TSUNAMI EVACUATION MAPPING & PLANNING

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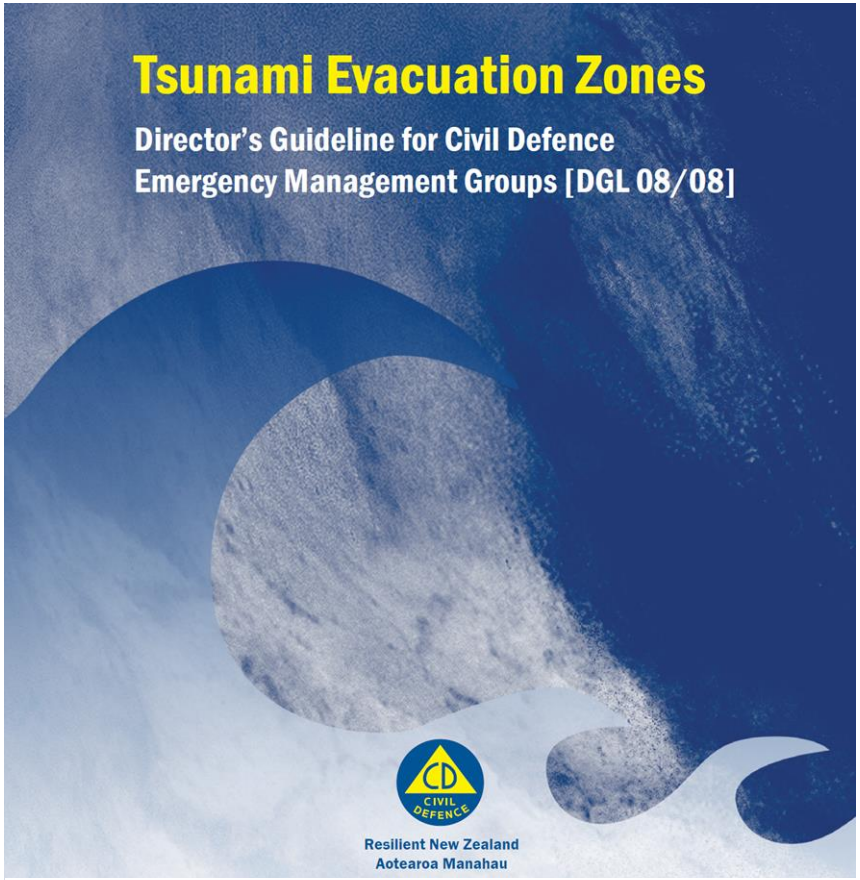
Overview

- Evacuation Mapping
- Evacuation Planning
- Evacuation Modelling
- Tsunami resilient buildings / vertical evacuation
- Challenges and opportunities

EVACUATION MAPPING



- **Evacuation zones need to allow for all** of the possible tsunami inundations that might occur

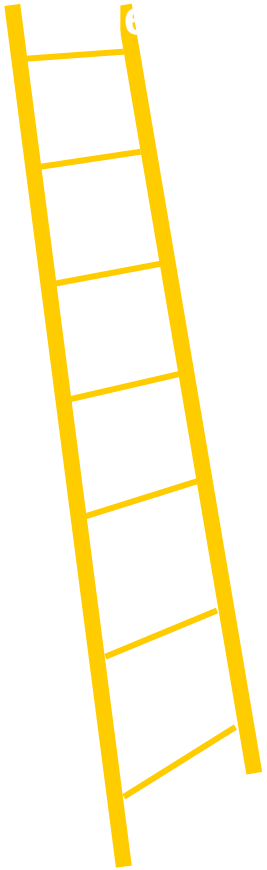
- Each tsunami can inundate quite a different area to another tsunami

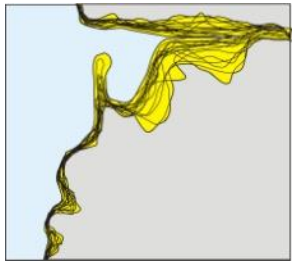
National evacuation mapping guideline

Nationally consistent tsunami evacuation zone maps provide a common language for:

- **Community planning** (modification / agreement by local communities and emergency managers)
- Public **education** to prepare for tsunami evacuation
- Emergency management evacuation **planning and exercises**
- During-event receipt of information from CDEM, **evacuations & decision-making**
- Placement of **signage** if desired
- Consistency for people **moving and holidaying nationwide**

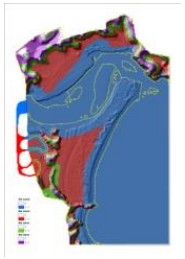
Ladder of four ‘development rungs’ for improving evacuation zone boundaries over time





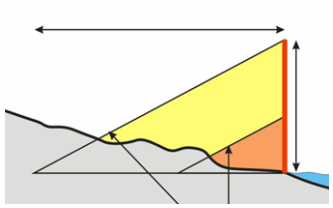
Rung 4

An **envelope around all inundations** from multiple (many?) well-tested computer models



