A method for assessing the vulnerability of buildings to catastrophic (tsunami) marine flooding

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Introduction – The coast of New South Wales and the tsunami risk

* 330.000 people live in the New South Wales coast, in no more than 1km away from the coastline and at 10m maximum height above sea level
* 20% of these people are over the age of 65
* 400.000 properties up to 3km from the coast with 200.000 of them within less than 15m above sea level
* Total value of these properties exceeds 150 billion US$
* Only small tsunamis have affected the coast during history (from marine landslides)
* However geology suggests tsunamis even larger than the 2004 tsunami of the Indian ocean during the Holocene period (10000 years before present)
* Development of the Australian Mega-tsunami Hypothesis (AMH) in 2003, but it is controversial

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Aims of the Project

* Determine a credible worst case scenario of tsunami innundation
* Collaboration with the Sydney Coastal Councils Group and Local Government authorities
* Select and modify as needed a tsunami vulnerability assessment tool
* Use the tool on collected building data
* Calculate a Relative Vulnerability Index (RVI) for every building in the inundated zone of the tsunami scenario
* Display the vulnerability in 1:5000 maps
* Discuss the results and its implications
* Use the results for recommendations

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Methodology – Inundation Scenario

* Underwater sediment slide occurs off-shore of Sydney
* It occurs without being triggered by an earthquake
* A tsunami arrives at shore within 10-15 minutes
* Run up height of the tsunami is +5 meters above sea level and occurs on top of the maximum astronomical tide for Sydney which is +2 meters, therefore maximum run-up is +7 meters
* Inundation is assumed to be parallel to the shore
* Single wave inundation
* Flow velocity, debris and sediment in the water are not considered

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Methodology – Inundation Scenario

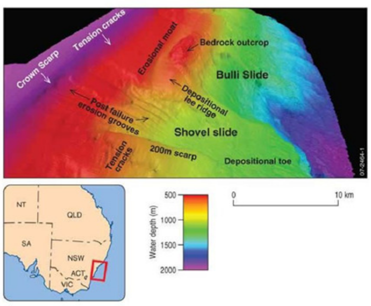

Figure 2. The slope failure architecture and slip-plane geometry of the Shovel Slide. Location of the large Bulli Slide is also indicated. Insert – the area of the NSW coast surveyed by Geoscience Australia (Glenn, 2008)

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Methodology – Study Area Selection

* Transparent consultation and collaboration with the local governments and its professionals
* Access to GIS data provided by these local governments
* Usefulness of results for the local governments and the State Emergency Service and their planning
* Inclusion of at least one site with high building density and exposure
* Inclusion of at least an area that has not been subject of significant research projects
* Inclusion of at least one iconic location for awareness purposes and publicity of the results
* Selection of Maroubra Beach area and Manly Ocean Beach area, both of them within the metropolitan area of Sydney

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Methodology - Vulnerability Assessment tool

* Papathoma Tsunami Vulnerability Assessement Model (PTVA) developed and applied in 2003
* Tested and proven to correlate well with data from the 2004 Indian Ocean tsunami
* Tested by the National Oceanic and Atmospheric Administration of the USA in the area of Seaside, Oregon
* Improved for the purposes of this study to include combination of damages both from hydrodynamics and water intrusion

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PTVA Model & Relative Vulnerability

* The Relative Vulnerability Index (RVI) Score is a weighted sum of two components:
  * The vulnerability of the carrying capacity of the building structure hit by the horizontal hydrodynamic force
  * The vulnerability of different building components due to their prolonged contact with water (plaster, fixtures, tiles appliances etc)

Therefore,

Relative Vulnerability Index (RVI)= (2/3)*(SV)+(1/3)*(WV)

Where SV is Structural Vulnerability and WV is vulnerability due to water intrusion

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PTVA Model & Structural Vulnerability

The Structural Vulnerability is calculated as:

SV= (Bv)*(Ex)*(Prot)

Bv is the vulnerability of the building itself. It depends on the physical characteristics of the building itself (Number of floors, building material, orientation, condition, movable objects, etc)

Ex is the water exposure or the water depth where the building is located

Prot is the level of protection of the building by its environment (building row, natuar barriers, vegetation, walls, etc)

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PTVA Model & Water Intrusion Vulnerability

The vulnerability of a building due to its contact with the water depends on the number of floors that are inundated, including the basement:

WV= (number of inundatet levels) / (total number of levels)

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Model Application – GIS data

* **Geo-referenced and ortho-rectified aerial images provided by the local governments**
* **Digital Elevation Model with good horizontal resolution and vertical accuracy, used to calculate water depths for the building footprints**
* **A polygon shapefile for the building footprints. These were provided for the Manly Beach, but had to be digitized manually in the case of Maroubra Beach**
* **Attribute data for every building: building properties, environment et cetera**

