Assessment of the impacts of urban drainage system failures on pluvial flooding in the Thac Gian-Vinh Trung lake area, Da Nang

Évaluation des impacts des défaillances du système de drainage urbain sur les inondations pluviales dans la zone des lacs Thac Gian-Vinh Trung, à Da Nang

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RÉSUMÉ

Da Nang, la plus grande ville du centre du Vietnam, est régulièrement touchée par des inondations localisées même sous des pluies modérées, en raison des limites structurelles de son système de drainage urbain. Alors que les pays développés disposent de réseaux séparés pour les eaux usées et pluviales, Da Nang, en tant que ville en développement, dépend encore d'un système unitaire. Durant la saison sèche, les mauvaises odeurs provenant des regards poussent les habitants à couvrir les avaloirs, ce qui entrave l'entrée de l'eau lors de pluies soudaines. La chute saisonnière des feuilles et les déchets obstruent également les conduites, favorisant l'accumulation de sédiments et réduisant la capacité hydraulique. Pour analyser ces dysfonctionnements, cette étude utilise un modèle intégré 1D-2D afin de simuler l'hydraulique du réseau d'égouts et l'inondation en surface dans la zone des lacs Thac Gian-Vinh Trung. Plusieurs scénarios de défaillance, tels que le blocage des avaloirs et la réduction de la capacité des conduites, sont évalués sous des événements pluviométriques réels. Les résultats révèlent des points critiques du réseau et fournissent des éléments scientifiques pour améliorer la gestion des eaux pluviales et réduire les risques d'inondation à Da Nang.

ABSTRACT

Da Nang, the largest city in central Viet Nam, frequently experiences localized flooding even under moderate rainfall due to inherent limitations in its urban drainage system. While developed countries employ separate sewer networks for wastewater and stormwater, Da Nang, as a developing city, still relies on a combined system. During the dry season, foul odors rising from manholes lead residents to cover street inlets with boards or plastic sheets, inadvertently blocking flow paths when sudden rainfall occurs. Seasonal leaf fall and improper waste disposal further clog inlets and underground conduits, creating debris and sediment accumulation that reduces hydraulic capacity. To investigate these operational malfunctions, this study applies an integrated 1D-2D model to simulate sewer hydraulics and surface inundation in the Thac Gian-Vinh Trung lake area. Multiple malfunction scenarios, including inlet blockage and reduced conduit capacity, are examined alongside real rainfall events. The results reveal critical system bottlenecks and provide scientific evidence to support targeted improvements in stormwater management and urban flood-mitigation planning for Da Nang.

KEYWORDS

Coupled 1D/2D modelling, extreme rainfall, drainage malfunction, storm water management, urban flooding.

1 INTRODUCTION

Urban drainage systems in rapidly growing cities are increasingly stressed, as rapid urbanization, insufficient maintenance and outdated combined sewers reduce their ability to manage stormwater effectively. In Viet Nam, these pressures are particularly evident in Da Nang, where even moderate rainfall can cause flooding due to limited conveyance capacity and the continued expansion of impervious surfaces.

The Thac Gian-Vinh Trung lake area is among the most flood-prone zones in the city. Interactions between limited lake storage, restricted conduit capacity and rapid catchment inflows create conditions where localized flooding frequently occurs. Field observations have shown recurring inlet obstruction **(Fig. 1)** and sediment buildup, indicating that both structural and operational factors contribute to reduced system performance.

Fig. 1. Daily conditions in the Thac Gian-Vinh Trung area: (a) dry-season conditions extracted from Google Earth, (b) localized flooding during heavy rainfall (photo by Anh Tuan Dang, December 9, 2018) and (c) a street inlet covered by boards to block sewer odors (photo captured by researchers, November 27, 2025)

Although numerous reports and discussions have mentioned this issue, there is still no scientific study that provides quantitative evidence or a detailed technical assessment. Consequently, it is unknown which measures are most effective to decrease the flood risk. Existing hydrodynamic analyses and multi-dimensional datasets remain insufficient to clarify the underlying causes of flooding in the Thac Gian-Vinh Trung lake area. To address this gap, the present study employs the PCSWMM software with a coupled 1D/2D modeling approach to more accurately evaluate sewer hydraulics and surface inundation.

2 METHODOLOGY

2.1 Case study

The study focuses on a 0.86 km² urban basin surrounding Thac Gian Lake, Vinh Trung Lake and March 29 Park Lake, where detailed 1D/2D hydraulic simulations are conducted. Downstream of this area, the drainage system conveys flows through an additional 7.21 km² corridor extending from the lakes to the outfall at Da Nang Bay. This downstream zone plays a critical role in regulating discharge and influences the overall hydraulic response of the system during storm events.

