The flood of Oct 2014 in Athens. Characteristics and impact assessment

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ABSTRACT

In 24 October 2014, a high intensity storm hit Athens western suburbs causing extensive flash flooding phenomena. The drainage and the sewerage network of the city were overwhelmed leading to catastrophic flood flows along the road network, flooding houses and businesses, sweeping away vehicles, injuring people and causing numerous problems in transportation across the city. Parts of the floodplain were inundated for several hours, particularly in Ilion, Peristeri, Acharnai, Korydallos and Piraeus. This work examines in detail and reconstructs both the storm's and the flood's characteristics, the different types of direct effects within the urban environment and the severity of its direct impacts across Athens basin. Results show a concentration of flood damages in specific locations mostly along the city's natural drainage network and even derelict streams and culverts converted in the 1950s and 1960s to streets. At their peak stage, floodwaters extended to an area of 4.9 square km recording a maximum depth of 170 cm in certain locations. Eight types of direct impacts were identified including effects on vegetation, geomorphology, erosion rates, mobile objects, buildings and infrastructure with low, medium and high damage severity levels across the flooded area. Mapping of effects made possible the delineation of high impact parts across the flooded areas.

INTRODUCTION

Floods pose a significant threat to human life (Jonkman and Kelman 2005) and cause extensive economic damages on a yearly basis (Barrero 2007). Especially in urban environments, vulnerability is significantly increased as a higher concentration of population and assets makes flooding costly and difficult to manage. In addition, given the complexity of socio-economic activities in urban settlements, urban floods can potentially disrupt activities, businesses and social groups beyond the actual flooded area such as transportation services and others (Mitsakis et al. 2014). Due to this complexity it is often particularly difficult to predict the impacts of floods in an urban environment and their severity. Moreover, the importance of urban floods in the overall risk is expected to grow even more (Jha et al. 2012) as global urban population is projected to increase further (Antrop 2004, UN 2011). Within the context of climate change extreme storms like the one of October 2014, are expected to become more frequent (Alfieri et al. 2015) increasing the problem even further.

Previous works have examined the impact of floods (Petersen 2001) categorizing the effects in various groups and severity levels (Calianno et al. 2013) such as: (a) impacts on human population (Jonkman and Kelman 2005), (b) impacts on environment (Phillips 2002), including agriculture (Chau et al. 2013), (c) impacts on transportation (Mitsakis et al. 2014) including vehicles and travel conditions and road infrastructure (Diakakis et al 2015), (d) impacts on buildings (Smith 1994, Fedeksi and Gwilliam 2007), € impacts on infrastructure (Diakakis et al. 2015).

To fully understand the impact of storm in a holistic way, it is important to identify and map the different types of effects in a highly detailed way. In this context, this work develops a geodatabase to map and classify the direct impacts of the flood of October 2014 in Athens, aiming to provide a better understanding of their spatial and qualitative characteristics, especially in relation to the storm. In addition, this paper reconstructs the flood event providing information on floodwaters depth and extent as a reference tool for risk studies.

STUDY AREA

Athens is the capital and the most extensive urban area in Greece. The city is situated in central Greece, in the region of Attica and is built in a morphologic basin that occupies an area of approximately 534 km2, formed between Penteli, Parnitha, Ymittos and Aigaleo mountains and Saronikos Gulf in the south (Fig. 1). The basin is shaped primarily by Kifissos and Ilissos river networks and is relatively dry with a mean annual rainfall of approximately 390 mm and a poorly developed river network dominated by streams with small amounts of water for most of the year (Koutsoyiannis and Baloutsos 2000). The increased pressure for development has led to the expansion of human activities and infrastructure within the vicinity of Athens' ephemeral watercourses, in many cases in areas of elevated flood hazard, not suitable for building. Several authors suggest that poorly-planned development in the city has affected the drainage capacity of the river network noting that several parts of it were shrunk or converted into streets while critical river cross sections were diminished. In fact, Diakakis (2014) suggests that of floods have increased in Athens basin during the last century, and even though immediate loss of life is not showing clear increase, fatalities still remain an issue.

