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The Levee Effect and Residual Risk in Sacramento, California: Have we been good or lucky?

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Abstract

The residual risk of extreme floods is increasing worldwide due to increased urban areas in high-hazard zones, aging infrastructure and the increased likelihood and magnitude of extreme events due to climate change. Areas protected by levees can create a false sense of security that increases developments in high-hazard zones, what is known as the *"levee effect"*. In this study we have analyzed the city of Sacramento, California, one of the cities at highest flood risk in the nation, with special interest to the community of Natomas. We have looked at how exposure changed over time and why, how the information in Sacramento's Flood Insurance Rate Maps has changed over time and why, and what are the implications of the effective Flood Insurance Rate Map in generating different scenarios for future flood risk. Our results show that despite efforts from the City of Sacramento to communicate flood risk, residual risk is increasing in Natomas largely due to increased exposure.

Key words: residual risk, the "levee effect," exposure, Natomas, Sacramento, NFIP

1. Introduction

Urban areas are expanding fast in flood hazard areas in many countries around the world (Rentschler et al. 2023). This is in part because levees create a false sense of security among residents, encouraging further development in what is still a hazardous area, a phenomenon known as the *"levee effect"* (White 1945; Hutton et al. 2019; Serra-Llobet et al. 2022). These floodplain residents are exposed to the 'residual risk' of flooding because levees can breach or overtop. Ignoring the residual risk associated with hydraulic infrastructure can have devastating consequences (Serra-Llobet et al. 2024). Furthermore, in the US, many levees are built to provide a level of protection of up to a 100-year flood, but in the context of climate change, larger floods are increasingly likely (IPCC 2023), meaning a greater probability that the levees will be overtopped or fail (Pawley et al. 2023).

1.1. Study area

The City of Sacramento is situated in the Central Valley of California, at the confluence of the Sacramento and American Rivers. Established in 1848 as a consequence of the Gold Rush (Zingraff-Hamed et al. 2022), Sacramento is the state capital with the greater Sacramento area having a population of over two million people and is currently the fastest-growing city in California. In the northwestern section of the city is the Natomas Basin, a low-lying floodplain in a historic lake bed with a current population of over 100,000 people. Natomas has a controversial history, and provides an example of how flood zoning designations and public flood risk perception can change over time (Pawley et al. 2023).

2. Hypothesis and Methods

Our research looks at risk as a dynamic process (Serra-Llobet et al. 2023) with a specific focus on the City of Sacramento, California, posing these questions: How has the exposure in hazard zones changed over time and why? How have the Flood Insurance Rate Maps (FIRMs) evolved in Sacramento and why? What are the implications of the "effective" FIRM in reducing or increasing flood risk in Sacramento? To answer these questions, we have analyzed: (1) the urban growth of the City of Sacramento since 1850 using historical information (e.g., Sanborn insurance maps, aerial photographs and satellite imagery, historical accounts, reports), (2) the evolution of FIRMs since 1978 (panels have been mosaiced and

digitized), to understand how changes in these maps may have been influenced by improved scientific information or political considerations, or both, and (3) the implication of the effective FIRM in increasing or reducing exposure in high hazard zones.

3. Results and Discussion

3.1. How and why has exposure changed in high-hazard zones?

Between 1907 and 1947, the city filled in Washington Lake and Bush Lake, resulting in their drainage and subsequent development (Figure 1.a,b,c). Additionally, the city constructed levees to reduce seasonal flooding and support urban expansion. After the construction of Folsom Dam in 1956, the city expanded further, assuming the dam would reduce floods in perpetuity (Figure 1.c,d) (Mayer et al. 2018, Zingraff-Hamed et al. 2022). In 1978, the city grew further but remained mostly concentrated outside of the former footprint of its historic lakes (Figure 1.d,e). By comparing the 2020 city limits (Figure 2.e) with the flood hazard map created by the California Department of Water Resources (DWR) (Figure 4.f), we can see that the City of Sacramento has high exposure to flood hazard zones due to the increased development especially during the second half of the 20th century (Figure 3). The city is now anticipating further development in Natomas, especially within the former footprint of Bush Lake in the Natomas Basin (Figure 2.e).

