# Representing real storm impacts: evaluating actual versus IDF-derived design storms in urban drainage modeling

## Représentation des impacts réels des tempêtes : évaluation des tempêtes réelles par rapport aux tempêtes de conception dérivées de l'IDF dans la modélisation du drainage urbain

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## RÉSUMÉ

Cette étude évalue la capacité des orages de projet basés sur le modèle IDF à représenter les impacts hydrologiques et qualitatifs des orages réels de périodes de retour équivalentes. À partir d'un enregistrement pluviométrique de 44 ans, les orages réels correspondant à différentes périodes de retour ont été identifiés grâce à la distribution de Weibull et comparés à trois configurations d'orages dérivés du modèle IDF : (i) orages standardisés sur 24 heures, (ii) orages de durée fixe utilisant la hauteur de pluie IDF et (iii) orages de profondeur fixe utilisant la durée basée sur le modèle IDF. Les réponses aux orages ont été évaluées dans le logiciel SWMM à l'aide de trois indicateurs de performance basés sur des seuils : la hauteur d'inondation des rues, la contrainte de cisaillement à l'exutoire et la concentration en MES. Les résultats montrent que les orages de durée fixe reproduisent le plus fidèlement les durées de dépassement observées lors des orages réels pour les inondations et la contrainte de cisaillement. Les orages de profondeur fixe correspondent mieux au comportement réel de dépassement des seuils de MES, tandis que les orages standardisés sur 24 heures, en raison de leur profil d'intensité plus régulier, produisent des estimations de dépassement plus prudentes et plus faibles pour tous les indicateurs. Bien qu'aucune configuration basée sur l'IDF ne reproduise entièrement la réponse du système aux tempêtes réelles, les tempêtes à durée fixe ont fourni l'approximation la plus cohérente sur l'ensemble des indicateurs, tandis que la tempête de 24 heures a servi d'option conservatrice et conforme à la réglementation pour la conception préliminaire.

## ABSTRACT

This study evaluates how well IDF-based design storms represent the hydrologic and water-quality impacts produced by actual storm events of equivalent return periods. Using a 44-year rainfall record, actual storms corresponding to different return periods were identified using the Weibull distribution and compared against three IDF-derived storm configurations: (i) 24-hour standardized storms, (ii) fixed-duration storms using IDF rainfall depth, and (iii) fixed-depth storms using IDF-based duration. Storm responses were assessed in SWMM using three threshold-based performance metrics: street flooding depth, shear stress at the outlet and TSS concentration. Results show that fixed-duration storms most closely reproduce the exceedance durations observed during actual storms for flooding and shear stress. Fixed-depth storms better matched actual TSS exceedance behavior, whereas the 24-hour standardized storms, because of their smoother intensity pattern, produced more cautious and lower exceedance estimates across indicators. Although no single IDF-based configuration fully replicated the system response of actual storms, the fixed-duration storms provided the most consistent approximation across metrics, while the 24-hour storm served as a conservative, regulation-friendly option for preliminary design.

## KEYWORDS

Actual storm, Design storm, Urban drainage, Stormwater, Water Quality

## 1 INTRODUCTION

Urban drainage systems are commonly designed using synthetic storms derived from Intensity–Duration–Frequency (IDF) relationships, which translate statistical rainfall characteristics into simplified design inputs for infrastructure sizing and regulatory compliance (Chow et al., 1988; Adams & Papa, 2000). These design storms offer practical advantages, yet their ability to reproduce the temporal variability, peak intensities, and multi-peak structure of real storm events remains limited (Mailhot & Duchesne, 2010). As cities become increasingly vulnerable to intense rainfall, rapid runoff generation, and pollutant wash-off, the shortcomings of idealized design storms may lead to misrepresentation of actual system performance during critical events (Schmitt et al., 2004). Nonetheless, IDF-based design storms remain widely used because of their simplicity and long-standing acceptance in engineering practice (Grimaldi et al. 2012).

There is therefore a need for a more systematic evaluation of how well synthetic design storms reflect the hydrologic and water-quality impacts produced by real rainfall events. The challenge extends beyond reproducing peak flows to determining whether synthetic storms accurately represent threshold-based exceedance behavior -such as street flooding depth, erosive shear stress, and TSS concentration- that governs system performance and regulatory outcomes.