THE OCTOBER 2014 FLOOD EVENT

On Friday the 24th 2014, a deep barometric low, which formed over the Adriatic Sea moved through the Ionian Sea towards Peloponnese and subsequently Attica. Simultaneously with its passing over Athens, the system matured developing a line of storms feeding from the gulf of Saronikos, just south of Athens, leading to accumulation of rain up to 130mm in 5 hours in the west part of Athens (Fig.1).

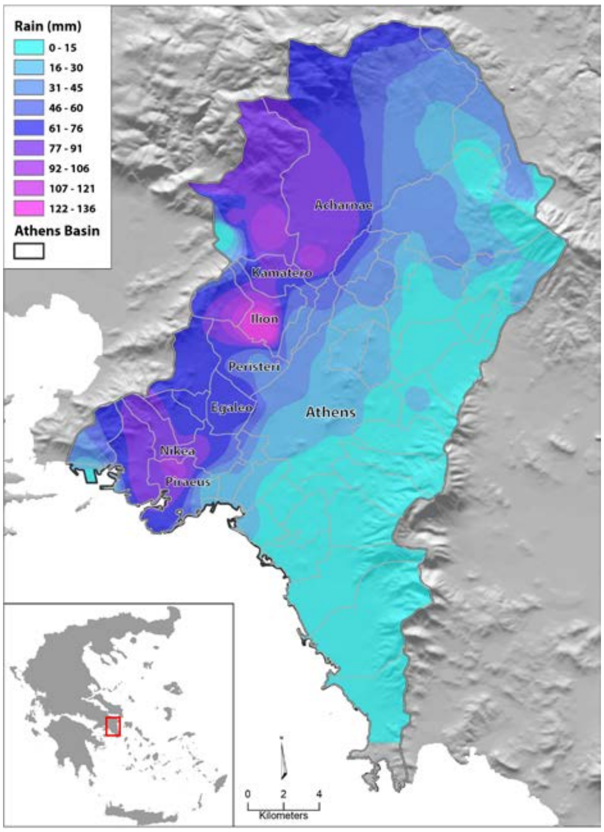

Figure 1: Map of the distribution of rainfall across Athens basin on the 24 October flood.

METHODOLOGY

Data on the effects of the October 2014 flood were collected from a variety of sources (Tab. 1) including official damage reports, visual material (pictures and video) and information gathered through post-flood field surveys. Data contained information on the exact location of damages, including detailed descriptions of the damage type and extent, the depth of floodwaters and in many cases visual material of the incident.

Table 1. Sources of information on 2014 floods effects and damages.

Type of source	Source	Form of data (short description)
Central Government records	Division of Natural Disaster Damages Restoration, Ministry of Infrastructure, Transport and Networks	Database of household damages recorded on Fire Service detailed reports, including information on address, type of damage, water level.
Local Government records	Affected Municipalities, namely: Acharnes. Agia Varvara, Agioi Anargiroi, Aigaleo, Fili, Haidari, Ilion, Keratsini-Drapetsona, Korydallos, Nikaia Peristeri, Piraeus	Official resolution documents regarding amends for residents, whose household has been recorded by the Fire Service as affected by the October 24th flood.
Media	The nationwide TV stations Alpha TV, Antenna TV, Mega TV, NERIT, SKAI TV and STAR TV	Video footage broadcasted between 24/10 and 30/10/2014 on news bulletin. Total duration: 16hours 16 minutes 08 seconds.
Web	News portals, Video web platforms, Blogs, Social media	Video & photos, recorded during or just after the rainfall.
Post-flood field survey	Survey	Post flood field survey material, including pictures, videos, depth measurements and field notes.

After the collection of data, a geo-database was developed to store all information. Each entry of the database corresponded to one damage location, which was plotted on the map of the study area in a GIS environment. GIS algorithms were used then to:

- define the extent of flooding based on all recorded flooded locations
- reconstruct the depth of floodwaters using extrapolation of known flow depth values
- define spatial distribution of damages and examine possible patterns in it
- define the spatial distribution of different types and different levels of damages to understand the severity of flooding in different locations

The impact types were divided in groups (Tab. 2), based on related literature classifications combined with observations carried out in the course of this study. In addition to the type of impact, in this work effects were also grouped according to their severity. The organization of different categories of severity is illustrated in the following table according to the type of impact (Tab. 2).