Fig. 2. Overview map of the Thac Gian-Vinh Trung lake area.

2.2 Model approach & Scenarios for modelling

A coupled 1D/2D dual-drainage model was developed in PCSWMM to simulate sewer hydraulics and surface inundation in the Thac Gian-Vinh Trung Lake area **(Fig 2)**. Runoff was generated from subcatchments based on land-use, slope and imperviousness. Impervious surface percentages for each subcatchment were derived from Sentinel-2 satellite imagery using spectral indices (NDVI, NDBI, MNDWI), which were processed to classify built-up areas and calculate impervious surfaces. These values were incorporated into the hydrological layer to improve runoff estimation.

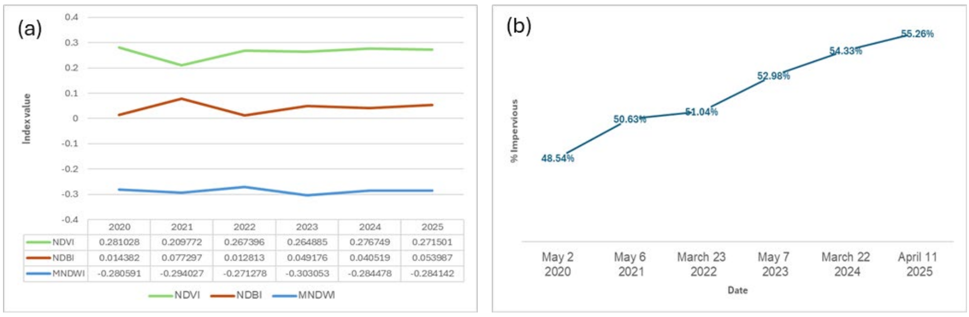

Fig. 3. Temporal variation of (a) remote sensing indices and (b) impervious surface extent in the central urban district of Da Nang.

The 2D surface domain was constructed using a 1 × 1 m Digital Elevation Model (DEM), with buildings treated as impermeable blocks. Surface flow between cells was solved using the dynamic-wave Saint-Venant equations. The 1D network represents the combined sewer system, including conduits, manholes, junctions and lake outlets. The 1D and 2D domains were linked bidirectionally at inlets and manholes to allow water exchange based on local water-level differences.

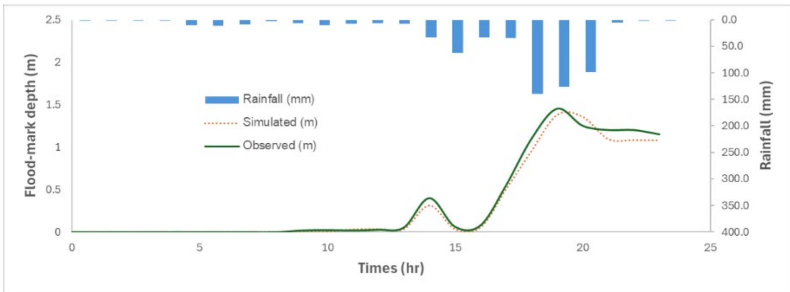

Fig. 4. Comparison of simulated and observed results during calibration.

Model calibration was performed using flood-mark observations collected during the extreme rainfall event of October 14-15 2022 (612 mm/24 hr) **(Fig. 4),** while validation was carried out using flood evidence from multiple storm events, including October 13-14 2023 (516 mm/24 hr), October 21-22 2024 (138.0 mm/24hr) and June 11-12 2025 (503.0 mm/24hr). Although the base case assumes an idealized, malfunction-free drainage system for reference, field inspections indicate that the actual system in Da Nang already experiences inlet obstruction and sediment accumulation. Therefore, the calibration was conducted under the assumption of an initial malfunction level of approximately 20% to better reflect real operating conditions. Under this assumption, the simulated water levels and inundation extents showed much closer agreement with observed flood marks, demonstrating that incorporating realistic malfunction levels yields a more plausible representation of the drainage system. The calibrated model therefore provides a robust and credible foundation for subsequent malfunction scenario simulations.

