

# Tsunami Evacuation plan of Paço de Arcos beach, Oeiras, Portugal

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## Abstract:

The coastline of the Oeiras municipality, Portugal is quite popular all year round among residents and tourists, especially due to the beaches. Previous research conducted by the authors (Santos et al., 2022) shows that a tsunami similar to the 1755 event would inundate the beaches. Moreover, the same study shows the first tsunami wave arrived at Paço de Arcos beach 31 minutes after the earthquake, inundating the beach up to 4.4 m high. For this reason, many people could die if they do not evacuate the tsunami inundation zone immediately after the earthquake and before the arrival of the first tsunami wave. Some studies show that delays can range between 5 to 28 minutes (Trindade et al., 2018), which may be crucial in an emergency evacuation. In addition, this beach is very interesting to study because it has 5 beach accesses and high ground nearby. Still, the lack of evacuation signs and regular practice of drills and evacuation exercises may delay the actions of the people. On the other hand, the pandemic situation in 2020-2021 allowed a unique opportunity to conduct a detailed analysis of the present population in the Paço de Arcos beach, with the use and collection of access turnstiles control data (CMO, 2021). Thus, the objective of this study is to conduct a tsunami evacuation plan to Paço de Arcos beach.

The research was developed on a GIS (Geographic Information System) environment, on which the mapping of the inundated area was considered, as well as the beach access locations. In addition, the Safe Area was identified; this is an area that must be located on high ground and outside the tsunami inundation zone. Moreover, the number of beach users was evenly distributed over the beach area, and the low-cost paths were calculated by using the Network Analyst tools for the roads' network. Finally, the calculation of the beach evacuation time and the total evacuation time was carried out. The population data at the beach consisted on a 24 h records during the summer months of June to September 2021 (Fernandes, 2023). The data is important for this research because there is no available data of the number of present population at the beach, before and after 2021.

The main results show the human carrying capacity of the Paço de Arcos beach was 1000 users as a recommendation during the pandemic of at least 1.5 m social distance between people (APA, 2021), but the data of access turnstiles control data show the maximum occupation was recorded on august 15, which is a national holiday, at 5 pm, with 611 people (Fernandes, 2023). On the other hand, the Safe Area near the beach has a capacity of 1236 people, considering the pandemic recommendations of a 1.5m distance. Therefore, with or without social distance the safe areas are large enough to accommodate the beach users of Paço de Arcos. The results also show the beach can be evacuated very quickly, in less than 3 minutes. The Safe Area can be reached between 8 and 12 minutes, given a total evacuation time of about 10 to 17 minutes, which is less than the tsunami travel time of 31 minutes. However, if people do not evacuate immediately after the earthquake, the total evacuation time can range between 16 to 43 minutes. Therefore, delays in the evacuation may lead to a chaotic evacuation causing unnecessary fatalities.

## References

APA – the Portuguese Environment Agency. 2021. Despacho nº: 05/VPRES/2021, de 08 de maio de 2021, ANEXO II. (In Portuguese). [https://apambiente.pt/sites/default/files/\\_A\\_APA/Comunicacao/Epoca\\_balnear/Anexo\\_II\\_DespachoVP\\_CapacidadeOcupacaoPraias\\_2021.pdf](https://apambiente.pt/sites/default/files/_A_APA/Comunicacao/Epoca_balnear/Anexo_II_DespachoVP_CapacidadeOcupacaoPraias_2021.pdf)

- CMO – Câmara Municipal de Oeiras. 2021. Measures implemented by the Municipality of Oeiras to combating COVID 19 (in Portuguese). [https://www.oeiras.pt/documents/20124/642956/Plano+COVID+19\\_\\_+31+de+Mar%C3%A7o+de+2021.pdf/31b7c3d7-b417-6cbc-2d09-94a1dc5a0fca?t=1619856999516](https://www.oeiras.pt/documents/20124/642956/Plano+COVID+19__+31+de+Mar%C3%A7o+de+2021.pdf/31b7c3d7-b417-6cbc-2d09-94a1dc5a0fca?t=1619856999516)
- Fernandes, J. 2023. Evacuation Strategies in the event of a Tsunami on the beaches of the municipality of Oeiras, Master Thesis, Universidade de Lisboa, (In Portuguese). <http://hdl.handle.net/10451/64355>.
- Trindade, A., Teves-Costa, P., and Catita, C. 2018. A GIS-based analysis of constraints on pedestrian tsunami evacuation routes: Cascais case study (Portugal). *Natural Hazards*, 93(1), 169-185. DOI: <https://doi.org/10.1007/s11069-017-3152-4>
- Santos, A., Fernandes, J., and Mileu, N. 2022. Tsunami Hazard Assessment at Oeiras Municipality, Portugal. *J. Mar. Sci. Eng.* 10, 1120. <https://doi.org/10.3390/jmse10081120>.