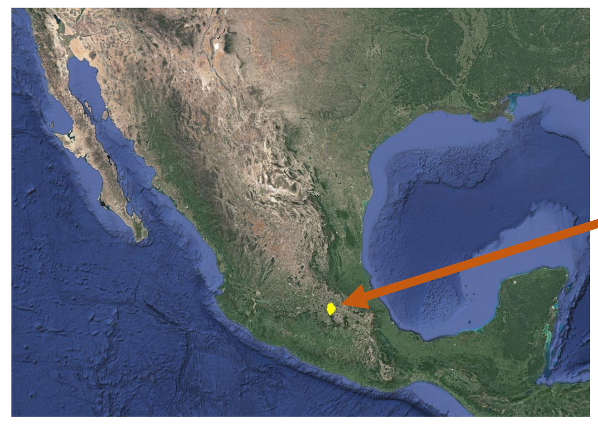
Forensic Analysis of Urban Flood using Ensemble Hydrologic Modeling

Xóchitl Peñaloza-Rueda*, Juan Carlos Centeno-Álvarez and Laurent G. Courty
Instituto Mexicano de Tecnología del Agua
*xochitl_penaloza@tlaloc.imta.mx

1. Introduction

In the night of 6 to 7 of September 2021, the Tula River in the municipality of Tula de Allende, Mexico, reached its highest level in living memory, flooding the city. More than 31,000 homes and 70,000 people were affected, and 17 patients at the local hospital died.



The Tula River catchment upstream of the city is complex, with four dams, three natural tributaries, and being the outlet of the drainage system of the urban area of Mexico City. In addition, most of the reaches of the Tula River watershed have patchy, inexistent, or unreliable hydrometric records, and discharge values of the Mexico City drainage are not available, complicating the task of understanding the causes of the flooding. To circumvent those issues related to hydrometric records, in this study we employ an ensemble hydrologic modeling to reproduce the event and shed light on the relative contribution of each tributary to the flood in Tula de Allende.

2. Methodology

The runoffs of the Tula River watershed are estimated using the semi-distributed version of the hydrological model HBV. The input ensemble data and parameters used are shown in the following diagrams:

HBV hydrology model
- **Precipitation** — IMERG — 1 data
- **Potential evapotranspiration** — Estimated based on ERA5 assembly data and the methodology presented by Singeret. al (2021). — 10 members
- **Temperature** — ERA5 assembly data — 10 members
- **12 parameters** — Ensemble of parameter maps obtained by Beck et. al (2020) — 10 members
- **MAXBAS routing parameter** — Estimated as a function of different time of concentration formulas — 3 members

The Mexico City drainage input is represented by SCS synthetic unit hydrographs, which peak values were estimated based on observed water levels and spillway modeling.

Requena dam has a spillway with crest gates and an ungated spillway, which make it more difficult to analyze.

The Muskingum method was used for reach routing.

Routing reservoir input hydrographs was carried out using the level pool routing method.