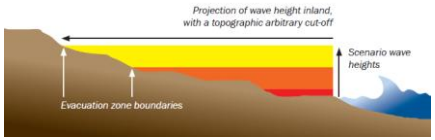
Rung 3

Hydrodynamic model of inundation for probabilistic wave heights



Rung 2

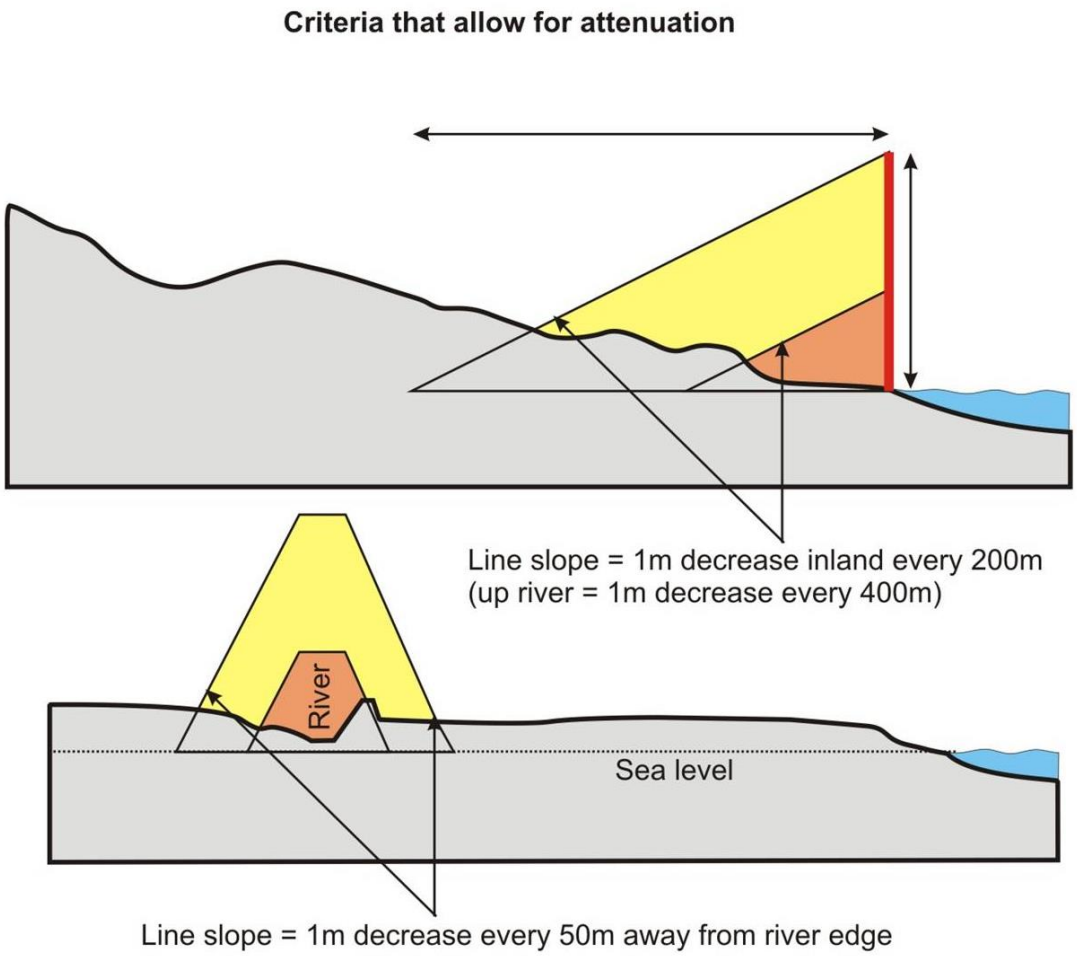
Approximation by a rule (can be prepared in **GIS**) **–** allowing for drop-off inland from the coast

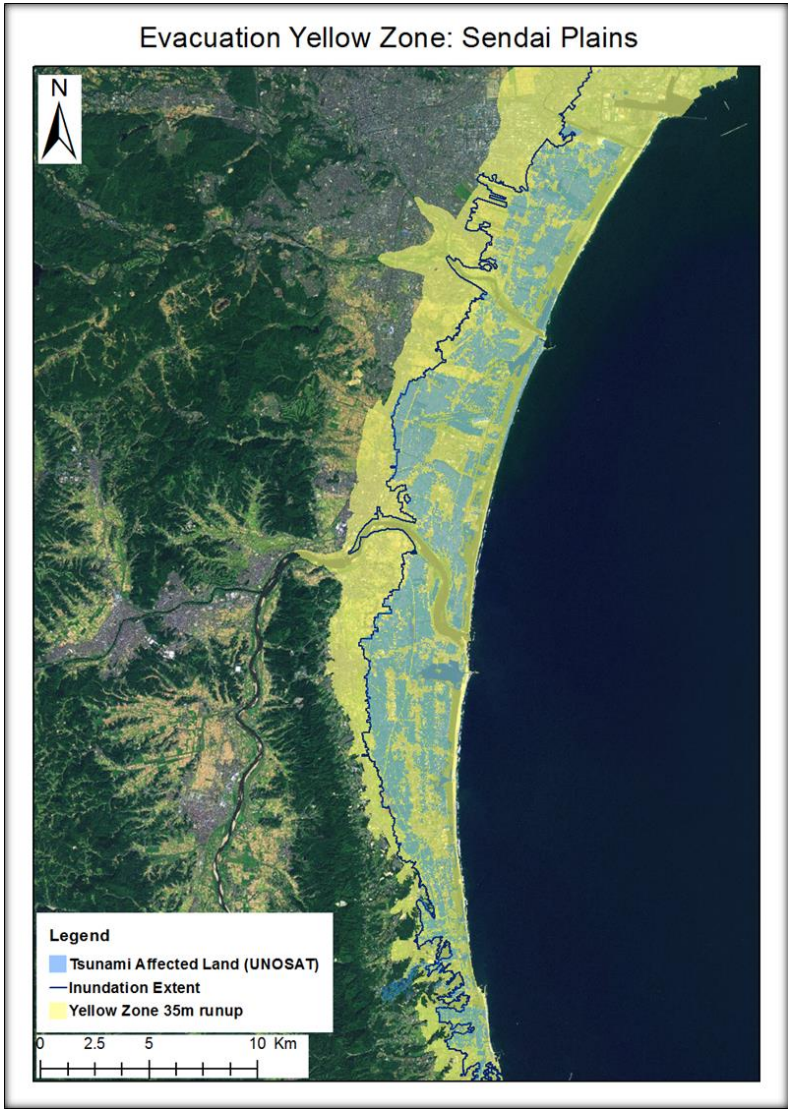


Rung 1

Bathtub inundation (i.e. up to a specific elevation)