Table 2. Severity classes in different types of damage.

Severity class	Effects on natural environment			Effects on mobile objects	Effects on population	Effects on built environment		
	Vegetation	Pollution	Geomorphic processes			Transportation infrastructure	Buildings	Other infrastructure
Low impact	Ground plants or reeds get uprooted or broken	No pollution phenomena	Minor erosion and deposition phenomena limited to the banks of the rivers	Rubbish bins, chairs, tables carried away by floodwaters	Locally affected (30-100 people)	Road inundated / Road circulation stopped	Basements partly flooded	River crossings inundated / water mains break and culverts block, power is down
Medium impact	Small trees broken or uprooted	Minor pollution phenomena (rubbish, house petrol tanks etc.)	River bed changes, coastline minor changes	Cars, SUVs carried away	Locally affected (100-200 people), Some injures	Road partly damaged (scouring, pot holes, lighting installations)	Ground floors houses or businesses flooded	Bridges suffer the same minor damages / gas mains break
High impact	Big trees broken or uprooted	Significant pollution phenomena (major h/c tanks, livestock farms washed away)	Change in riverbed at over 3 times the initial width	Trucks, busses etc. carried away by floodwaters	Fatalities	Road have significant structural damage or completely demolished	Buildings have structural damages	River crossings have significant structural damage or collapse

RESULTS

In total, 1498 entries (damage locations) were stored in the database representing locations where the flood had an observable impact (Fig. 2). The effects spread in 16 municipalities covering a large part of the western part of the city, mostly following the rainfall accumulation distribution (Fig. 1).

Comparison of flooded locations with the local streams shows that the majority of locations are within 200m of an existing natural or artificial, derelict or active part of the local drainage network. Using the locations, visual material and information from the post-flood field survey it was possible to delineate the extent of the flood and to reconstruct the depth of floodwaters across the flooded area (Fig. 3). From this reconstruction it was found that floodwaters extended to an area of 4.9 km2, recording depths up to 170 cm in certain locations.

The types of effects were mapped individually, leading to the development of a concise map of different types of impacts. In addition, 3 grades of severity of effects (low, moderate and high) were included to identify possible patterns in damage level across the floodplain, information particularly useful for future risk and flood loss studies. Based on a preliminary analysis of 199 damage locations, results highlighted areas with concentrated effects of high, moderate and low impacts. In specific, a clustering of high and medium impacts was recorded in particular locations within Korydallos, Peristeri, Ilion and Acharnes (Fig 4). Future research is needed to detail the impact levels in all 1498 damage locations using the classification system presented in this study. The method can be used in future and past flood events as a system of ranking the impact of each event in diverse environments.

