26th International Congress on Modelling and Simulation, Adelaide, SA, Australia, 30 Nov–4 Dec 2025
mssanz.org.au/modsim2025

Session G06 – Invited speaker

Urbanisation and climate variability impacts on hydrological and geomorphological changes: Implications for flood risk

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ABSTRACT: Urban expansion is one of the most significant anthropogenic pressures on riverine systems worldwide. The conversion of natural landscapes to built-up infrastructure fundamentally alters natural hydrological processes, leading to increased surface runoff and a reduction in both infiltration and retention capacity. Simultaneously, climate variability introduces significant uncertainties in precipitation and temperature regimes, further complicating how a catchment responds to storm events. These dual pressures collectively accelerate erosion, increase sediment loads, and heighten flood risks, making the intricate interplay between land use, hydroclimatic trends, and geomorphological responses a crucial area of study for water resources management and disaster risk reduction. This study investigates the synergistic impacts of urbanisation and climate variability on hydrological responses and channel morphology in the Dry Creek catchment, South Australia.

The Dry Creek catchment in northern metropolitan Adelaide, South Australia, provides a compelling case study for these combined impacts, as it has experienced rapid urbanisation since the 1970s and is prone to seasonal flooding. Despite these recognized challenges, a comprehensive and integrated assessment of the long-term effects of land use changes, hydroclimatic patterns, and resulting geomorphological responses has been notably absent. This study addresses this critical knowledge gap by providing an integrated analysis of Dry Creek's hydrological and geomorphological responses to urbanisation and climate variability, leveraging a novel methodology that synthesizes high-resolution remote sensing data, LiDAR-derived topography, and hydroclimatic time series.

The study employed an integrated spatio-temporal framework to assess the impacts of urbanisation and climate variability on hydrological and geomorphological characteristics of Dry Creek. To monitor changes over time, land use and land cover (LULC) were classified using a Support Vector Machine (SVM) algorithm on a combination of high-resolution aerial imagery from 1979 and 2019, SPOT data from 2006. The hydrological impact of these changes was then quantified by calculating alterations in the runoff coefficient, curve number, and retention capacity of the catchment. For the hydroclimatic analysis, trends in daily rainfall and temperature from the Bureau of Meteorology (BoM), along with streamflow records from Water Data Services (WDS), were analysed using a combination of statistical methods, including Trend-free pre-whitening Mann-Kendall (TFPW-MK), Simple Linear Regression (SLR), and the Innovative Trend Analysis (ITA). The study also performed change point detection to assess data homogeneity and used the coefficient of variation and precipitation concentration index to quantify variability. For the geomorphological assessment, high-resolution imagery and LiDAR-derived Digital Elevation Models (DEMs) from 2018 and 2022 were the primary data sources for monitoring changes in the creek's physical form. This allowed for the investigation of both planform and vertical changes, such as channel migration, deposition, and erosion.

Between 1979 and 2019, the Dry Creek catchment underwent a substantial transformation due to urbanisation. The study found that the built-up area expanded by 34 km^2, representing a 136.6% increase, primarily by replacing 43.1 km^2 of grasslands. This transformation significantly altered the catchment's hydrological character. The increase in impervious surfaces led to a 60.6% rise in both the runoff coefficient and the equivalent impervious area (EIA). The weighted Curve Number also rose from 80.9 to 87.4, a 7.9% increase. These changes caused the catchment's retention capacity to fall by 38.6%, from 59.8 mm to 36.8 mm, indicating a substantial increase in surface runoff and a heightened flood risk.

Hydroclimatic analysis revealed significant trends and variability. All three analytical methods indicated a statistically significant upward trend in mean and maximum temperatures, with the most pronounced increase observed in spring. Annually, the average mean and maximum temperatures rose by 0.02°C/year and 0.04°C/year, respectively. The mean daily temperature increased by 0.23°C per decade over the study period, a trend driven by both global warming and the Urban Heat Island (UHI) effect. While rainfall patterns showed high variability, analysis with the ITA method identified a decreasing trend in annual flow volume at both studied gauging stations. This complexity is reflected in hydrological variability, with streamflow exhibiting higher temporal variability, increased flashiness, and an increase in zero-flow days. Streamflow also showed a notable decline of 172 ML/year at the Bridge Road station, highlighting the compounding effects of reduced rainfall and increased imperviousness on baseflow.

The geomorphological assessment revealed that the urbanisation and hydroclimatic changes had a profound impact on the creek's physical form. Channel planform changes included a downstream migration of up to 478 meters and an increase in sinuosity from 1.08 to 1.22. Additionally, the channel experienced significant widening, with an average increase of 40 meters observed in the downstream case study reach. The study also quantified extensive sediment deposition, or aggradation, in the lower reaches. Between 2018 and 2022, a mean net deposition depth of 3.5 cm was estimated. This sediment buildup, exacerbated by increased riparian vegetation, reduced the channel's conveyance capacity and heightened flood vulnerability. The findings of this research serve as a valuable case study, offering a robust framework for understanding the complex interactions between urban development and hydro-meteorological hazards. Our findings provide direct and actionable knowledge for policymakers and land managers. We recommend prioritizing a 1D/2D flood modelling study to assess the combined effects of channel modifications and infilling on downstream flood dynamics. Proactive, regular maintenance, such as desilting identified sediment hotspots, is crucial for maintaining channel capacity. Additionally, we advocate for enhancing the hydrological monitoring network and promoting nature-based solutions like green infrastructure to increase infiltration and mitigate the urban heat island effect, ensuring the long-term health and resilience of the Dry Creek catchment.

Key words: *Dry Creek; Climate Variability; Flood Resilience; Hydrological and Geomorphological Responses; Urbanisation*

