speculative real estate development (Beckwith, 2020; Marks & Baird, 2025; STT, 2019). This environment constrains the direct transfer of centralized, technocratic approaches such as Singapore's ABC Waters or China's Sponge City. Nevertheless, core principles such as ecological integration, decentralized drainage, and active community participation remain relevant as benchmarks for evaluating existing developments and identifying context-appropriate improvements.

This study adopts these international frameworks not as prescriptive blueprints but as analytical tools. By assessing Borey and non-Borey housing projects, both on wetland and non-wetland sites, against the principles of WSUD, NBS, and related models, the research seeks to identify disparities in drainage infrastructure and spatial design, and to provide recommendations tailored to Phnom Penh's governance and environmental context.

3. Study Area

Chbar Ampov District, located in southeastern Phnom Penh, Cambodia, serves as a critical study area for examining the interaction between urbanization and environmental change (Figure 3). Its geographic significance lies in its mix of wetland and non-wetland residential developments offering a representative microcosm of the challenges and transformations faced by rapidly urbanizing regions. Over the past decade, the district has undergone dramatic change, shifting from a peri urban landscape of marshes and rice paddies to a densely populated area dominated by commercial and residential infrastructure (Kosal, 2018). This rapid transformation, fueled by Phnom Penh's eastward expansion, has led to the widespread filling of wetlands for housing projects and road networks (Fredriech, 2022).

As a result, Chbar Ampov has experienced the loss of natural water retention systems, significantly impacting both long established communities and new developments (Table 2). Visual analyses, including maps comparing historical and current wetland coverage, reveal a stark reduction in ecologically vital areas (Mialhe et al., 2019).

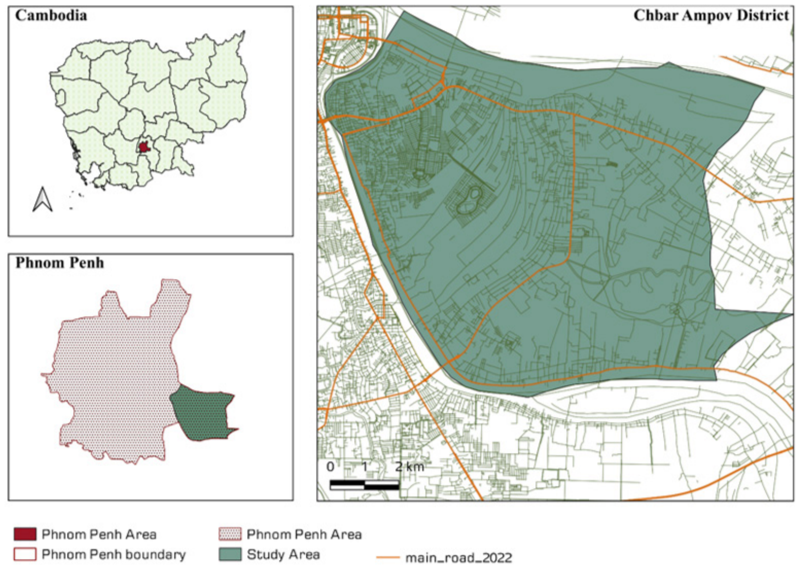

Figure 3. Study area (Chbar Ampov, Phnom Penh, Cambodia)
Source: Researcher ,2024

Table 2. Show all wetland loss in Phnom Penh
Source: Researcher, 2024

N	Districts	Name Of Lake	Wetland Area (km²)			Reason for change	Amount of Borey 2017
			2003	2012/13	2018		
1	Prek Pnov	Boeung Tamok	31.6	25.3	31.9 legally demarcated	(Satellite city) ING City	6
		BoeungSamrong	5.15	3.19	2.8	Sand-infilling/fish- farming	
2	Chroy ChongVa	North Chroy Changva	21.5	15.19	14.67	Satellite city (Orkide, Garden City)	13
		South Chroy Changva	1.5	1.15	0.17	Satellite city (OCIC project)	
3	SenSok	Boeung Reach Sei	5.48	2	0.78	(Satellite city) ING City	14
		Sensok	3.13	1.8	0.118	Borey Peng Huoth, Camko Satellite city , AEON 2	
4	Russey Koe	Boeung Chhouk	-	-	-	-	43
5	Toul Kork	Boeung Salang	-	-	-	Residential area	3
6	Chamka Morn	Boeung Trabek	-	-	-	Residential	5
7	Por Senchey	No Lake					23
8	Mean Chey	Cheung Ek	14.9	14.9	(2019) 1.07 legally demarcated	(Satellite city) ING City	17
9	Dong Kao	Tompun	0.542	0.386	0.333	Residential buildings	12
10	Chbar Ampov	Boeung Snor /Boeung Chhouk	10.8	9.08	5.84	Borey Peng Huoth - The Star Platinum Rosato	16
		Prel Thom Chhouk	5.52	6.01	1.43	Vattanac Golf Course	
	Total		101.0	79.0	59.7	Loss of over 40% of wetlands area	152

In 2019, Chbar Ampov District had a total of 35,244 households and a population of 164,379, making it one of the most rapidly growing districts in Phnom Penh (National Institute of Statistics, 2019). Among its eight communes in Chbar Ampov District which show in Figure 4, Nirouth commune stood out with the highest concentration of housing, comprising 7,561 households and a population of 35,237 (General Population Census of Cambodia, 2019). This significant residential density reflects the area's rapid urban expansion and its role as a key site for housing development. As such, two of the four case study housing projects selected for this research are located within Nirouth commune. The area's growing population, driven by migrant inflows and rising land prices, illustrates broader patterns of urbanization taking-place across Phnom Penh (Yin et al., 2017). By integrating spatial, environmental, and socio-economic data, Chbar Ampov particularly Nirouth commune emerges as a compelling case study that reveals the tensions between rapid urban growth and the urgent need for more sustainable and resilient development.