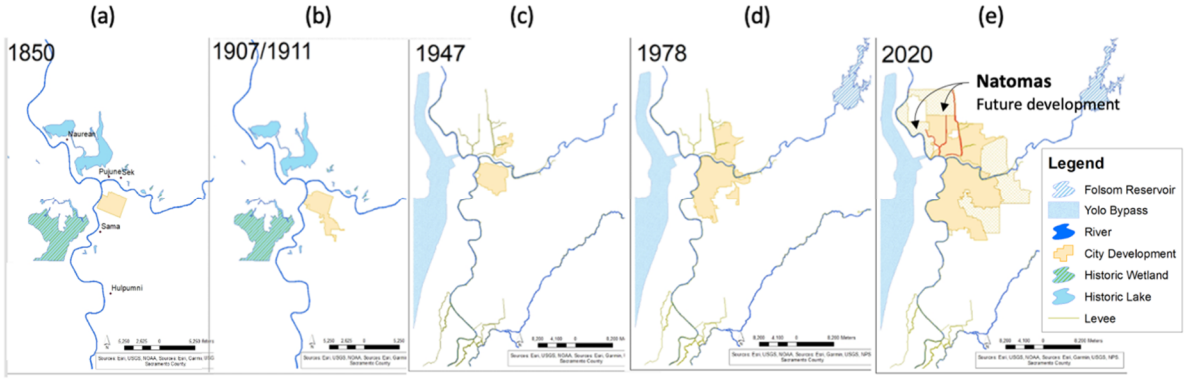

FIGURE 1. Evolution of exposure and changes in the waterscape of Sacramento area (1850-2020).

3.2. How and why has the information in the FIRMs changed over time?

In the FIRMs from 1978 and 1982, most regions were designated as either B or C zones (Figure 2.a,b,c), corresponding to the current “Shaded X” and “Unshaded X” zones. These zones are considered moderate (0.2% - 1% annual flood risk) or minimal (less than 0.2% annual flood risk) risk areas (in FEMA nomenclature) requiring no flood insurance due to levee protection. At that time, these designations were based on the 1957 Army Corps of Engineers' assessment of the levees.

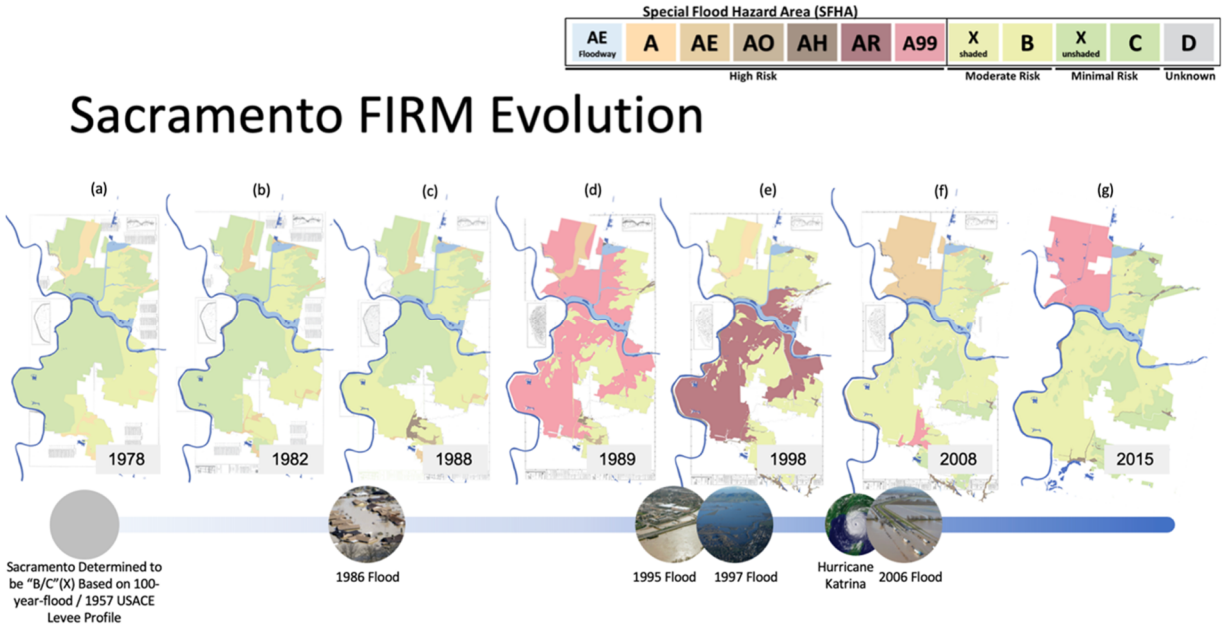

FIGURE 2. Evolution of Sacramento Flood Insurance Rate Maps (1978-2024).