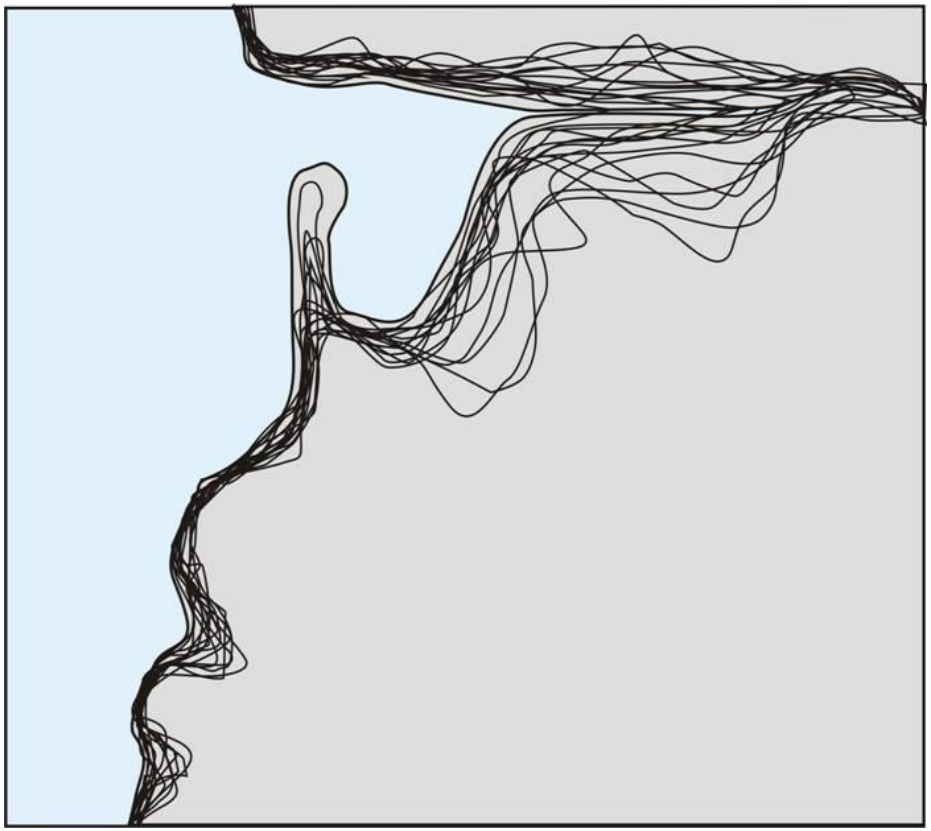
Rung 2: GIS-calculated rule





Rung 4:

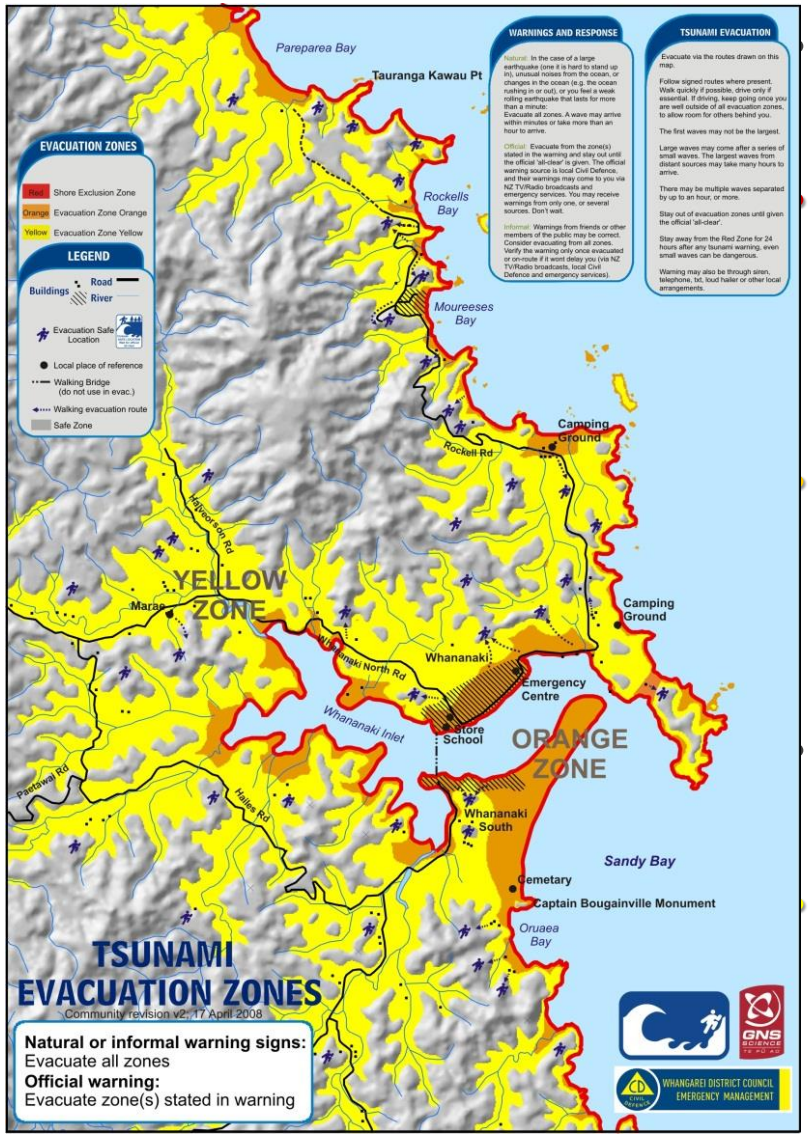
Each modelled earthquake scenario produces a different tsunami inundation extent



