Hydrological Investigation of the Catastrophic Flood Event in Mandra, Western Attica

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INTRODUCTION

On 14-15/11/2017, a flash flood occurred in Western Attica (west of Athens, Greece) causing 24 fatalities and substantial damages in the city of Mandra. The storm causing the flooding was intense, but its spatio-temporal characteristics are unknown. A debate ensued on whether the devastating results were due to an extreme rainfall or due to poor flood protection works.

The study reported here contributes to resolving this question (1) by presenting information gathered from several sources, including hydrometric data from the neighboring basin of Sarantapotamos, point rainfall data from the wider area of interest, estimates of areal rainfall based on satellite images and a meteorological radar, and audiovisual material, and (2) by attempting to unravel the flood event via reverse rainfall-runoff modelling; further, it analyzes the available data to approximately estimate the return period of the storm event.

1. The mysterious storm

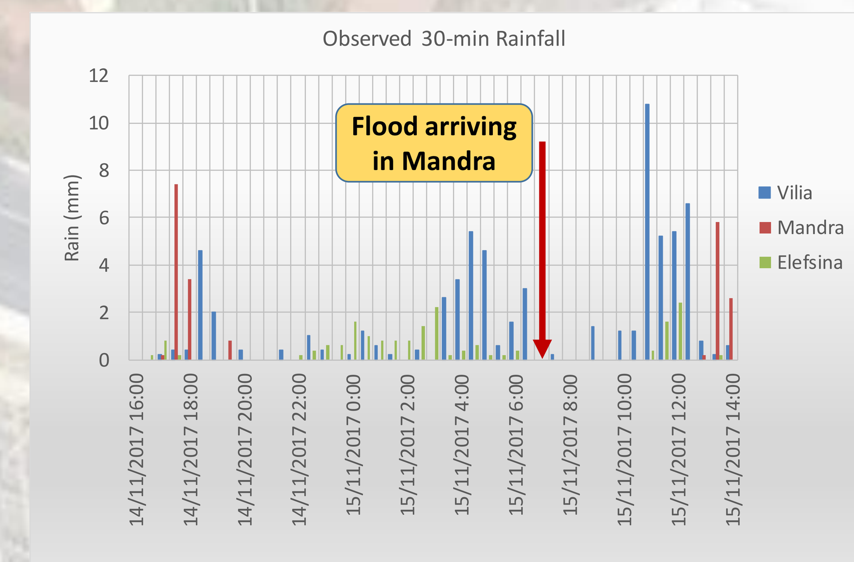
Mandra is a small industrial city, located 40 km west of Athens, that has significantly grown during the last years. The city is crossed by two small ephemeral streams (Soures, Agia Aikaterini) draining an area of 75 km^2.

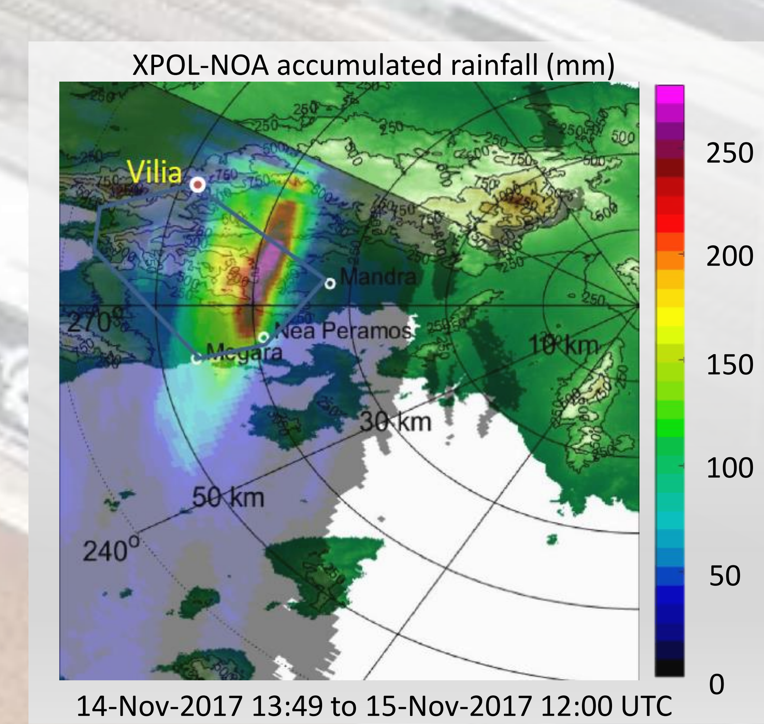
At around 7:00 am on November 15th, a large and fast-moving flood wave, carrying heavy sediment loads, arrived in Mandra. At that time, and for several hours earlier, the weather around the city area was quite clear. Taking this into account, as well as the small extent of the catchment upstream of Mandra, it becomes apparent that the flood event was due to an unusual storm, of extreme intensity yet very local scale.