Following the record flood of 1986, the Army Corps of Engineers determined that the levee system did not provide 100-year flood protection. However, the 1988 FIRM (Figure 2.c) showed no major changes in zone designations after the flood, particularly in Natomas. In 1989, Congress authorized the A99 zone for Sacramento (Serra-Llobet et al. in preparation A), and most of the levee-protected areas were subsequently rezoned as A99 zones (Figure 2.d). The A99 zone is described in the Federal Register under the nomenclature of “Adequate Progress” and regulated through 44 CFR 61.12. The A99 designation results in “lower flood insurance premium rates in areas where FEMA determines that a community has made adequate progress on its construction or reconstruction of a project designed for flood risk reduction.”. The City of Sacramento established new building restrictions that essentially brought all development projects in Sacramento to a grinding halt (County of Sacramento). Soon after in

1992, Congress passed new legislation for FEMA to create a new "Zone AR", or Flood Protection Restoration area, regulated through 44 CFR 65.14. The AR zone may "provide reduced flood insurance premium rates and floodplain management regulations in areas where FEMA has issued a determination that a project is sufficiently underway to restore a flood protection system to meet 44 CFR 65.10 accreditation requirements". Thus, properties may have base flood elevations (BFE) representing the current risk as if the flood protection system was not in place.

The 1995 and 1997 floods prompted a remapping in 1998, resulting in most of the city being designated as AR zones due to a series of levee failures or underseepage during the floods. Surprisingly, the Natomas region and the North Arcade Creek region in south Sacramento were remapped to X zones (Figure 2.e). However, following Hurricane Katrina, the Army Corps of Engineers decertified the Natomas levee system, leading to the remapping of the entire Natomas region to AE zones in 2008, which hindered development in the area (Figure 2.f) (personal communication, Ricardo Pineda, California Department of Water Resources, February 2022).

With the authorization of a bill for upgrades in 2014, Natomas was again remapped to A99 zone in 2015, as long the levee meets 200-year flood protection. Thus, today, the effective FIRM shows most of Sacramento as X zones and Natomas as A99 (Figure 2.g).

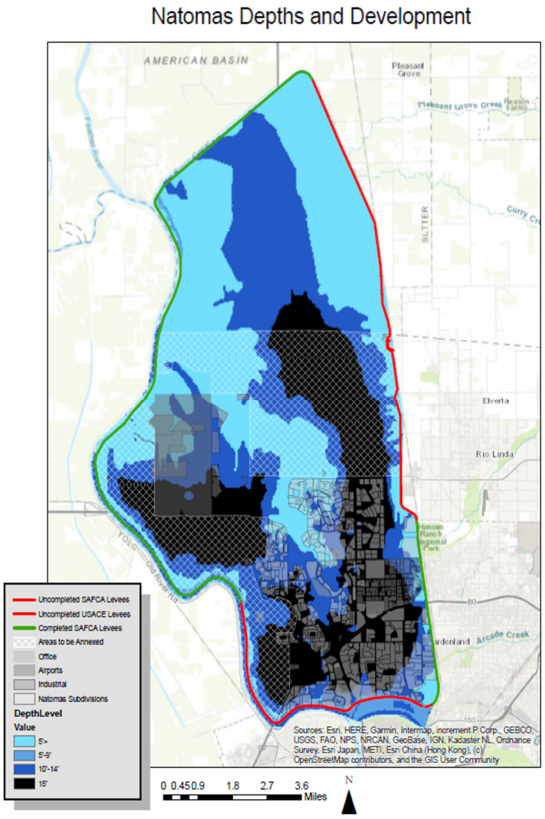

FIGURE 3. Overlay of flood hazard map showing potential flood depths in Natomas with urban footprint.

3.3. What are the implications of the effective FIRM in reducing or increasing flood risk?

If we look at the DWR flood hazard map (Figure 4.f) we can see that most of the city is at risk. We have analyzed the land use zoning map and we have seen that around 20% of Sacramento cannot be built (e.g., open space, agriculture or parks), but around 80% can be built. Furthermore, more than 60% of the city is zoned as residential, the least compatible zone with flood hazard. We have also analyzed the implications of the effective Flood Insurance Rate Map (from 2015) on urbanization (development restrictions and requirements for flood-related building codes) and insurance requirements (Figure 4).