An envelope around many inundation models (yellow), to cover all expected tsunami:

Forms the evacuation zone

New Zealand evacuation map style



Recommended to have three zones:

Red zone: shore-exclusion zone that can be placed off limits in the event of any expected tsunami

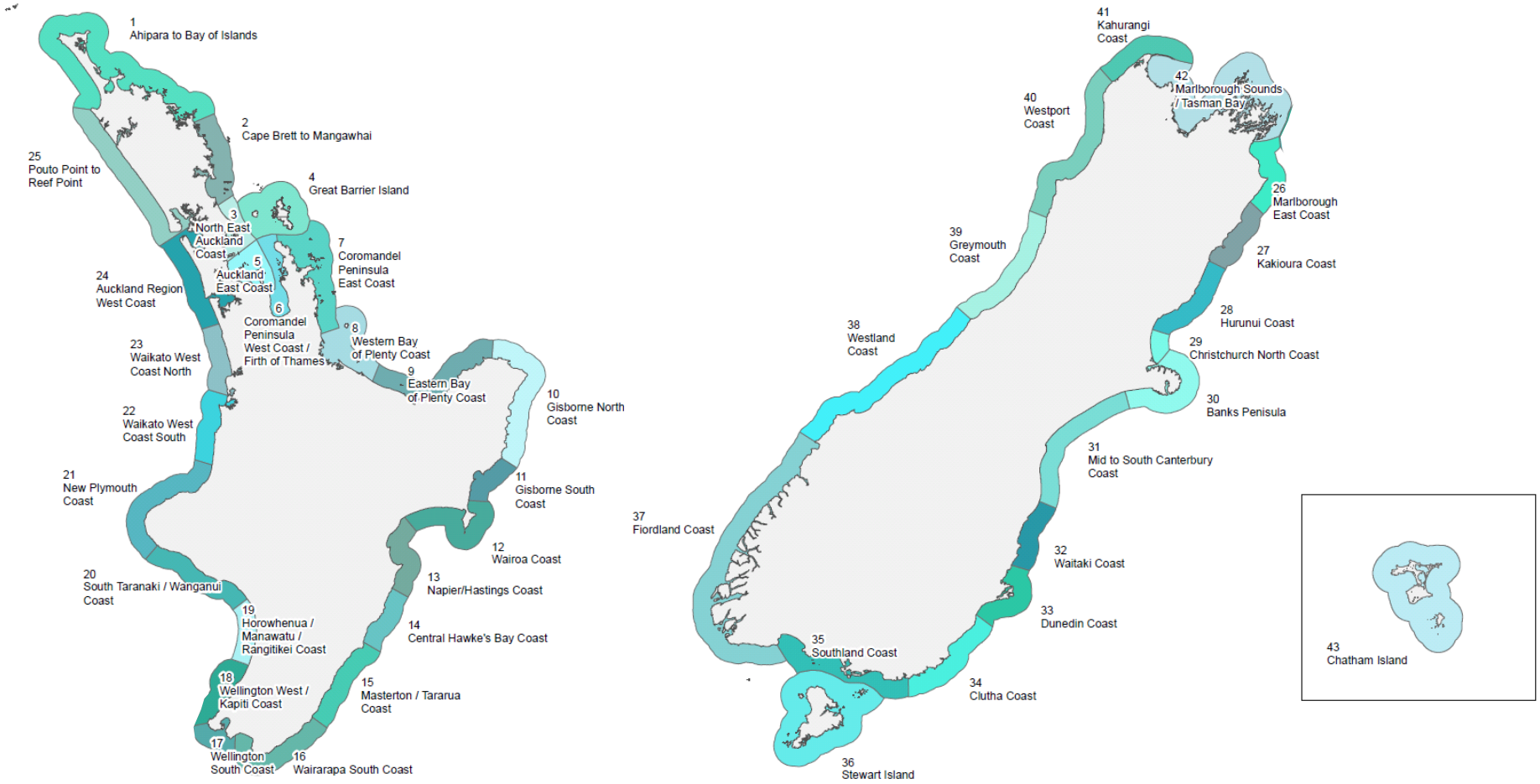
Orange zone: intended to be evacuated in most if not all distant- and regional-source official warnings that extend beyond the red zone

Tied to a warning threat level

Yellow zone: allows for all local-source expected events

- Very unlikely that an event will inundate much of this zone in a person's lifetime

Coastal Zones for Tsunami Warnings



Triggering evacuations
- five official-warning threat levels

AT SHORE:

- **20cm - 1m Threat to beach and small boats**
- **1m - 3m Some land threat**
- **3m - 5m Moderate land threat**
- **5m - 8m High land threat**
- **8m + Severe land threat (local & regional sources)**

NB: Run-up up to twice as high on steep slopes near the coast (onshore). I.e. 5m at shore can run up as high as 10m near the shore.