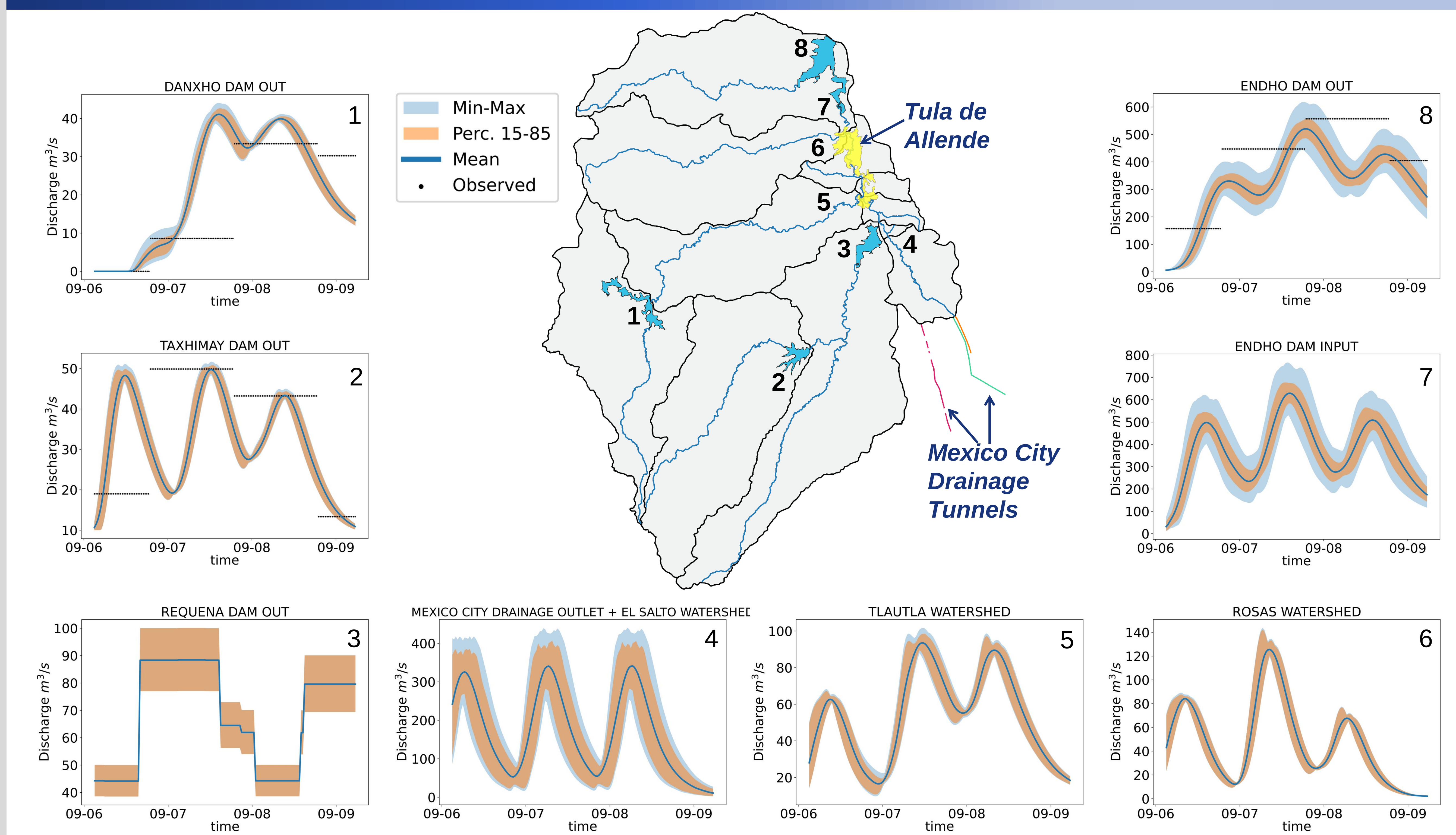
Simulations were carried out by combining the members of the input data and parameter ensembles, wherewith ensembles up to 218,700 hydrographs were obtained, from which those that are closest to observed data were selected through a sensitivity analysis of the parameters, resulting ensembles up to 4860 hydrographs.

- **Drainage of Mexico City** — Hydrographs —
  - 3 peak Flow: the calculated and ± 10%
  - 3 time to peak
  - 3 hydrograph start time

  — 27 members
- **Requena Dam** — Hydrographs — 77, 88 and 100% of reported discharge measurements — 3 members
- **Reach Routing: Muskingum method**
  - **K Muskingum parameters** — The travel time through the reach was estimated based on different time of concentration formulas — 3 members
  - **X Muskingum parameters** — For the weighting between inflow and outflow influence was proposed that: X=0.5,0.4,0.3 for s>0.9% X=0.3,0.2,0.1 for s<0.9% — 3 members

One discharge measurement is available for each day at the dams, but the time of measurement is unknown, so the graphs show the same value observed during the day.

3. Results



The reported discharges at Danxho, Taxhimay, and Endho dams coincide with the ensembles at a time of the day.

Of the three tributaries of the Tula River (points 3, 5, and 6), the Rosas River presented a peak discharge about 43% more than the Tlautla and Tepeji (Requena Dam) rivers. The peak discharge produced by the Mexico City drainage exceeds that of any other tributary.

4. Conclusions

With the proposed methodology and the data used, it was possible to approximate the scarce data observed in the dams, which sheds light on the contributions received by the Tula River, being equally important the runoff generated by the catchment and the contribution of the Mexico City drainage.

5. Future work

This result will be used as an input of a hydrodynamic model to further the analysis of the event.

6. Acknowledgments

The authors would like to thank Juan Pablo Rodríguez Rincón and Edgar Eduardo López López for their support and comments.

7. Bibliography

Beck, H. E., Pan, M., Lin, P., Seibert, J., van Dijk, A. I. J. M., & Wood, E. F. (2020). Global fully distributed parameter regionalization based on observed streamflow from 4,229 headwater catchments. Journal of Geophysical Research: Atmospheres, 125, e2019JD031485. https://doi.org/10.1029/2019JD031485

Singer, M.B., Asfaw, D.T., Rosolem, R. et al. (2021). Hourly potential evapotranspiration at 0.1° resolution for the global land surface from 1981-present. Sci Data 8, 224 (2021). https://doi.org/10.1038/s41597-021-01003-9