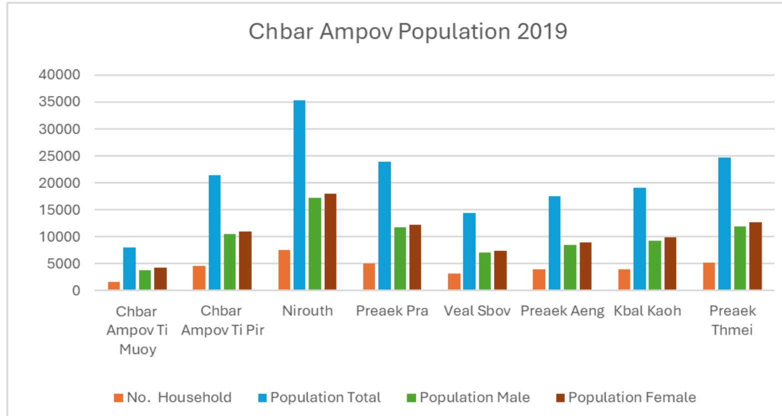

Figure 4. Chbar Ampov population 2019
Source: Researcher, 2024

4. Methodology and Tool analysis

This study adopts a qualitative research approach, supported by mixed methods, to examine water management in Phnom Penh's wetland housing developments. Data collection combined primary data (field surveys, interviews) and spatial data (mapping and GIS analysis), alongside policy review, to provide a comprehensive understanding of the issue (Figure 5).

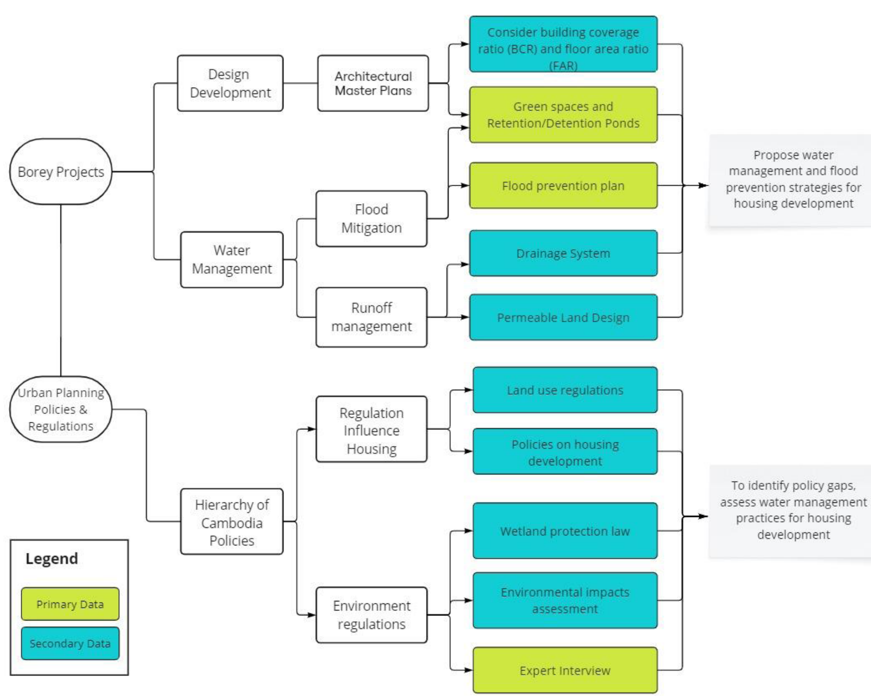

Figure 5. Conceptual framework
Source: Researcher, 2024

4.1 Interview

We conducted semi structured interviews with 27 key stakeholders, including residents from both Borey and Non Borey communities, government officials from the Ministry of Environment, and environmental experts from academia and the private sector. This method was chosen to provide in-depth perspectives from groups directly involved in, or affected by, housing development on wetlands. The sample was designed to capture variation in developer type, land condition (wetland vs. non-wetland), and housing scale in order to reflect the diversity of development practices within the district.

These projects were divided into three groups (Figure 6) as Household, Expert, and Borey Staff. For the Household group five individuals from each project were interviewed, totaling 20 participants. For the Expert group, three individuals were interviewed, including an environmental expert from the academy, a government official specializing in environmental issues, and a representative from a private company with expertise in environmental matters. As for the Borey staff group, four individuals from Borey (gate community) projects were interviewed, totaling 4 participants. Non-Borey projects were excluded from the staff interview category because such communities typically lack formal management structures. Instead, household interviews served as the primary means of capturing resident experiences in these areas.

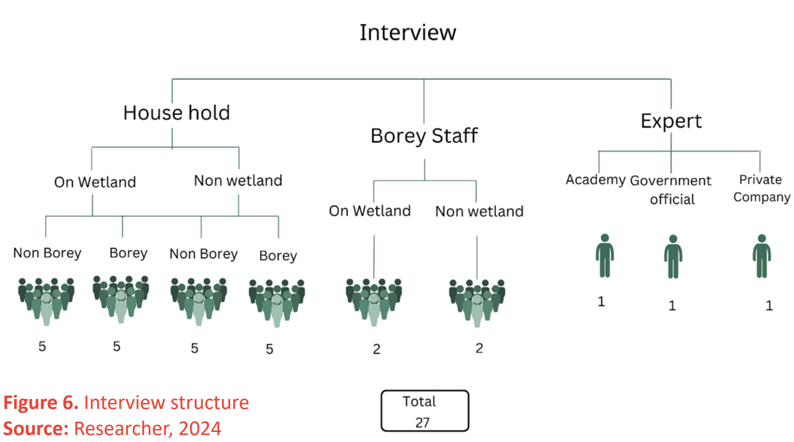

Figure 6. Interview structure
Source: Researcher, 2024

Interviews were designed to gather both factual and experiential data. The majority of questions focused on flooding, drainage systems, and observed changes to wetlands. Some open-ended questions allowed participants to elaborate on challenges, identify causes of flooding, and suggest improvements. All interviews were audio recorded and transcribed to ensure accuracy and to capture nuanced perspectives on flood experiences, policy enforcement, and community adaptation strategies.