Given as height above ambient water level at time of wave arrival

EVACUATION PLANNING

CORE WARNING RESPONSE MESSAGE:

Natural or informal warning:

- A huge earthquake is one that is **long**er than a minute OR too **strong** to easily stand up in
- Evacuate all zones (**beyond the blue line in Wellington)**

- Immediate evacuation increases chance of survival (discourage fatalism)

Official warning:

- Evacuate zone(s) stated in the official warning

Tsunami Evacuation Planning

- Identification of
  - evacuation routes
  - safe locations
- Locate signs
- Walk-through chosen routes – participant feedback
- Final update of map with findings of walk-through

Tsunami Evacuation Exercise – Notes

Issue	Comments
Pocket Location and Contact details of person undertaking test	POCKET II WHANANAKI VILLAGE 2 BRUCE & MARILYN YOUNG
Time it took to evacuate to safe location	20 MINUTES WALK.
Terrain: Easy/Medium/Difficult	EASY ON ROAD, MEDIUM CLIMB UP THE HILL
Items carried with you	DOGS!
Clothing worn	SHORTS/T SHIRT ETC.
Which map was easier to use and why?	COLOURED MAP EASIER TO READ.
Would you be able to use this route in all weather conditions?	PRETTY MUCH
Would you be able to use this route in the dark?	YES - WITH TORCH.
What would you need to have at your safe location if you were to stay there?	FOOD, SHELTER, & ENTERTAINMENT.

Don't forget to mark your route on the map(s) provided.

Evacuation signs if desired

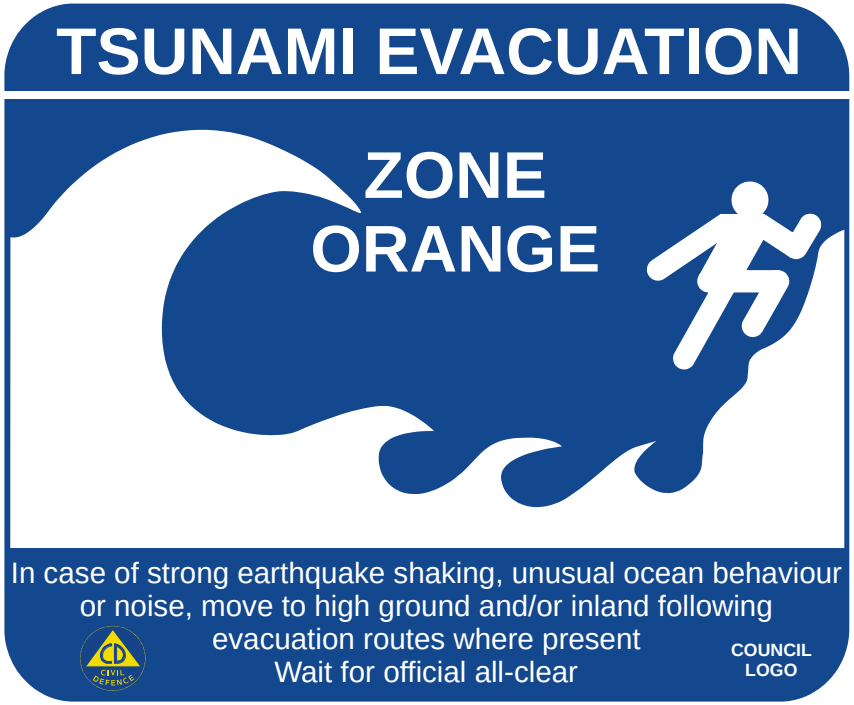
- Decide on sign locations as part of the evacuation mapping process
- It is difficult to locate signs without first laying out the evacuation zones and routes on the map
- Prioritised categories of sign in the “MCDEM Technical Standard: Tsunami Signage” as follows