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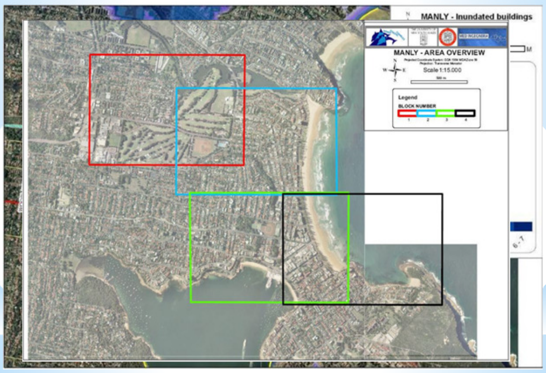
Model Application – GIS database Manly



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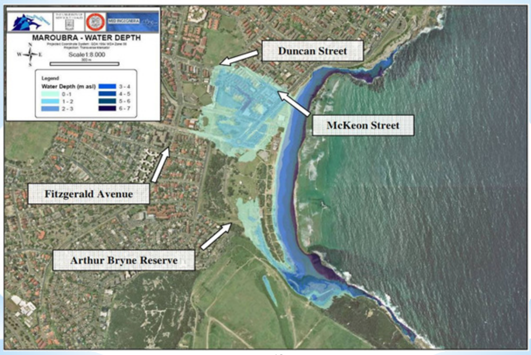
Model Application – GIS database Maroubra



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Results – Building Classes

* Local Government Buildings
* Health and Medical Service Buildings
* Recreation and Culture Buildings
* Utility Buildings (Water, Electricity, etc)
* Transport Buildings
* Tourism Buildings
* Commercial Buildings
* Residential Buildings

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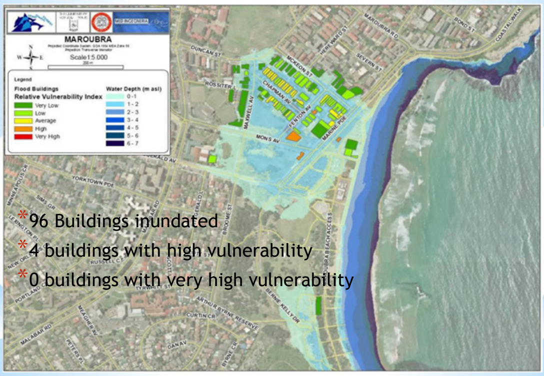
Results – RVI Maroubra Beach



* 96 Buildings inundated
* 4 buildings with high vulnerability
* 0 buildings with very high vulnerability

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Results – RVI Manly Beach

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Results – RVI Manly Beach

Manly (Blocks 1 – 4)		Relative Vulnerability Index (RVI) Scores				
Building class type	Number of buildings	Buildings with "Very Low" RVI	Buildings with "Low" RVI	Buildings with "Average" RVI	Buildings with "High" RVI	Buildings with "Very High" RVI
Local Government	23	4	9	3	1	6
Health & Medical	19	10	5	3	0	1
Education	19	7	5	6	1	0
Recreation &Culture	22	5	7	5	2	3
Utilities	12	2	0	2	4	4
Transport	5	2	0	1	0	2
Tourism	24	11	10	1	2	0
Commercial	217	113	66	21	7	10
Residential	865	218	295	193	119	40
Vacant and being redeveloped	8	-	-	-	-	-

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Discussion – Limitations of the study

* Absence of probabilistic tsunami event, the deterministic substitute could be considered unrealistic
* A numeric scenario based on a simulation could provide more accurate results
* The scenario could be conservative, as a real event could be of a greater magnitude
* Only two small areas covered by the study area, and therefore generalizing for the whole Sydney metropolitan area is impossible
* Focus on the vulnerability of structures. The vulnerability of community, local economy, natural environment and humans is not considered
* The tsunami impact on buildings with multiple uses is not clear. However, such buildings were catalogued for future research

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Discussion - Recommendations

* Geological studies for better understanding paleo-tsunamis in the region and verifying the Australian Mega-tsunami Hypothesis
* Tsunami Modeling for key locations in the New South Wales area
* Distribution of the study results to Local Governments
* Collaboration with the State Emergency Service for evacuation plans
* Minimize development in areas of low altitude
* Coordination with the Local Governments for reviewing and improving the buildings with high and very high vulnerability

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Conclusions – Initial aims fulfillments

* Successful establishment of a credible worst case tsunami scenario
* Successful collaboration with the Local Governments
* Successful improvement and utilization of a tsunami vulnerability assessment model
* Successful utilization of data and calculation of RVI
* Realization of limitations to this approach, such as flow approach and velocity
* Series of recommendations based on the results
* The PTVA model was proven to be useful and is recommended for similar assessments in Australia and other areas of the world

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