The objectives of this study are twofold: (1) to quantify how closely different IDF-based design storms reproduce the exceedance behavior of actual long-term storms, and (2) to identify which storm configuration offers the most representative and practical basis for urban drainage assessment.

Through this comparison, the study clarifies the strengths and limitations of existing design practices and demonstrates the importance of temporal alignment with real storm duration for realistic drainage system performance evaluation. These findings support more robust storm selection for preliminary design, regulatory assessment, and detailed operational analysis.

## 2 METHODOLOGY

This study compares actual storm events extracted from 44 years of continuous rainfall data with three IDF-derived storm configurations commonly used in practice: (i) standardized 24-hour storms, (ii) fixed-duration storms using IDF rainfall depths, and (iii) fixed-depth storms using IDF-derived durations. The evaluation is performed for five major streets in the San Eugenio neighborhood of Santiago, Chile. The description of the study area can be found in Cerda et al. (2025). Using SWMM, each storm type is evaluated across three key performance indicators representing street flooding, stream stability and water quality.

### 2.1 IDF based design storm

IDF curves for the study area were used to derive design storms of 2-, 5-, 10-, 25- and 50-year return period. Also, actual storm events of 2-, 5-, 10-, 25- and 50-year return period -based on their total magnitudes- were obtained from the long-term rainfall records of 44 years using Weibull distribution. Three storm configurations were developed:

(i) 24-hour storm: Standardized 24-hour storms were developed for the same return periods for broader comparison (A1).

(ii) Actual storm: Actual Storms obtained from long-term rainfall data (A2)

(iii) Fixed duration - The storm duration matched the actual event, while rainfall depth was obtained from the IDF curve (A3).

(iv) Fixed depth- The total rainfall depth was set equal to the corresponding actual event, and storm duration was determined from the IDF relationship (A4).

Thereafter, the hyetographs were prepared using the Alternate Block Method (Osheen et al. 2023). These synthetic storms were used to assess how well idealized design events capture the hydrologic and water quality responses produced by actual long-term storms.

### 2.2 Performance metrics and analysis

Three key parameters were analyzed to evaluate system performance:

- Street flooding depth, with a critical threshold of 0.04 m, i.e. 1 m of flow width in typical streets' gutter (MOP 2013, Cerda et al. 2025).
- Shear stress at the outlet, compared against stability threshold values of 0.194 and 5.7 Pa (Pomeroy,

2007).

- Total Suspended Solids (TSS) concentration, compared against threshold values of 80 mg/l & 300 mg/l (Ministerio Secretaría General de la Presidencia, 2000).

## 3 RESULTS

The efficacy of IDF-based design storms in replicating the hydrologic and water quality impacts of actual storm events was evaluated by the three key performance metrics previously depicted. The analysis contrasted actual storms (A2) of 2-, 5-, 10-, 25-, and 50-year return periods (asigned based on events' magnitude) against three types of synthetically derived storms: 24-hour standard (A1), fixed duration (A3), and fixed depth (A4).

### 3.1 Flooding Depth Exceedance

For the street flooding depth analysis, five representative conduits with the highest flow capacities (C76, C80, C44, C32, and C26) within the drainage network were selected. Across the five representative conduits, fixed-duration storms (A3) showed the closest agreement with actual storms, successfully reproducing both the magnitude and the increasing trend of flooding duration with return period (Fig. 3.1). The 24-hour storms (A1) consistently underestimated exceedance due to their smoother intensity distribution, while fixed-depth storms (A4) tended to slightly overestimate flooding at higher return periods. These results highlight the importance of matching storm duration to capture realistic surface flooding dynamics.