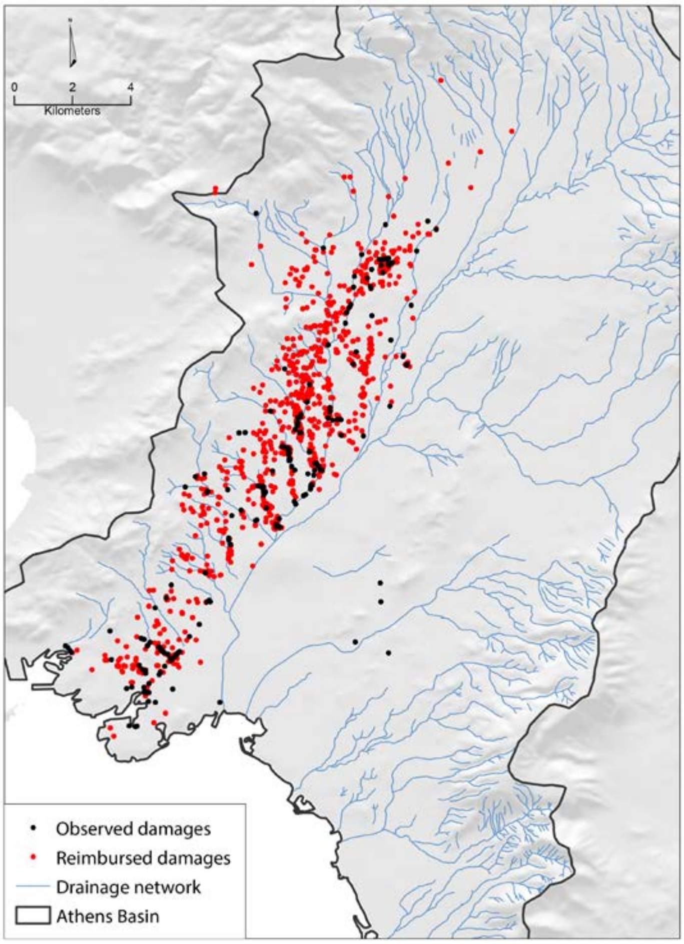

Figure 2: Map of the study area depicting all recorded flood impact locations.

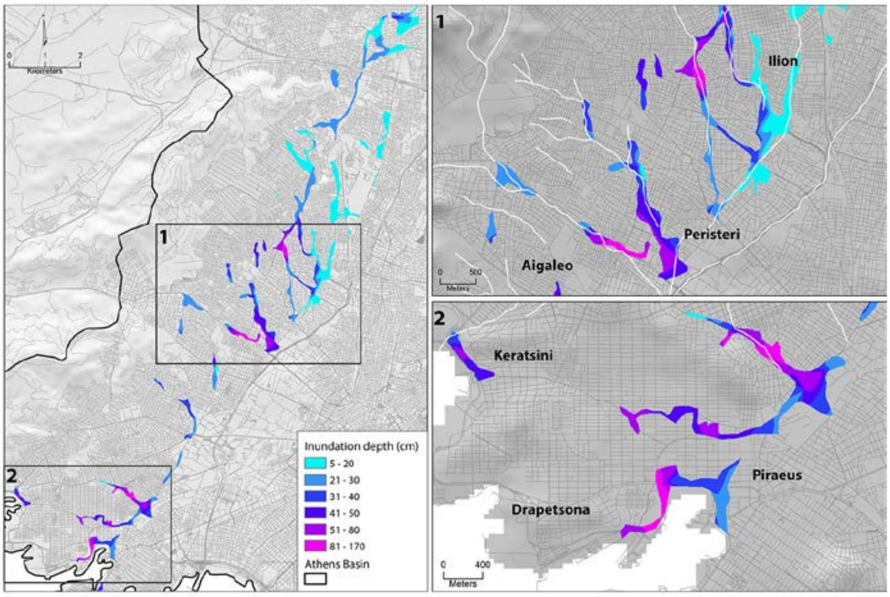

Figure 3: Reconstruction of the extent and depth of floodwaters.

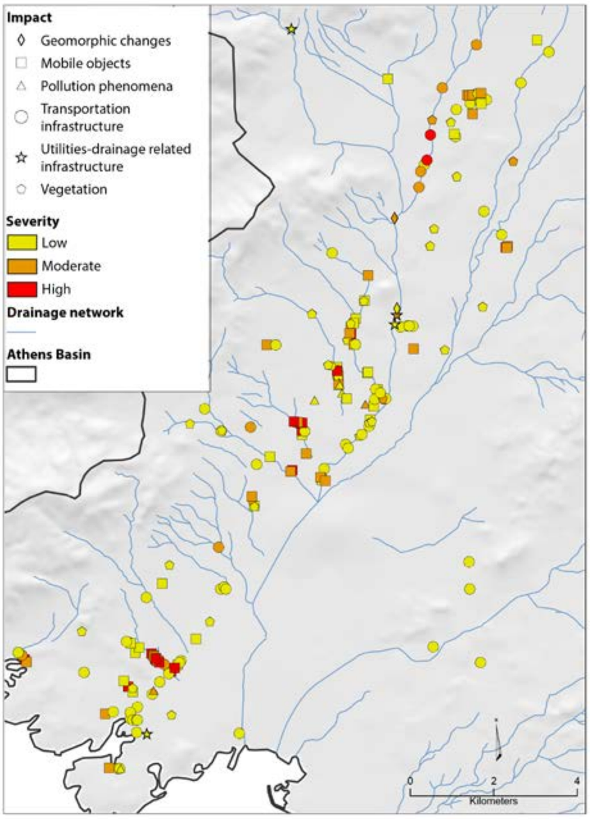

Figure 4: Map of the study area depicting the severity classes at 199 damage locations.