Table 1. Summary of malfunction scenarios used in the model

Scenario Group	Scenario Level	Description	PCSWMM Adjustment
Inlet clogging	25%, 50%, 90%	Inlets partially or fully blocked by boards, leaves, or debris	Inlet capture efficiency × {0.75, 0.50, 0.1}
Inlet flow restriction	75%, 50%, 25%	Reduced stormwater intake due to partial obstruction or inlet covering	Inlet maximum flow × {0.75, 0.50, 0.25}

Scenario Group	Scenario Level	Description	PCSWMM Adjustment
Sediment filling in circular side sewers	Light, Moderate, Severe	Sediment accumulation reducing effective conduit cross-section	Conduit geometry × {0.75, 0.50, 0.25}

3 KEY RESULTS & CONCLUSION

Simulation results show that the malfunction scenarios lead to varying levels of flooding across the Thac Gian-Vinh Trung area. Inlet clogging increases the extent of inundation, particularly when the degree of blockage becomes severe. Flow restrictions in the sewer conduits also elevate water depths, especially when the effective pipe diameter is reduced by half. Sediment filling in the circular side sewers causes additional changes in hydraulic behavior and affects several downstream locations during intense rainfall events as well. These results indicate that various types of malfunctions can influence localized flooding, depending on their severity and where they occur in the drainage system.

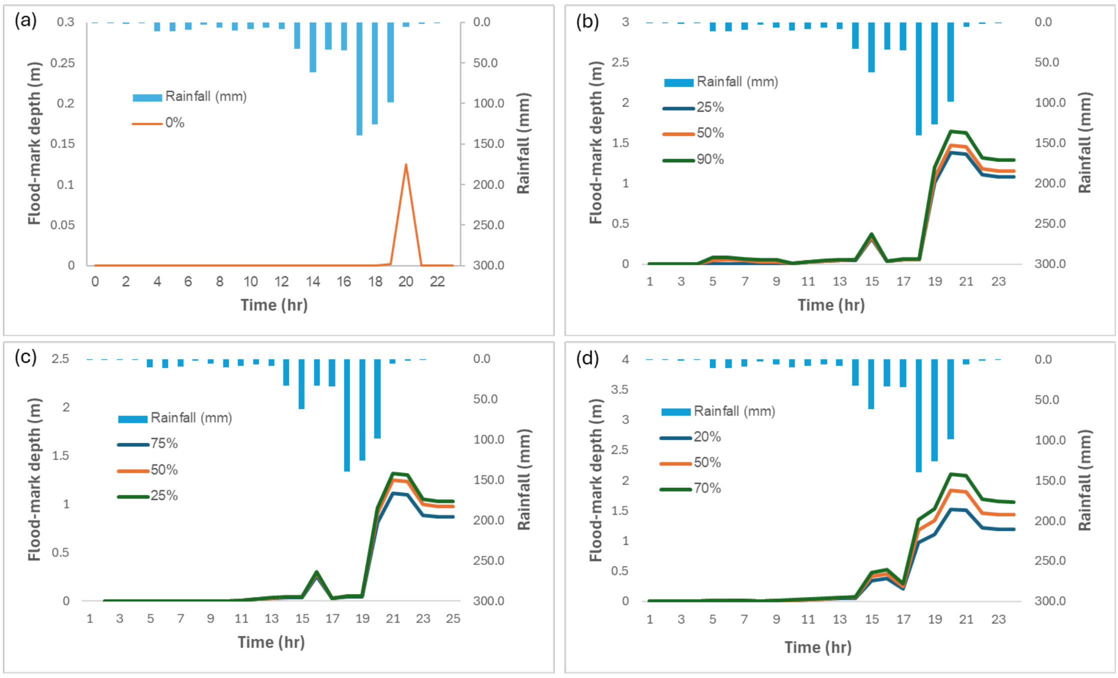

Fig. 5. Variation in maximum surface water depth under: (a) without malfunctions, (b) inlet clogging, (c) inlet flow restriction and (d) sediment filling scenarios.

This study shows that drainage malfunctions, including inlet clogging, conduit flow restriction and sediment accumulation in side sewers, significantly contribute to localized flooding within the Thac Gian-Vinh Trung basin. Although anti-odor sewer valves may reduce the need for residents to cover street inlets during the dry season, their effectiveness is limited when side sewers are obstructed or overloaded. In such cases, backwater pressure keeps the valve closed, preventing stormwater from entering the system and consequently contributing to surface flooding. The results underscore the importance of integrating inlet design improvements with enhanced sewer capacity to strengthen pluvial flood resilience in Da Nang. Moreover, this study provides scientific evidence that can support urban planners and drainage engineers in redesigning and upgrading stormwater collection systems for more effective and sustainable urban drainage management.

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