4.2 Data analysis

Spatial analysis was conducted using QGIS version 3.32.3 to map the distribution of Borey and non-Borey developments within Chbar Ampov District. Historical satellite imagery from 1 April 2003 (Maxar Technologies) and 1 April 2024 (CNES/Airbus) was accessed via Google Earth Pro, with a spatial resolution of approximately 0.5 meters per pixel. These datasets were used to track the transformation of wetlands into residential zones over time. Wetland extent for both years was delineated manually in QGIS through polygon mapping, based on visual interpretation of key indicators such as lake, vegetation cover, and land texture. The total wetland area was calculated for each year, and percentage change was computed to quantify loss. To ensure accuracy, these results were cross validated with the wetland loss map from Sahmakum Teang Tnaut (STT), enabling the identification of overlapping trends and confirming spatial accuracy.

Document analysis was undertaken to review Cambodia's legal and policy frameworks for urban expansion and wetland conservation, including the Land Law and Environmental Protection Law. Compliance of identified housing developments with these regulations was assessed.

Field surveys of four selected housing projects (two Borey and two non-Borey) provided ground truthing of spatial data and allowed for direct observation of drainage systems, green space allocation, and physical evidence of flooding.

This mixed methods approach ensures our findings are both empirically grounded and contextually, combining the precision of spatial analysis with the depth of stakeholder perspectives to paint a complete picture of Phnom Penh's urban water management challenges. The methodology was deliberately designed to be replicable, using widely available tools that can be adapted for similar studies in other rapidly urbanizing contexts.

The interview data were systematically analyzed to identify key themes and patterns. All interviews with experts, staff, and residents were transcribed word for word to ensure accuracy and preserve full details. The responses were grouped to highlight major themes, such as common concerns about flooding, while differences between expert perspectives and residents' experiences were compared. Maps and satellite imagery were employed to track changes in wetlands over time, identifying areas converted to housing and linking them to wetland loss. Cambodia's land and environmental laws were reviewed to assess wetland protection regulations, and housing projects were evaluated for compliance. Resident surveys were analyzed quantitatively to examine flood frequency in wetland versus non-wetland areas and to explore relationships between drainage quality and residents' satisfaction

Finally, detailed case studies of four housing projects were conducted, comparing features like parks, drainage systems, and flood protection measures to evaluate whether Borey (gated communities) manage water more effectively than non-Borey (non-gated) developments, and how these projects impact nearby wetlands. By combining these different methods, the study provided a comprehensive understanding of how housing development, water management, and wetland loss are interconnected, offering insights into the causes of urban flooding and suggesting ways to improve policies and practices.

4.3 Housing Project in Study area

A total of 64 housing developments were identified within Chbar Ampov District through spatial surveys and analysis of high-resolution satellite imagery. These developments were categorized into four types based on two key criteria as distinguishing between Borey projects and non-Borey projects and land condition, differentiating between developments constructed on former wetlands versus non-wetland (Figure 7).