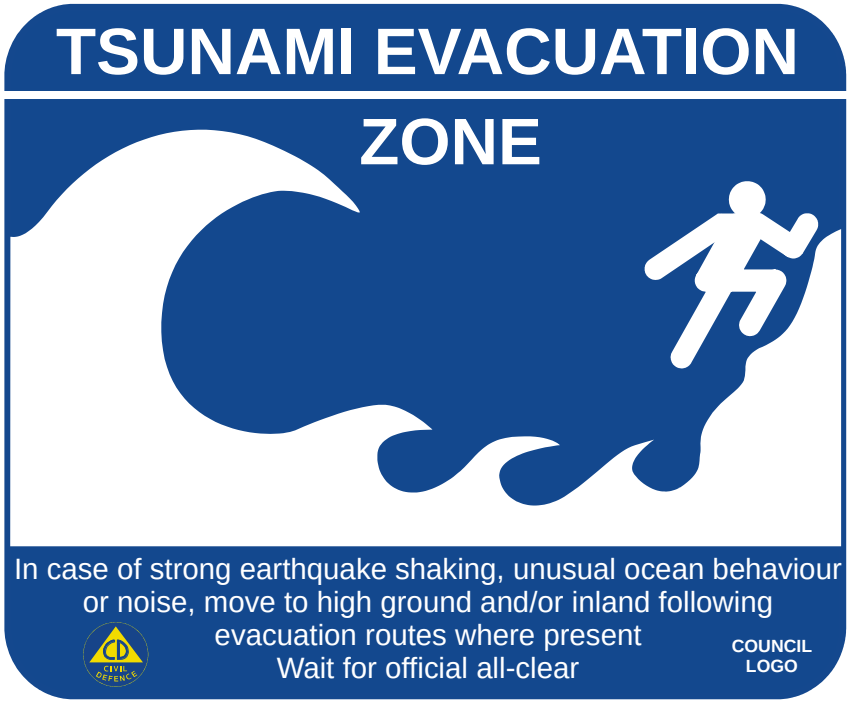
Priority 1 - Evacuation zone

Placed within zones to indicate a person should evacuate this zone in a warning

Contain natural warning sign information

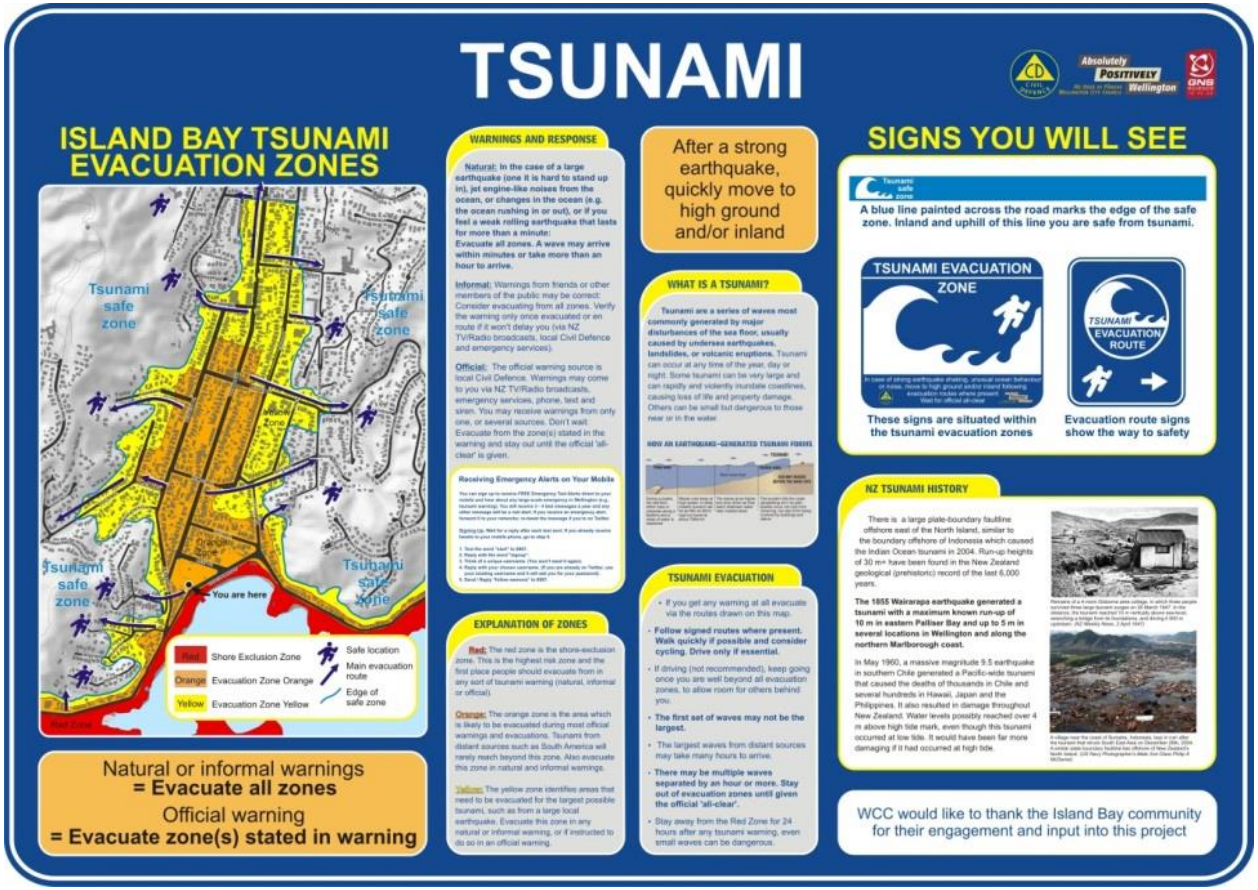
- zone boundaries can be moved as hazard understanding improves,
- implicit required action (evacuate)



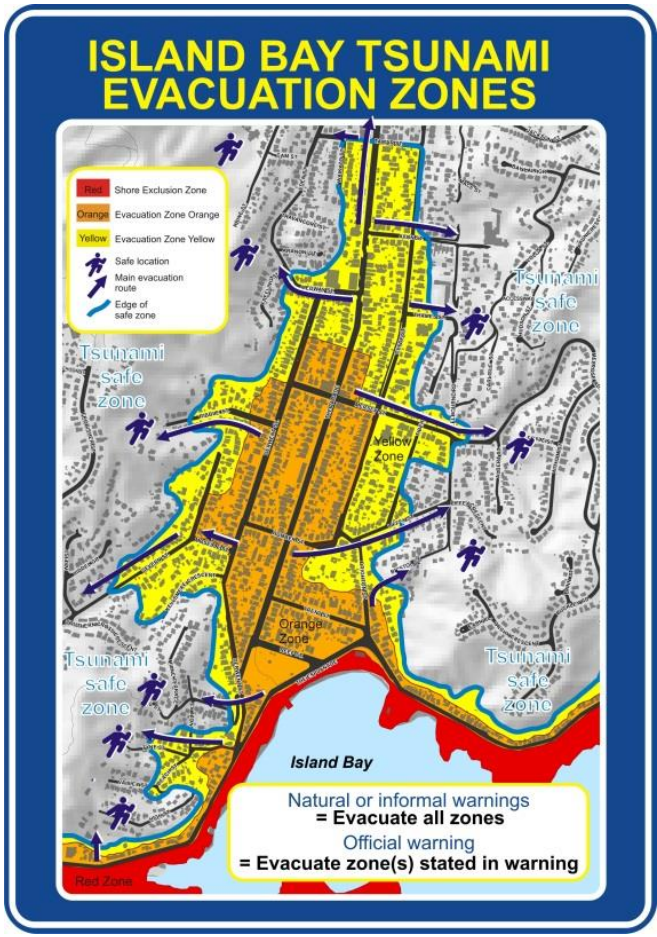


Priority 2 – Information Boards

Board including evacuation map



Map as board



Priority 3 - Evacuation route (generic)
(add white adhesive arrow according to required direction)

Priority 4 – Safe Location

TEXT ON MAPS: “Tsunami evacuation”