This assumption is supported by the observed rainfall at the meteorological stations in Mandra, Elefsina and Vilia, all located in the wider area around Mandra, but outside of the two catchments of interest, Soures and Agia Aikaterini. Nevertheless, the volume of the observed rainfall in those stations is not significant enough to explain such a severe flooding.

The mysterious rainfall event can be better understood with the help of the (approximate yet indicative) rainfall information recorded by an X-band weather radar, which shows an elongated and narrow core of the storm passing outside the area covered by the three stations.

The rainfall pattern estimated based on the radar data agrees with reports by residents in the catchment upstream of Mandra. According to these reports, an intense storm started in the early hours of November 15th and continued during the night. The soil got likely saturated, resulting in a significant flash flood.





Observed rainfall at three meteorological stations (up) and image from the weather radar (down)

2. The neighboring catchment and its valuable information

We study the catchment of Sarantapotamos, the largest stream in the region. It is a narrow basin north of Mandra, stretching from East to West with slopes ranging from 10% to 30%, and in some areas up to 100% or even higher; the basin is also characterized by great water permeability, due to the karst nature of the limestone in the region.

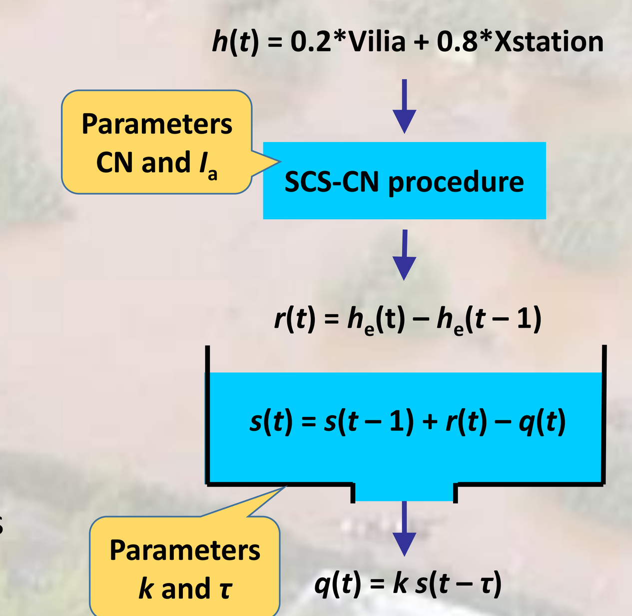
We gathered data from a hydrometric station installed in a culvert near Gyra Stefanis and point rainfall data in Vilia. However, due to the extreme flows, the water rose rapidly to ~0.5 m from the stage-gauging sensor (the sensor's measuring limit), and then overtopped the bridge above the culvert, also destroying the instrument's assembly; thus, the collected data do not cover the entire flood range. Due to the fact that such a flash flood could not be justified by the rainfall observed in Vilia, it prompted us to investigate it further.

3. Rainfall estimation through inverse hydrological modelling

- **Problem statement**: Estimation of rainfall from Nov. 14 10:00 am to Nov. 15 10:00 am, resolved in 30-min intervals (48 values), at a hypothetical X-station, located in the part of Sarantapotamos basin that has been considerably affected by the storm event.
- **Key assumption**: The point rainfall at X-station controls 80% of the runoff of Sarantapotamos basin, upstream of Gyra Stefanis; the remaining runoff is controlled by the point rainfall at Vilia station, thus the areal rainfall is 0.8*Xrain + 0.2*ViliaRain.
- **Methodology**: Inverse calibration against the observed hydrograph at Gyra Stefanis station and a simple event-based hydrological model, comprising two components:
  - the SCS-CN relationship for extracting the effective, $h_e(t)$, from the total rainfall, $h(t)$, using two parameters, the curve number, CN, and the initial abstraction, I_a.
  - a lag-and-route model for propagating the generated runoff, r(t), to the basin outlet, q(t), with parameters a recession coefficient k and a lag time τ.
- **Hydrological scenarios**: Model runs with two parameter sets; for both scenarios we set CN = 60, as estimated from flood-event analyses during 2012-2014.
- **Calibration assumptions**: Fitting to measured flow data (until Nov. 15 9:00 am, Q_{max} = 50 m^3/s), generation of flows quite larger than the capacity of the culvert (~100 m^3/s) during the morning hours of Nov. 15 (thus taking advantage of the **known overflow of the bridge**, which is key information).
- **Probabilistic analysis**: Use of a given idf relationship (ombrian curve) from the station in Elefsina, to estimate the return period, T, of the two point rainfall scenarios at the X-station, for temporal scales (durations, d) from 0.5 to 24 hours; its analytical expression is:

$$i = 213.4\,(T^{0.125} - 0.641)\,/\,(1 + d/0.124)^{0.622}$$

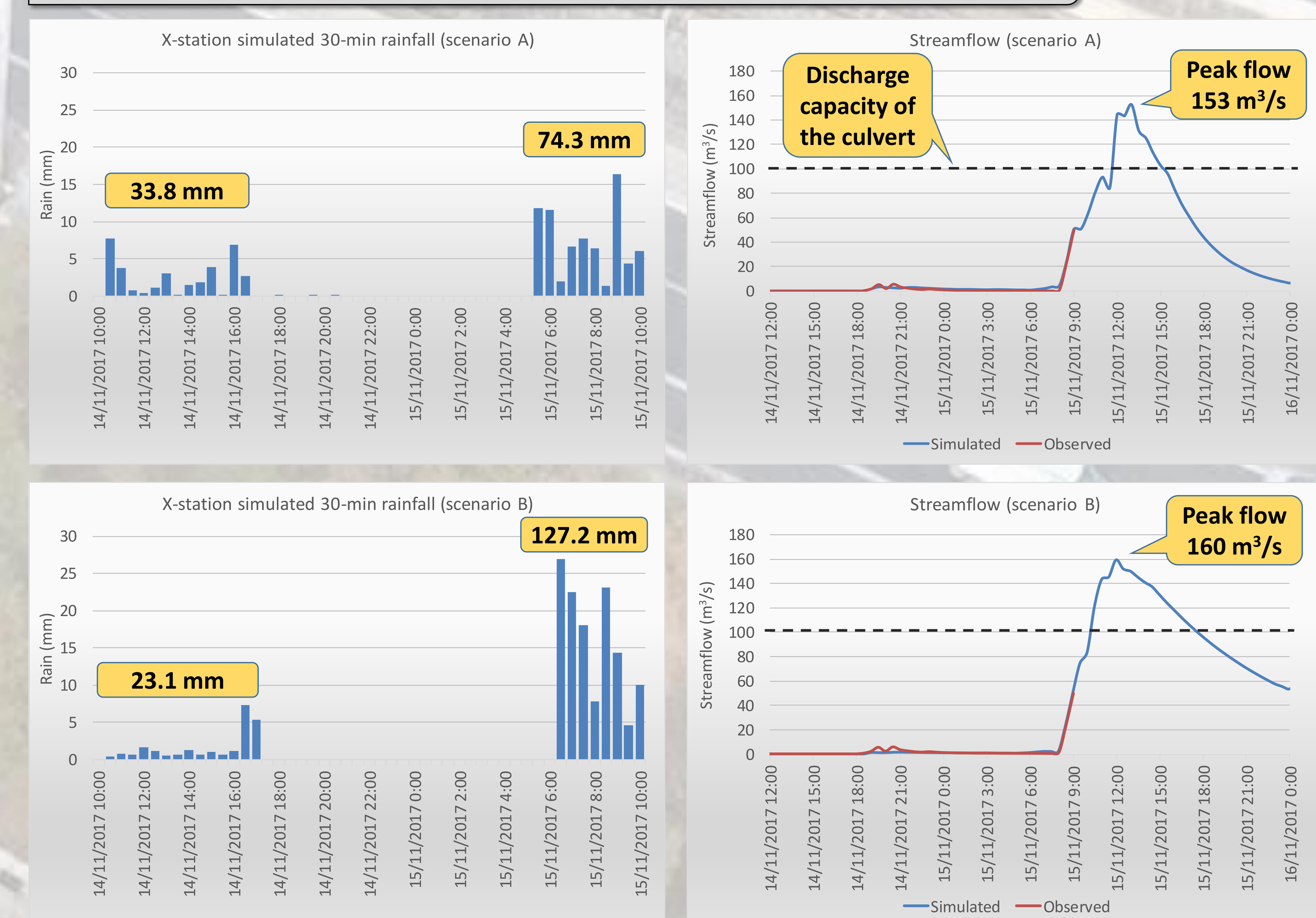
where i is the rainfall intensity (mm/h).