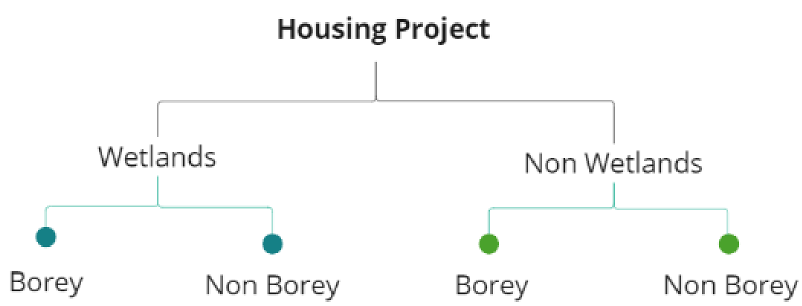

Figure 7. Housing project types
Source: Researcher, 2024

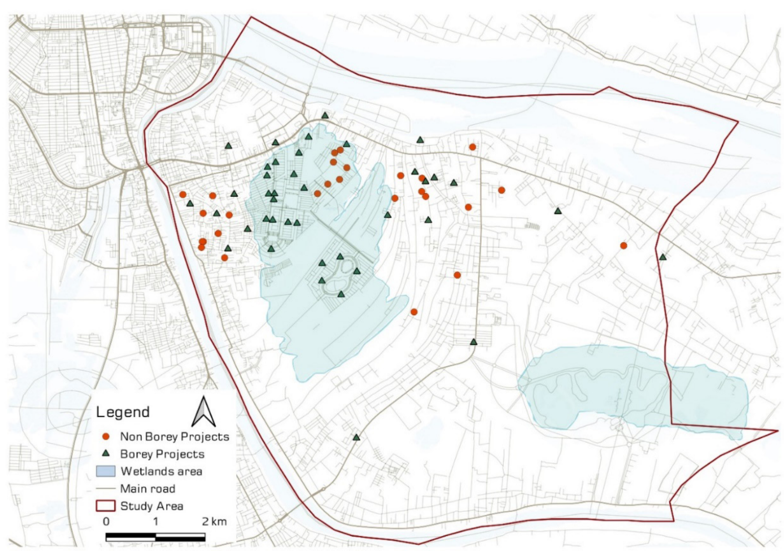

Figure 8. Housing projects in study area
Source: Researcher, 2024

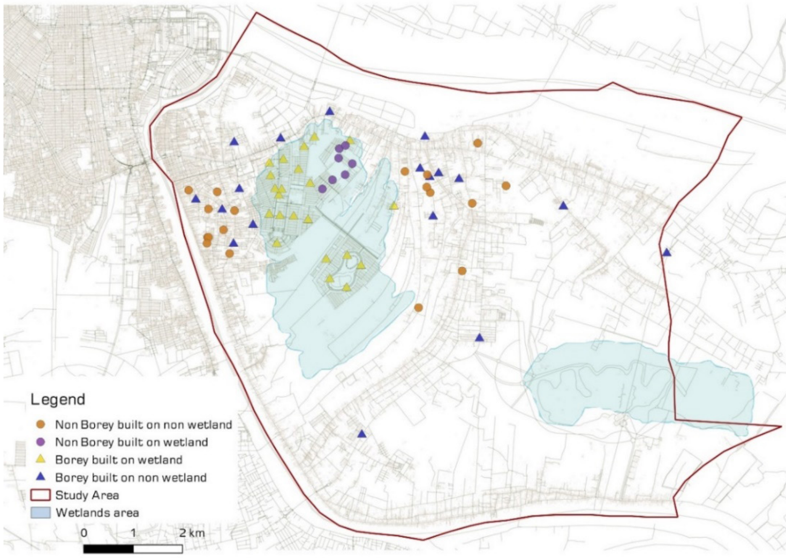

Figure 9. Categories of housing projects in study area
Source: Researcher, 2024

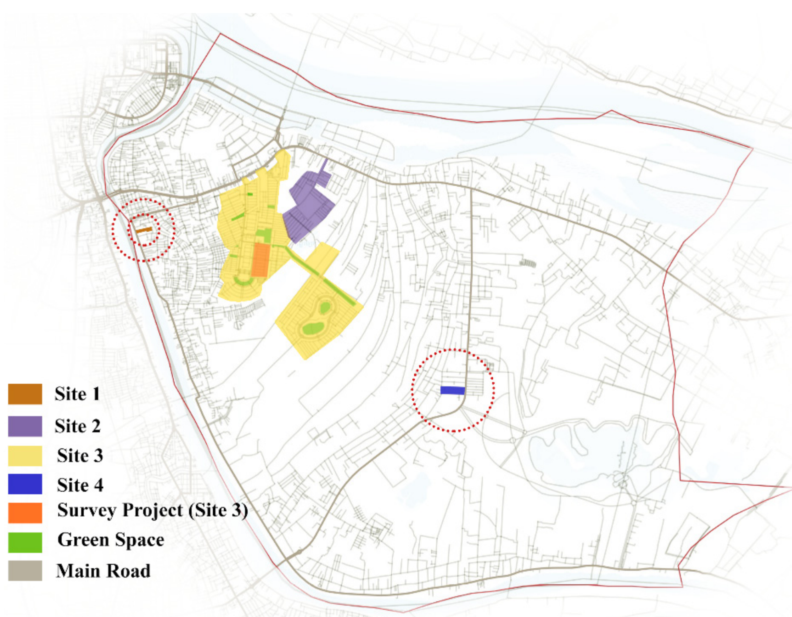

Figure 10. Housing projects selected and presented as site 1,2,3 and 4
Source: Researcher, 2024

This classification forms the analytical framework for assessing variations in spatial layout, drainage infrastructure, and vulnerability to flooding. Among the identified, 29 were built on former wetlands, comprising 22 Borey and 7 non-Borey projects, while remaining 35 projects were situated on non-wetland land, including 18 Borey and 17 non-Borey developments. As shown in Figure 8, Borey developments typically represented by green triangles tend to cluster along major roads and exhibit more organized spatial layouts.

In contrast, non-Borey developments marked as orange circles are more scattered and often located in or near former wetland areas, shaded in blue. This spatial distribution highlights a growing trend of urban encroachment into ecologically sensitive zones, especially by informal and semi-formal housing developments that frequently lack adequate drainage systems or flood protection infrastructure. In Figure 9 illustrates location each category of housing project in study area.

To further examine this pattern, four representative housing developments were purposively selected as case study sites, each corresponding to one of the four typological combinations a non-Borey project on non-wetland land (Site 1), a non-Borey project on former wetland (Site 2), a Borey project on former wetland (Site 3), and a Borey project on non-wetland land (Site 4) in Figure 10 was show each site boundary was selected. Figure 11 present the location of four housing development case study , while red circles indicate projects constructed on former wetlands (Site 2 and 3) and blue circles denote projects location on non-wetland (Site 1 and 4), Base on this figure, site 1 is notably location close to the river, distinguishing it from the other sites. Selection criteria included typological representativeness, visibility of drainage features and flood vulnerability, accessibility for field observation and interviews, and diversity in spatial design and infrastructure quality.

Figure 11. Location of 4 case study,
Source: Researcher, 2024

Site 1. non-Borey on non-Wetland: Site 1, located on non-wetland land, is a high-density, non-Borey development covering approximately 86,319 m^2, with limited infrastructure (Figure 12). It has a high Built-up Coverage Ratio (BCR) 73% and Floor Area Ratio (FAR) 1.6, as shown in Figure 13 the area lacks public green space, and relies on natural land elevation rather than engineered drainage systems.

Field observations revealed an absence of retention systems and predominance of impermeable surfaces. Residents reported short term surface runoff during heavy rain, but no significant flooding. Interviews indicated limited maintenance services and reliance on household level flood response strategies.