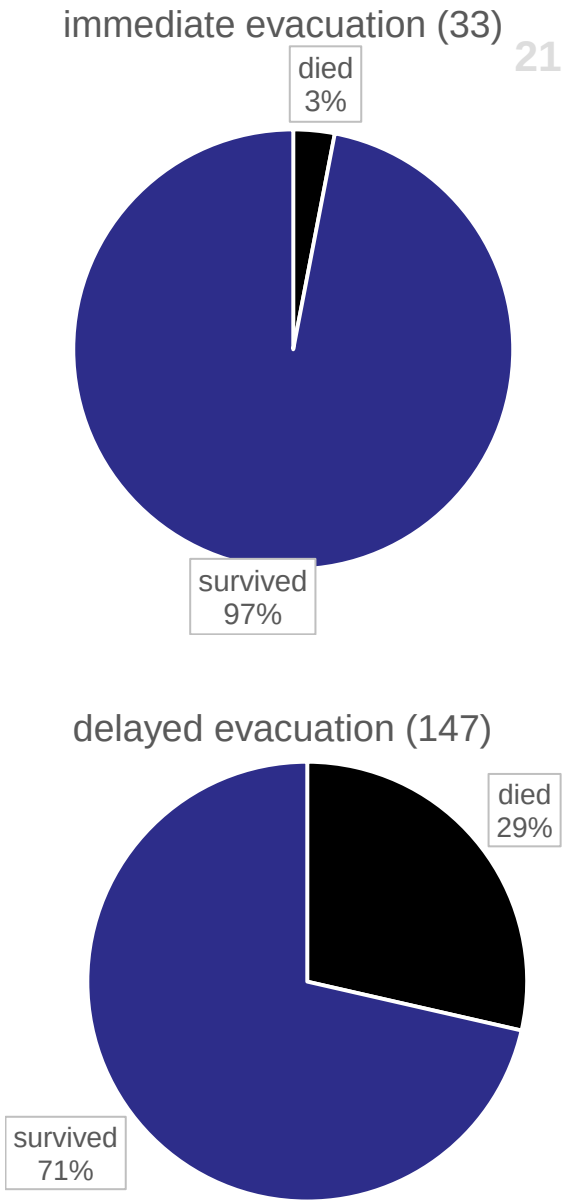
- Evacuate via the routes drawn on this map
- Follow signed routes where present. Walk quickly if possible, drive only if essential. If driving, keep going once you are well outside of all evacuation zones, to allow room for others behind you
- The first waves may not be the largest
- Large waves may come after a series of small waves. The largest waves from distant sources may take many hours to arrive

TEXT ON MAPS: “Tsunami evacuation”

- There may be multiple waves separated by up to an hour, or more
- Stay out of evacuation zones until given the official 'all-clear‘
- Stay away from the Red Zone for 24 hours after any tsunami warning, even small waves can be dangerous
- Warning may also be through siren, telephone, txt, loud hailer or other local arrangements

Education around evacuation

- **Consistent expectation of technological warning (Siren, TV / Radio), less recall of natural warning message**
- **Confusion about tone / meaning of expected messages**
- **Indirect / delayed evacuation**
  - **school pick-up, helping others, contacting family, confirming warning, gathering belongings**



Education around evacuation

- Usual method of transport is key for determining evacuation travel mode

- Recent survey, 50/50 - 60/40 pedestrian vs. vehicle
  - Some recognition that road condition might preclude vehicles

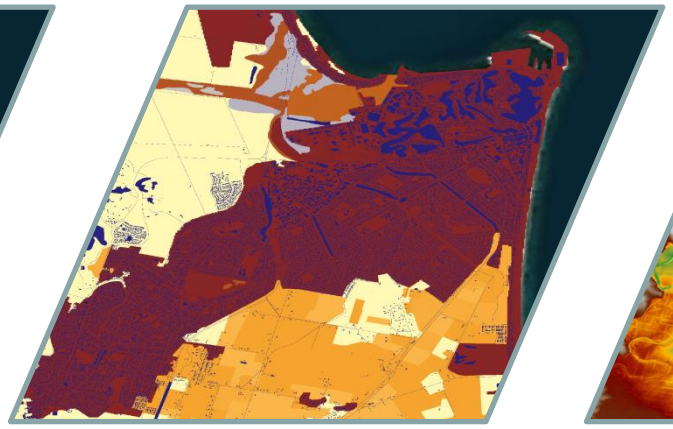
EVACUATION MODELLING
(SIMULATION OF EVACUATION POTENTIAL)

Evacuation Modelling

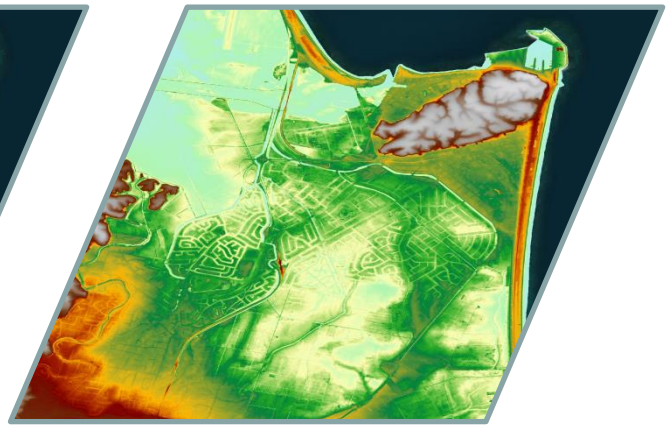
- Purpose: identify most suitable routes (travel time, avoidance of other hazards)
- Purpose: identify populations with poor evacuation potential
  - A need for alternative options (e.g. vertical evacuation)?
- Grid-based GIS approach (least-cost path distance)
  - Slope, landcover impact on travel speed
  - Require good exposure data
- Number of people able to evacuate in available time

