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

ArcGIS Toolbox Extension

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Introduction - PTVA Model

- The Papathoma Tsunami Vulnerability Assessment (PTVA) Model calculates the tsunami vulnerability of buildings in a given tsunami flood area
- It was first developed and applied in 2003, tested on the effects of the 2004 Indian Ocean tsunami, and then improved and applied again in 2009 for calculating the tsunami vulnerability of two coastal areas in Sydney Australia
- It is a deterministic model that uses the characteristics of buildings and their surroundings to determine their vulnerability due to their exposure and prolonged contact with water by a tsunami

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

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)

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 inundated levels) / (total number of levels)

PTVA Model - Required Data

- Inundation Scenario
- Geo-referenced and ortho-rectified aerial images
- 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
- Attribute data for every building

PTVA Model – Building Attributes

- Inundation depth
- Building material
- Number of stories
- Ground floor hydrodynamics
- Foundations type
- Shape and orientation of building's footprint
- Preservation Conditions
- Proximity to movable objects
- Building Row
- Presence of seawall
- Presence of natural barriers
- Brick wall around the building
- Basement levels
- Number of units
- Building use

7

PTVA Model – Building Attributes Scores

	-1	-0.5	0	+0.25	+0.5	+0.75	+1
s	more than 5 stories	4 stories	3 stories		2 stories		1 storey
m	reinforced concrete		double brick		single brick		timber OR fibro
g	open plan	open plan and windows	50% open plan		not open plan, but many windows		not open plan
f	deep pile foundations (>5 stories)		average depth foundations (3 stories)				shallow foundations (1 story)
so	rounded OR triangular building footprint	square building footprint with oblique orientation OR lengthened rectangular footprint with the main side perpendicular to the shoreline	rectangular building footprint with the main side perpendicular to the shoreline, OR slightly oblique		square building footprint OR rectangular with the main side parallel to the shoreline		lengthened rectangular building footprint with the main side parallel to the shoreline
mo			buildings far from sources of movable objects	buildings along roads with many parked cars	buildings before a car park, OR on intersections without parked cars	buildings on a side of a car-park OR on intersections with many parked cars	buildings behind large car-parks
pc	very poor	poor	average		good		excellent

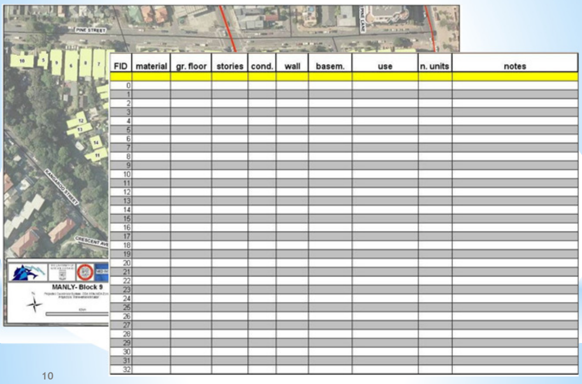
8

PTVA Model – Building Protection Scores

	0	0,25	0,5	0,75	1
Prot_br (building row)	>10th	7th - 10th	4th - 6th	2nd - 3rd	1st
Prot_nb (natural barriers)	very high protection	high protection	average protection	moderate protection	no protection
Prot_sw (seawall height and shape)	vertical and >5m	vertical and 3 to 5m	vertical and 1.5 to 3m	vertical and 0 to 1.5m OR sloped and 1.5 to 3m	sloped and 0 to 1.5m OR no seawall
Prot_w (brick wall around buildings) ***(calculated by the model)***	height of the wall is from 80% to 100% of the water depth	height of the wall is from 60% to 80% of the water depth	height of the wall is from 40% to 60% of the water depth	height of the wall is from 20% to 40% of the water depth	height of the wall is from 0% to 20% of the water depth

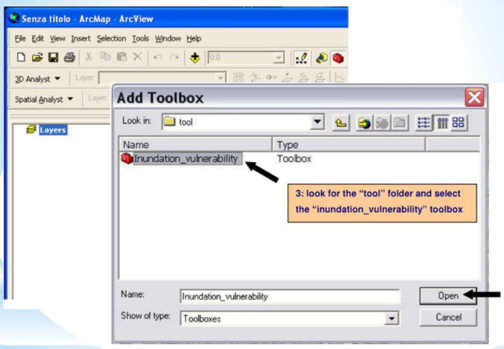
9

PTVA Model – Field Survey



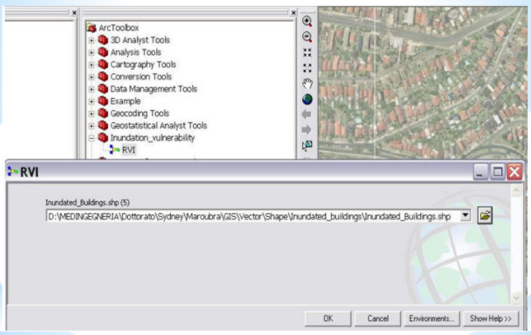
10

Toolbox Installation



11

Running the toolbox



12

PTVA Model - Outputs

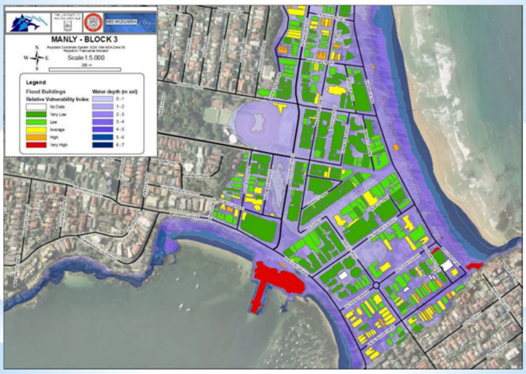
* RVI Score

RVI_1_5	[1 - 1.8]	[1.8 - 2.6]	[2.6 - 3.4]	[3.4 - 4.2]	[4.2 - 5]
RVI	VERY LOW	LOW	AVERAGE	HIGH	VERY HIGH

* Prolonged contact with water vulnerability score (WV)
* Structural vulnerability score (SV)
* Building vulnerability score (BV)
* Protection score (Prot)
* Exposure score (Ex)
* Other statistics

13

PTVA Model - Visualization



14

Thank you for your attention