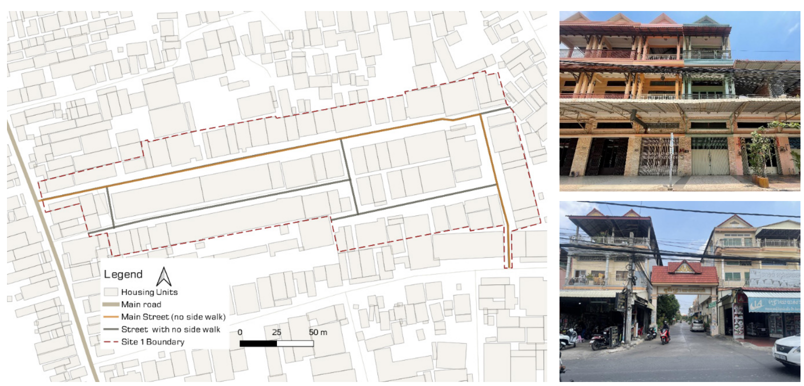

Figure12. Boundary area of site 1 and housing types
Source: Researcher, 2025

Figure13. Road surface and lack of green space for residential
Source: Researcher, 2025

Figure 14. Road surface and kerb of housing projects
Source: Researcher, 2025

Figure 15: Road in housing project.
Source: Researcher, 2025

Figure 16. Green infrastructure of site 3, Drain and side gutter
Source: Researcher, 2025

Site 2. non-Borey on Wetland: This site is the largest and densest of all, with 2,695 units across 453,189 m^2, and is built on former wetland land (Figure 14). The development shows a relatively high Floor Area Ratio (FAR) of 1.37 and Building Coverage Ratio (BCR) of 62%, indicating dense construction with minimal space allocated for environmental infrastructure or public open space. It faces the most severe flooding issues due to minimal green space, heavy use of impervious materials (Figure 15), and informal drainage systems.

Residents experienced floodwater up to 40-50 cm in depth that persisted for over three weeks in the past. Despite some recent improvements, trash blockages and a lack of formal infrastructure continue to cause frequent runoff. The drainage system is poorly designed and inadequately maintained. Community members highlighted the absence of flood emergency protocols.

Site 3. Borey on Wetland: Site 3 is a planned Borey project on former wetland terrain, covering approximately 131,216 m^2 (Figure 16). It features better drainage and more green areas compared to Sites 1 and 2. With a lower BCR 41% and FAR is 1.0, the site includes playgrounds and semi permeable surfaces. Although drainage systems help reduce flooding, they remain prone to leaf blockages. Surface runoff lasts around 5 to 15 minutes during rainstorms (Figure 18). Borey staff confirmed weekly maintenance routines but lacked formal training. Ponds and gardens as shown in Figure 17 are mostly decorative, and the project contributed to substantial wetland loss. Residents were unaware of the drainage functions of green infrastructure.

Figure 17. Pond of site 3
Source: Researcher, 2025

Figure 18. Flooding in site 3
Source: Researcher,2025

Site 4. Borey on non-Wetland: Performing the best among all sites, Site 4 is a Borey development located on non-wetland land and spans approximately 144,380 m^2. It benefits from higher elevation and structured planning. It has moderate FAR 1.36 and BCR 56%, well paved roads, and semi-permeable surfaces. Drainage systems efficiently manage runoff with minimal flooding even during peak rainfall. The project includes decorative green areas that, while aesthetically pleasing, are not designed for stormwater management. Borey staff reported few maintenance issues but also lacked formal knowledge of water sensitive design. This site represents a more effective model of flood resilient development but still lacks ecological water management elements.

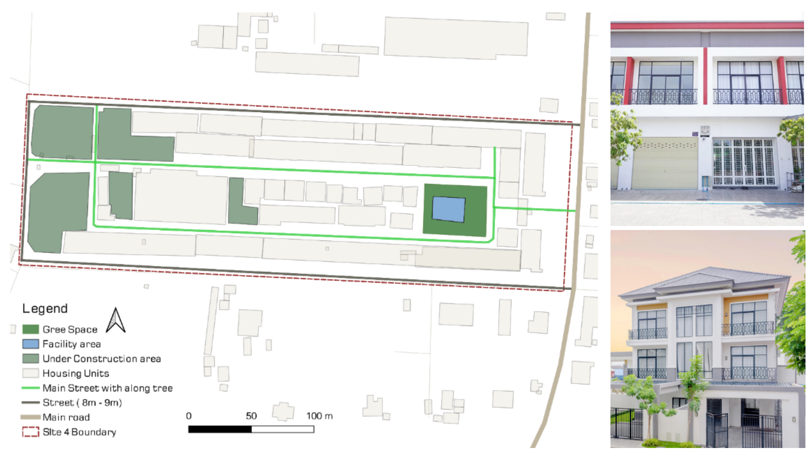

Figure 19. Map of site 2 and housing type
Source: Researcher, 2025

5. Results

Spatial analysis of satellite imagery revealed a dramatic transformation of wetlands in Chbar Ampov District. Between 2003 and 2024, wetland coverage declined from 16.5 km² to 3.05 km², representing an 80% reduction (Figure 20). These boundaries were manually delineated in QGIS using imagery from Maxar Technologies (2003) and CNES/Airbus (2024), with an approximate resolution of 0.5 meters per pixel. Validation against Sahmakum Teang Tnaut's (STT) wetland loss map confirmed the accuracy of this estimate and highlighted the role of residential development as a major driver of wetland conversion. Sites 2 and 3, both located on former wetlands, accounted for nearly half of the observed loss in study area, demonstrating how housing expansion has directly contributed to the erosion of Phnom Penh's natural flood buffer.

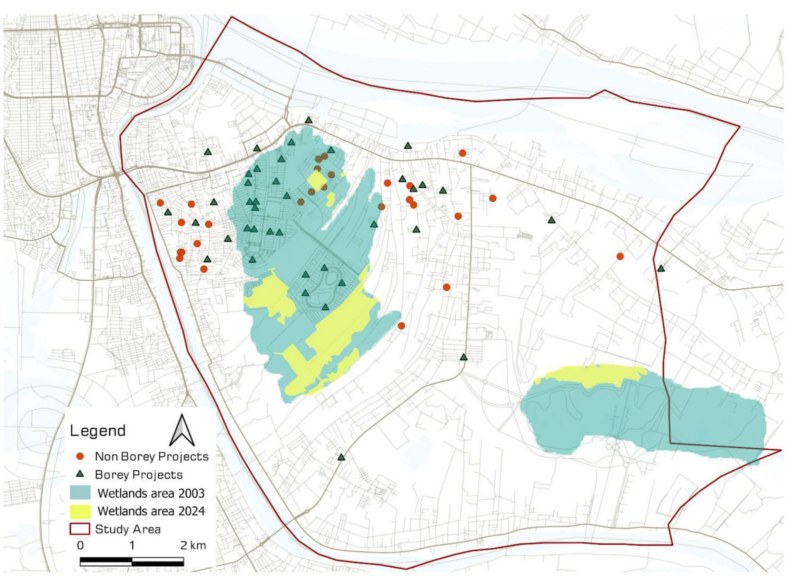

Figure 20. Wetlands loss map
Source: Adapted from STT, 2019 and Google earth pro accessed on (1st, April 2024)