CONCLUSIONS

This work examines the effects of the flash flood of October 2014 in Athens basin, in Greece in an effort to reconstruct its characteristics, the different types of direct effects within the urban environment and the severity of its direct impacts across the flooded area. The study identifies 1498 damage locations spread across 16 municipalities of Athens basin, including damages on buildings, vegetation, geomorphology, erosion and deposition, humans, mobile objects, transportation and other infrastructure elements. Results showed a concentration of flood damages in specific locations mostly near the city's natural drainage network, parts of which have been converted to culverts or streets and were derelict for decades. Floodwaters were found to extend to an area of 4.9 square km recording a depth up to 170 cm in certain locations. Direct impacts were grouped 3 classes of severity with low, medium and high damage severity levels across the flooded area, with most serious effects clustering in particular locations within Korydallos, Peristeri, Ilion and Acharnes.

REFERENCES

ALFIERI, L. et al. (2015) Global warming increases the frequency of river floods in Europe. *Hydrol. Earth Syst. Sci. Discuss.*, 12, 1119–1152.

ANTROP, M. (2004) Landscape change and the urbanization process in Europe. *Landsc. Urban Plan.* 2004, *67*, 9–26.

BARREDO, J.I., (2007). Major flood disasters in Europe: 1950–2005. *Nat. Hazards*, 42, 125–148.

CALIANO, M., RUIN I., GOURLEY, J.,(2013) Supplementing flash flood reports with impact classifications. *Journal of Hydrologie* 477 (2013) (1-16)

CHAU V.,N. et al. (2013) Using GIS to map impacts upon agriculture from extreme floods in Vietnam. *Applied Geography* 41 (2013) 65e74

FEDEKSI, M. & GWILLIAM, J. (2007) Urban sustainability in the presence of flood and geological hazards: The development of a GIS-based vulnerability and risk assessment methodology. *Landscape and Urban Planning*, 83, 50–61

JHA, A.K., BLOCK, R.; LAMOND, J. (2012) Cities and Flooding. In *A Guide to Integrated Urban Flood Risk Management for the 21st Century*; The World Bank: Washington, DC, USA, 2012; pp. 14–49.

JONKMAN, S.N., & KELMAN, I., (2005) An analysis of the causes and circumstances of flood disaster deaths. *Disasters*, 29 (1):75-97.

PETERSEN, M.S. (1999) Impacts of flash flood. In GRUNTFEST, E. & HANDMER, J.(eds.). Coping with flash flood. *Nato Science Series*, Environmental Securities Vol 77 J.,(pp. 11-13).

PHILLIPS, J., (2002) Geomorphic impacts of flash flooding in a forested headwater basin. *Journal of Hydrology* 269 (2002) 236–250

SMITH, DI. (1994) Flood damage estimation - A review of urban stage damage curves and loss functions. Australian National Univerisity, Canberra 0200, Australia

UNITED NATIONS (2011) *World Urbanization Prospects*; United Nations, Department of Economic and Social Affairs (DESA), Population Division, Population Estimates and Projections Section: New York, NY, USA, 2011.

DIAKAKIS, M. (2014) An inventory of flood events in Athens, Greece, during the last 130 years. Seasonality and spatial distribution. *Journal of Flood Risk Management*. Wiley, DOI: 10.1111/jfr3.12053

DIAKAKIS, M. et al. (2015) Vulnerability of transport infrastructure in Greece to high intensity rainstorms in small rural catchments. European Journal of Transport and Infrastructure Research, Special Issue 'Climate Adaptation and Infrastructures' (accepted for publication).

KOUTSOGIANNIS, D & BALOUTSOS, G. (2000), Analysis of a long record of annual maximum rainfall in Athens, Greece, and design rainfall inferences. Nat. Hazards 2000, 22, 29–48.

MITSAKIS, E. et al. (2014) Impacts of high intensity storms on urban transportation: Applying traffic low control methodologies for quantifying the effects. *International Journal of Environmental Science and Technology*, DOI: 10.1007/s13762-014-0573-4.