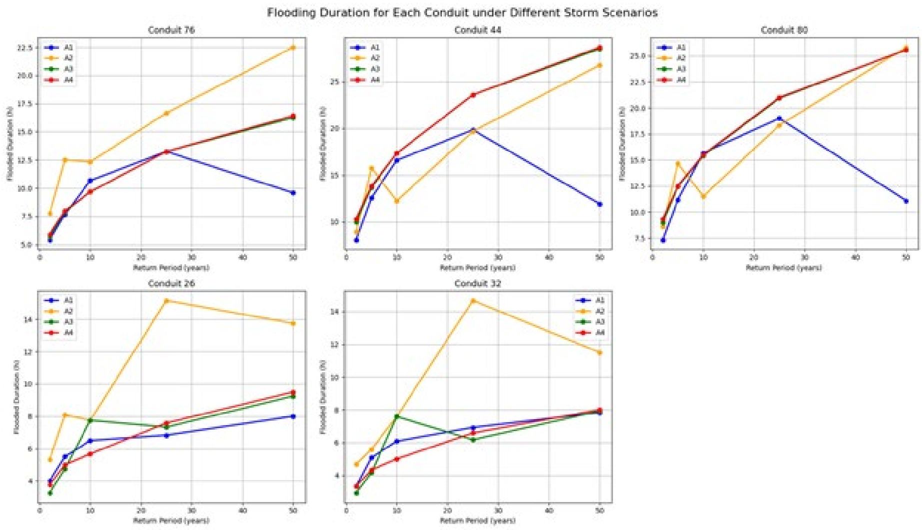


Figure 3.1 Flooding duration exceeding the critical depth for five representative conduits (C76, C80, C44, C26, and C32) under actual (A2) and IDF-based storm scenarios

### 3.2 Shear Stress Exceedance

At both critical shear thresholds (0.194 Pa and 5.7 Pa), fixed-duration storms (A3) most accurately reproduced the exceedance durations of actual events (Fig. 3.2). A4 provided reasonable but slightly lower estimates for higher return periods, whereas A1 systematically underpredicted shear exceedance across all return periods. This again reflects the inability of 24-hour storms to generate short-duration intensity peaks necessary to produce erosive conditions.

### 3.3 TSS Exceedance

For TSS thresholds (80 mg/L and 300 mg/L), fixed-depth storms (A4) offered the closest approximation to actual storm behavior, particularly for intermediate and high return periods. A3 captured the overall trend but underestimated exceedance for smaller events (Fig. 3.3). The 24-hour storms (A1) produced negligible TSS exceedance across all return periods, indicating insufficient intensity to mobilize pollutants. Although A3 and A4 more closely reflected actual storm responses for individual metrics, the A1 configuration still provides a consistent, conservative basis for preliminary design where regulatory compatibility and safety margins are prioritized.

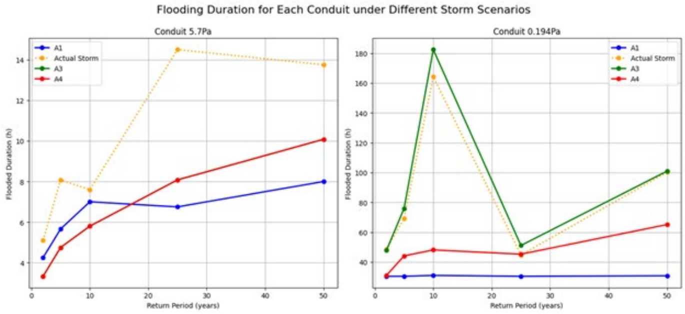

Figure 3.2 Duration of shear stress exceedance with critical thresholds of 5.7 Pa and 0.194 Pa under different storm scenarios.

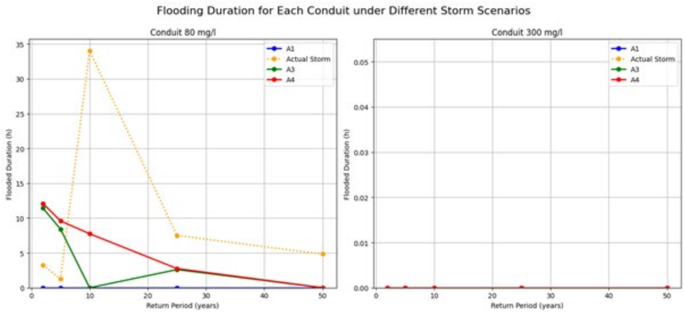

Figure 3.3 Duration of TSS concentration exceeding 80 mg/L and 300mg/L under actual (A2) and IDF-based

## 4 CONCLUSIONS

This study demonstrates that while fixed-duration and fixed-depth storms more closely represent the hydrologic and water-quality responses of actual long-term events, each IDF-based configuration offers distinct advantages depending on the performance metric of interest. Fixed-duration storms provided the most reliable overall approximation of real exceedance behavior, and fixed-depth storms captured pollutant mobilization more effectively. The 24-hour standardized storm, though yielding more conservative exceedance estimates due to its smoother intensity distribution, remains a valuable option for regulatory compatibility and preliminary design. Together, these insights highlight the importance of selecting storm configurations that balance realism, practicality, and design objectives.

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