Comparative analysis across the four housing typologies demonstrated that flood vulnerability is shaped by both land history and development type. Site 2, a non-Borey project on former wetland, experienced the most severe flooding. Residents consistently recalled inundations lasting up to three weeks, with floodwater reaching 40-50 cm. One interviewee reported: *"Before, the sewage underground broke, so when it rained, the water stayed for almost a month, and we had to walk through dirty water every day."* Although recent drainage upgrades reduced flood duration, flooding remains seasonal and disruptive. In contrast, Site 3, a Borey project on former wetland, showed shorter flood retention times of 5-15 minutes after rainfall. While residents attributed this to planned drainage and higher elevation, experts noted that 15-20% of land allocated to green space was primarily decorative rather than functional. As one environmental specialist explained, *"Green space in most Borey projects looks nice but is not designed to help with flooding it is mainly for beauty or facilities."*

Sites located on non-wetland land showed markedly different outcomes. Site 4, a Borey development, demonstrated relatively strong flood resilience. Drain cleared water quickly during heavy rainfall, though blockages caused by solid waste were common. Residents frequently described clogged drains, one noting: *"The drain in front of my house is always full of plastic. When it* rains hard, the water has nowhere to go." Site 1, a non-Borey project on non-wetland land, reported no major flooding. Residents attributed this to the site's naturally higher elevation, though the area lacked engineered drainage systems or green infrastructure.

Drainage maintenance emerged as a recurring challenge across all housing types. In non-Borey sites, residents often relied on self-funded measures such as elevating floors and digging private ditches to protect their homes. A participant from Site 2 observed: *"Our housing project built our floor 15 cm higher; otherwise, water would come into the house."* Borey sites exhibited more organized layouts and paved drainage channels, but maintenance remained inadequate, with staff acknowledging limited resources and technical expertise.

Policy and document analysis highlighted a consistent gap between Cambodia's legal requirements and their implementation. National regulations mandate Environmental Impact Assessments (EIAs) and restrict construction on wetlands, yet interviews with officials indicated that these procedures are often bypassed. A Ministry of Environment officer confirmed: *"Some housing projects might bypass the EIA procedure. Developers often fail to build the roads, sewage, drainage, and water systems that they promised, especially in Borey (gated communities)."* Similarly, private consultants stressed that while features such as rain gardens or ponds are promoted in project designs, they are insufficient without integration into broader stormwater management systems. As one expert stated: "Rain gardens can help reduce flood risk, but they require space, proper design, and high maintenance. In high-risk areas, you need stronger structural systems or integrated flood management, not just green landscaping."

In summary, the findings reveal that flood exposure in Phnom Penh is determined by the interaction of land history (wetland versus non-wetland) and development type (Borey versus non-Borey). Wetland-based projects, whether Borey or non-Borey, were consistently the most vulnerable. Borey developments showed advantages in planned infrastructure but often prioritized aesthetics over effective water management. Non-Borey developments lacked systematic drainage, leaving households dependent on individual adaptation. These outcomes underscore the urgent need for stricter enforcement of wetland protection laws, improved maintenance of drainage infrastructure, and the integration of Water Sensitive Urban Design (WSUD) principles into both formal and informal housing projects.

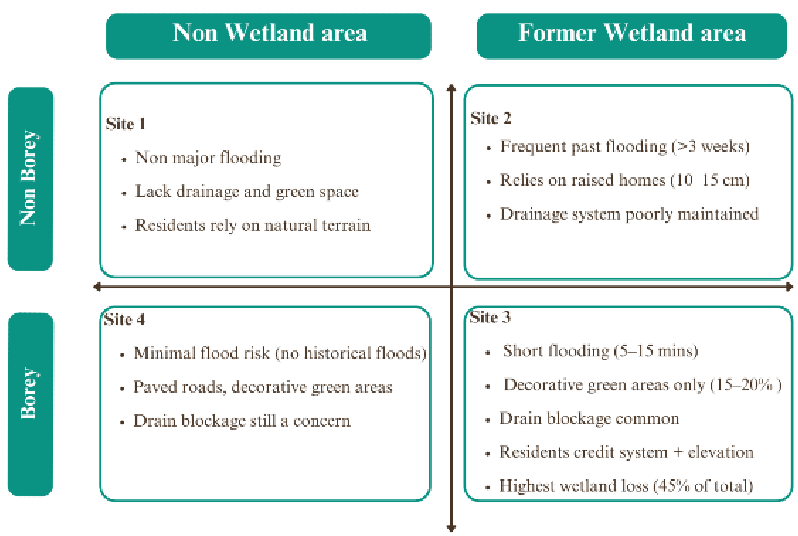

Figure 21. Comparing of water management in housing projects
Source: Researcher, 2025

6. Discussion

This study reveals a critical challenge in Phnom Penh's urban transformation the rapid loss of wetlands and the limited integration of effective water management in both formal and informal housing projects. Spatial analysis demonstrated that approximately 80% of wetlands in Chbar Ampov District were lost between 2003 (16.5 km^2) and 2024 (3.05 km^2). This transformation has intensified flood vulnerability, particularly in areas where wetlands have been replaced by residential developments. While Borey projects appear more organized, with paved roads and landscaped green areas, these features remain primarily decorative and provide little measurable impact on flood reduction. Non-Borey developments, especially those on former wetlands, face severe flood risks due to inadequate drainage and reliance on short-term household-level adaptations, such as elevating floors.