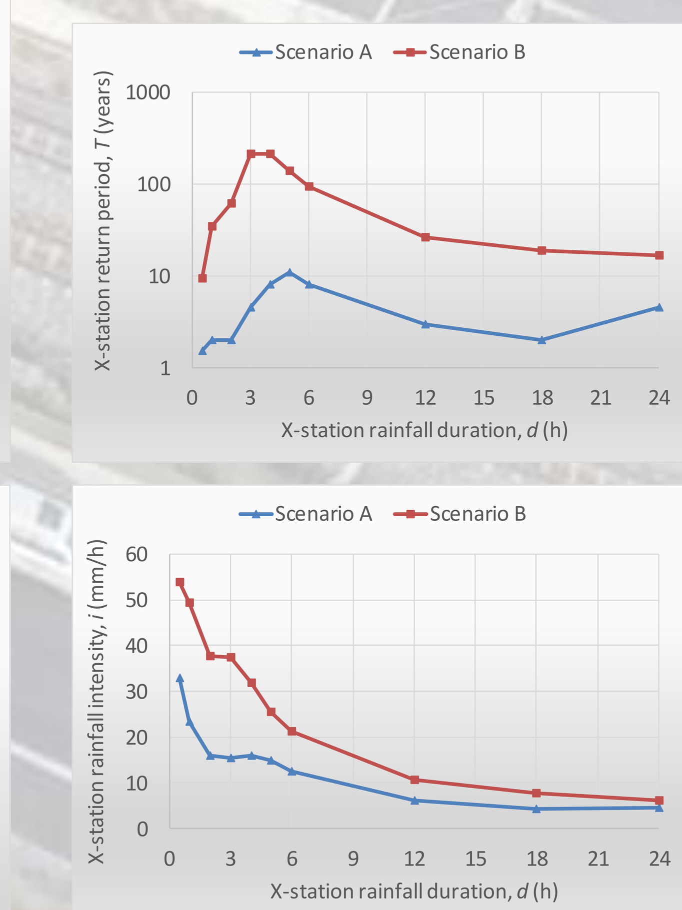
Hydrological scenario	A	B
Initial abstraction, I_a (mm)	20	10
Recession coefficient, k (h^{-1})	0.15	0.05
Lag time, τ (h)	3.0	2.0

Sketch of flood simulation procedure and parameter values considered for the two hydrological scenarios (table)

4. Simulation results and return period estimations



Simulated rainfall at X-station (left) and simulated vs. observed flows (right) for hydrological scenarios A (up) and B (down)



Scatter plots of simulated rainfall intensities (up) and estimated return periods (down) vs. time scale (duration), for the two hydrological scenarios

5. Conclusions

- Hydrological scenario B provides systematically larger rainfall intensities at the hypothetical X-station; at all temporal scales up to four hours, the maximum intensities that are estimated by scenario B are 2.0 to 2.5 times larger than those estimated by scenario A.
- Despite their significant differences in rainfall estimations, in terms of intensity and temporal pattern, both scenarios ensure perfect fitting to the observed flows of Sarantapotamos until 9:00 am, and they also result in almost identical estimations of the peak flow, some hours later.
- Scenario B, resulting in significant intensities over short durations seems to be closer to reality, given that due to the small size of the two catchments upstream of the city of Mandra, their response time is quite short, thus the maximum rainfall at such duration is the most critical.
- Ongoing research aims at improving rainfall estimations, by taking advantage of quantitative estimations by satellite and radar data.

REFERENCES

Apostolidis, I., V. Perleros, V. Tsatiris, and G. Vassilopoulos, *Report on the flood of November 15th 2017 at Mandra and Nea Peramos, Attica*, December 2017; http://www.geotee-anste.gr

Kalogiros, J., A. Retalis, D. Katsanos, M. Anagnostou, and E. Nikolopoulos, *National Observatory of Athens press release on 20-11-2017*; http://www.noa.gr

Lekkas, E., N. Voulgaris, and S. Lozios, *Flash Flood in West Attica (Mandra, Nea Peramos) November 15, 2017;* Newsletter of Environmental, Disaster and Crisis Management Strategies, Issue No 5

Michailidi, E., *Investigation of flood simulation for design in ephemeral basins – Application to Sarantapotamos basin*, Diploma thesis, Department of Water Resources and Environmental Engineering – National Technical University of Athens, December 2013

DEUCALION – Assessment of flood flows in Greece under conditions of hydroclimatic variability: Development of physically-established conceptual-probabilistic framework and computational tools; http://deucalionproject.itia.ntua.gr/

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The presentation is available at:
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