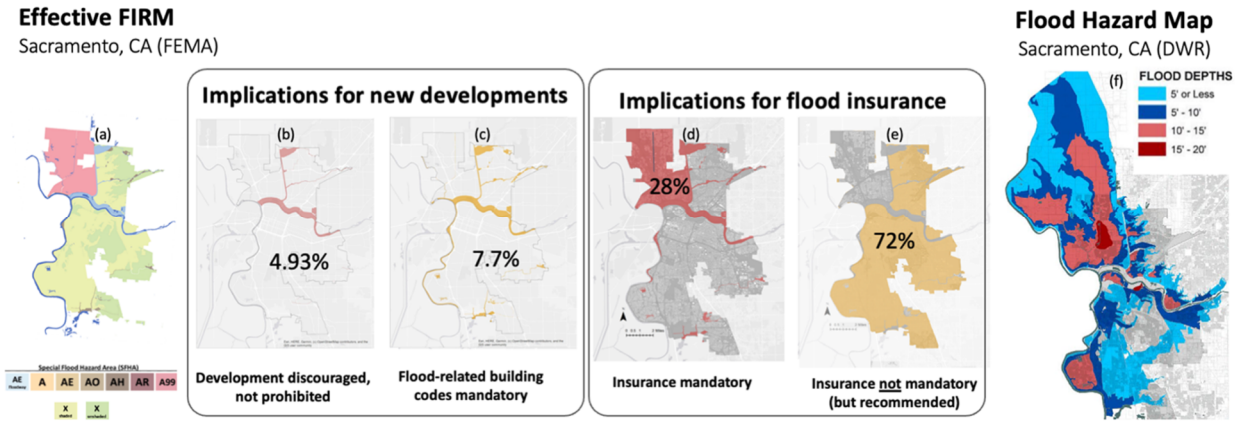

FIGURE 4. Effective FIRM in Sacramento from 2015 (City of Sacramento 2021) (a), implications of the effective Sacramento FIRM in land use regulations, flood-related building codes and flood insurance requirements (b,c,d,e), Sacramento flood hazard map showing water depths (source: DWR) (f).

Regarding development restrictions in high-hazard zones, building in the FEMA regulatory floodway is currently 'discouraged' but not prohibited. The regulatory floodway is less than 5% of the city and most of it is located on the *wet* side of the levee (Figure 4.b). Although most of the FEMA regulatory floodways are part of the American River Parkway, there are areas with private property that can still be built if the applicant provides evidence that "no rise" will occur. Flood-related building codes only apply to 7.7% of Sacramento (Figure 4.c), including 100-year Floodway, A, AE, and AH, Zones.

Flood insurance is mandatory in 28% of Sacramento, including 100-year Floodway, A, AE, and AH, Zones and the A99 zone (Figure 4.d). In the A99 zone, due to the "adequate progress" determination, insurance premiums are generally less than those required in other Special Flood Hazard Areas (SFHAs) (e.g., Zone AE, Zone AO, and Zone AH). Thus, residents in Natomas are getting somewhat contradictory

messages: they need to purchase flood insurance because they are in a SFHA but are not regulated by any flood-related building codes (due to the A99 zone designation).

In the US, through the Community Rating System (CRS), communities that proactively undertake floodplain management activities can also get discounts on flood insurance. In May 2020, FEMA retrograded the City of Sacramento's CRS rating from a Class 2 to a Class 3, resulting in a lower percent discount in the cost of flood insurance for flood-prone areas (FEMA 2020). However, it is still one of the highest-rated cities in the US, translating into a substantial discount in the cost of flood insurance. Analyzing the CRS verification report, we notice that most of the points (1,094 points over 3836) come from classifying 73% of the SFHA as open space where development is prohibited.

4. Conclusion

Although the National Flood Insurance Program (NFIP) was intended to discourage developments in high-hazard zones and the City of Sacramento has been very proactive in communicating risk to its citizens, our findings show that NFIP implementation may have increased residual risk in some areas of Sacramento by inducing more development through the *"levee effect."* Moreover, the creation of the "A99" zone to allow development in the Natomas district reflects pressure to develop this area behind levees that do not yet provide a level of protection for a 100-year flood (Serra-Llobet et al. in preparation A). We also find that the effective FIRM requires flood-related building codes in only 7.7% of the City of Sacramento, which corresponds mainly to the area *inside* (i.e., within) the levees. All these factors exacerbate residual risk in Sacramento. The findings from this study may be used to inform how land use planning and risk classification can increase exposure and thus increase risk, and potential avenues to mitigate this problem.

Acknowledgements

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