Interviews and field surveys highlighted a consistent pattern of blocked drainage systems across both Borey and non-Borey sites. The prevalence of this issue suggests that the problem extends beyond design weaknesses to broader failures of infrastructure maintenance and institutional coordination. Policy analysis further underscored these governance challenges. Evidence shows that several housing projects bypassed Environmental Impact Assessments (EIAs) or exploited regulatory loopholes.

Despite these shortcomings, lessons from international frameworks provide valuable pathways for adaptation. China's Sponge City initiative demonstrates how Water Sensitive Urban Design (WSUD) elements such as permeable pavements, bioretention basins, and detention ponds can reduce stormwater runoff by 20-30% (Li et al., 2017; Jia et al., 2020). Singapore's Active, Beautiful, Clean Waters (ABC Waters) Programme shows how stormwater management can be integrated with urban amenities, turning functional wetlands and canals into dual-purpose landscapes that store floodwater while enhancing public space (PUB Singapore, 2017). Although Phnom Penh's governance differs markedly from Singapore's centralized model, core WSUD and ABC Waters principles ecological integration, decentralized drainage, and multifunctional landscapes remain highly relevant benchmarks.

Crucially, Phnom Penh must adapt these strategies to its governance realities. Unlike Singapore or China, where state-led, centralized approaches dominate, Phnom Penh requires a more decentralized and participatory model. Evidence from Southeast Asia suggests that community-based wetland conservation, participatory planning, and localized maintenance of drainage networks can complement state policies in fragmented institutional contexts (Chan et al., 2018). Such approaches would also enhance local ownership and accountability, reducing reliance on purely top-down enforcement, which has historically been inconsistent.

7. Conclusion

This study examined water management practices in four housing typologies Borey and non-Borey developments on both wetland and non-wetland land in Phnom Penh's Chbar Ampov District. By integrating spatial analysis, site surveys, and stakeholder interviews, the research demonstrates how rapid urbanization has resulted in the large-scale conversion of wetlands and increased flood exposure. Findings reveal that Borey projects, despite having formal infrastructure, often substitute functional flood management with aesthetic landscaping, while non-Borey settlements remain highly vulnerable due to inadequate drainage and limited investment.

In terms of scholarly contribution, this study extends existing literature on Phnom Penh's urban governance (Beckwith et al., 2020; Marks & Baird, 2025; STT, 2019) by linking land history (wetland vs. non-wetland), development type (Borey vs. non-Borey), and flood vulnerability in a single comparative framework. Previous studies have explored wetland loss or governance issues independently, but this research shows how ecological baselines and housing models interact to shape differential risks. This framing not only clarifies Phnom Penh's unique vulnerabilities but also contributes to broader debates on how international water-sensitive urban models can be adapted in contexts of weak governance and fragmented enforcement.

Policy recommendations are threefold. First, wetlands must be recognized as critical natural infrastructure and integrated into land-use planning strategies. Second, WSUD principles including permeable pavements, rain gardens, and stormwater detention ponds should be mandated for all new developments, with functional requirements clearly specified in building approvals. Third, decentralized nature-based solutions (NbS) should be piloted at both household and community levels, ensuring that solutions are scalable and affordable in-Phnom Penh's financial and governance context. Stronger inter-agency coordination, transparent EIAs, and community participation are essential to achieving these reforms.

Overall, this study highlights how housing development, governance, and ecological conditions jointly shape urban resilience. By embedding WSUD and NbS features into both Borey and non-Borey projects, Phnom Penh can transition from reactive flood management to proactive adaptation. More broadly, the findings illustrate that sustainability models developed in highly centralized or high-income contexts must be recalibrated to fit the realities of rapidly urbanizing cities with fragmented governance structures. In doing so, Phnom Penh has the opportunity to transform wetlands from perceived barriers to development into assets for urban resilience, ensuring that housing growth aligns with long-term climate adaptation and ecological sustainability.

CRediT Authorship Contribution Statement

Khoem Sovanborey: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data curation, Writing - Original draft, Writing - Review & editing, Visualization, Funding acquisition.
Nij Tontisirin: Conceptualization, Methodology, Writing - Review & editing, Supervision, Project administration.

References

Beckwith, L. (2020). *When the lakes are gone: The political ecology of urban resilience in Phnom Penh* [Doctoral's dissertation], University of Ottawa. https://www.researchgate.net/publication/351480407_When_the_Lakes_Are_Gone_The_Political_Ecology_of_Urban_Resilience_in_Phnom_Penh

Chandran, Rina. (2020, July 27). *Phnom Penh residents face increased flooding, displacement and loss of livelihoods as wetlands are filled in*.

Chen, B., & Chui, T. F. M. (2025). A review on implementing sustainable drainage systems in sloping environments: understanding, approaches, and opportunities. *Journal of Hydrology, 661*(Part A), 1-14. https://doi.org/10.1016/j.jhydrol.2025.133577

Cui, M., Ferreira, F., Fung, T. K., & Matos, J. S. (2021). Tale of two cities: How nature-based solutions help create adaptive and resilient urban water management practices in Singapore and Lisbon. *Sustainability, 13*(18), 10427. https://doi.org/10.3390/su131810427

Dietz, M. E. (2007). Low impact development practices: A review of current research and recommendations for future directions. *Water, Air, and Soil Pollution, 186*(1–4), 351–363. https://doi.org/10.1007/s11270-007-9484-z

Doyle, S. E. (2012). City of water: Architecture, urbanism and the floods of Phnom Penh. *Nakhara Journal of Environmental Design and Planning, 151*, 135-154. https://www.academia.edu/2502352/City_of_Water_Architecture_Urbanism_and_the_Floods_of_Phnom_Penh

European Commission. (2020). *EU-Funded Nature-based solutions research projects addressing Societal Challenges across Ecosystems*. https://networknature.eu/sites/default/files/uploads/nn662visualisation.pdf

Fletcher, T. D., Shuster, W., Hunt, W. F., Ashley, R., Butler, D., Arthur, S., Trowsdale, S., Barraud, S., Semadeni-Davies, A., Bertrand-Krajewski, J. L., Mikkelsen, P. S., Rivard, G., Uhl, M., Dagenais, D., & Viklander, M. (2015). SUDS, LID, BMPs, WSUD and more – The evolution and application of terminology surrounding urban drainage. *Urban Water Journal, 12*(7), 525–542. https://doi.org/10.1080/1573062X.2014.916314

Fredriech, I. C. (2022, January 12). Bay Area Economic Circle" starting to form in Phnom Penh. *Realestate.Com.Kh.*

Hails, A. J. (1996). *Wetlands, biodiversity and the Ramsar Convention: The role of the Convention on Wetlands in the conservation and wise use of biodiversity*. Ramsar Convention Bureau. https://www.ramsar.org/sites/default/files/documents/library/wetlands_biodiversity_and_the_ramsar_convention.pdf

Hui, C. X., Dan, G., Alamri, S., & Toghraie, D. (2023). Greening smart cities: An investigation of the integration of urban natural resources and smart city technologies for promoting environmental sustainability. *Sustainable Cities and Society, 99*(2210–6707), 104985. https://doi.org/10.1016/j.scs.2023.104985

Jia, H., Yao, H., & Yu, S. L. (2013). Advances in LID BMPs research and practice for urban runoff control in China. *Frontiers of Environmental Science and Engineering, 7*(5), 709–720. https://doi.org/10.1007/s11783-013-0557-5

Kosal, K. (2018, November 17). *Chbar Ampov: From traditional to modern*. Khmer Times.

Li, H., Ding, L., Ren, M., Li, C., & Wang, H. (2017). Sponge city construction in China: A survey of the challenges and opportunities. *Water, 9*(9). https://doi.org/10.3390/w9090594

Lloyd, S. D. (2001). Water sensitive urban design in the Australian context. *Synthesis of a Conference Held 30-31 August 2000, Melbourne, Australia*. CRC For Catchment Hydrology.

Marks, D., & Baird, I. G. (2025). The urban political ecology of worsening flooding in Phnom Penh, Cambodia: Neopatrimonialism, displacement, and uneven harm. *International Journal of Disaster Risk Reduction, 118*. https://doi.org/10.1016/j.ijdrr.2025.105229

Mialhe, F., Gunnell, Y., Navratil, O., Choi, D., Sovann, C., Lejot, J., Gaudou, B., Se, B., & Landon, N. (2019). Spatial growth of Phnom Penh, Cambodia (1973–2015): Patterns, rates, and socio-ecological consequences. *Land Use Policy, 87*. https://doi.org/10.1016/j.landusepol.2019.104061

Phnom Penh Municipality. (2019). *Phnom Penh, extension et mutations*. Atelier Parisien D'urbanisme. https://www.apur.org

PUB Singapore. (2017). *Active, beautiful, clean waters*. https://www.pub.gov.sg

Sahmakum Teang Tnaut. (2019). *The last lakes*. www.teangtnaut.org

Santos, E. (2025). Nature-based solutions for water management in Europe: What works, what does not, and what's next? *Water, 17*(15), 2193. https://doi.org/10.3390/w17152193

Sharma, S. N., & Ayuba, D. (2024). *Nature based solutions to prevent urban flooding* (1st ed.). Edupedia Publications. https://doi.org/10.5281/zenodo.10651295

Susilo, K., Matasovic, N., & Johnson, R. S. (2009). Considerations, opportunities, and strategies for infiltration stormwater BMPS. *Proceedings of World Environmental and Water Resources Congress 2009 - World Environmental and Water Resources Congress 2009: Great Rivers, 342*, 971–980. https://doi.org/10.1061/41036(342)97

Tochaiwat, K., Kulintonprasert, W., Jiraprasertkun, C., & Yang, C. Y. (2018). Influence of Master Plan Designs on Housing Project Purchase Decisions in Bangkok Metropolitan Areas. *International Journal of Building, Urban, Interior and Landscape Technology, 11*, 43–54. https://ph02.tci-thaijo.org/index.php/BUILT/article/view/167878

United States Environmental Protection Agency New England. (2009). *Incorporating low impact development into municipal stormwater program*s. https://www3.epa.gov/region1/npdes/stormwater/assets/pdfs/IncorporatingLID.pdf

Wong, T. H. (2000). Improving urban stormwater quality-from theory to implementation. *Water-Melbourne Then Artarmon, 27*(6), 28-31.

Wong, T. H. (2001). A changing paradigm in Australian urban stormwater management. *2nd South Pacific Stormwater Conference*, pp. 1-18.

Wong, T. H. (2002). Urban stormwater management and water sensitive urban design in Australia. *Global Solutions for Urban Drainage*, pp. 1-14.

Yin, D., Xu, C., Jia, H., Yang, Y., Sun, C., Wang, Q., & Liu, S. (2022). Sponge city practices in China: from pilot exploration to systemic demonstration. *Water, 14*(10). https://doi.org/10.3390/w14101531

Yin, S., Kikutake, N., Lin, S. X., Johnson, E. C., Baker, J. L., & Ou, N. (2017). *Urban Development In Phnom Penh.* http://documents.worldbank.org/curated/en/286991511862455372/Urban-development-in-Phnom-Penh

Zhang, Y. (2016). Sponge city theory and its application in landscape. *Urban Transportation & Construction, 3*(1), 5. https://doi.org/10.18686/utc.v3i1.2