Least-cost path distance model

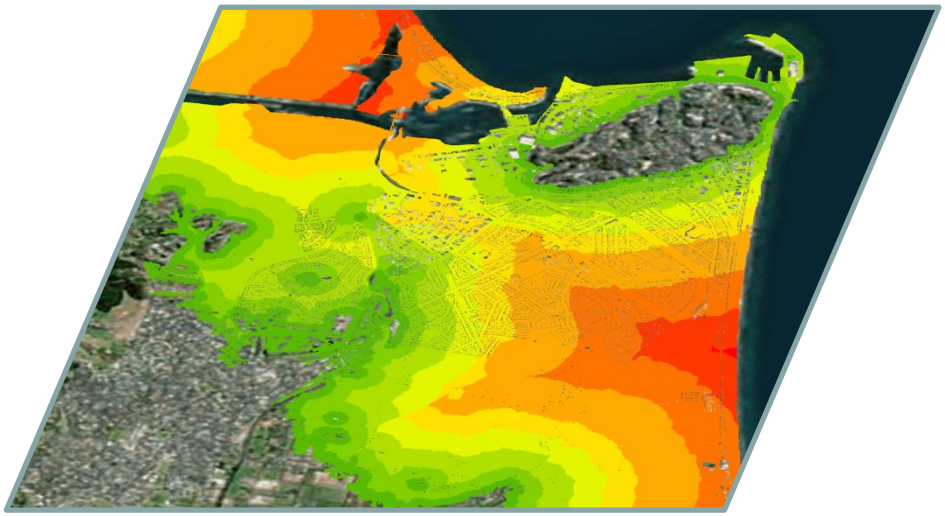
Safe zone



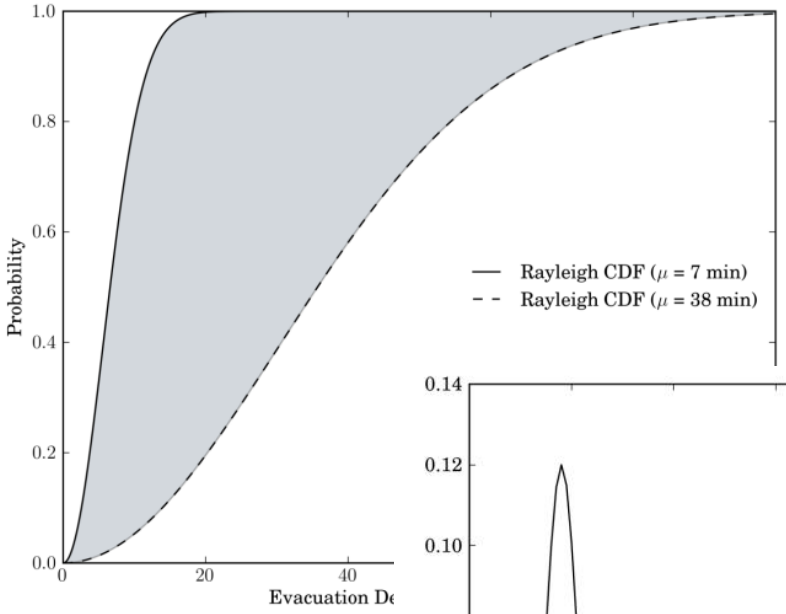
Landcover

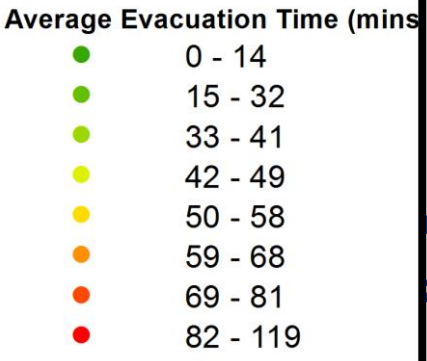


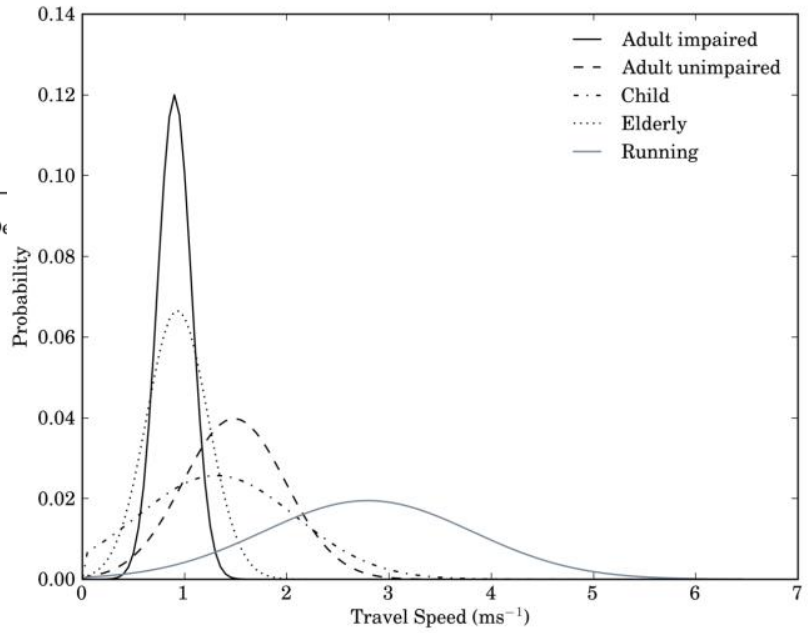
Topography

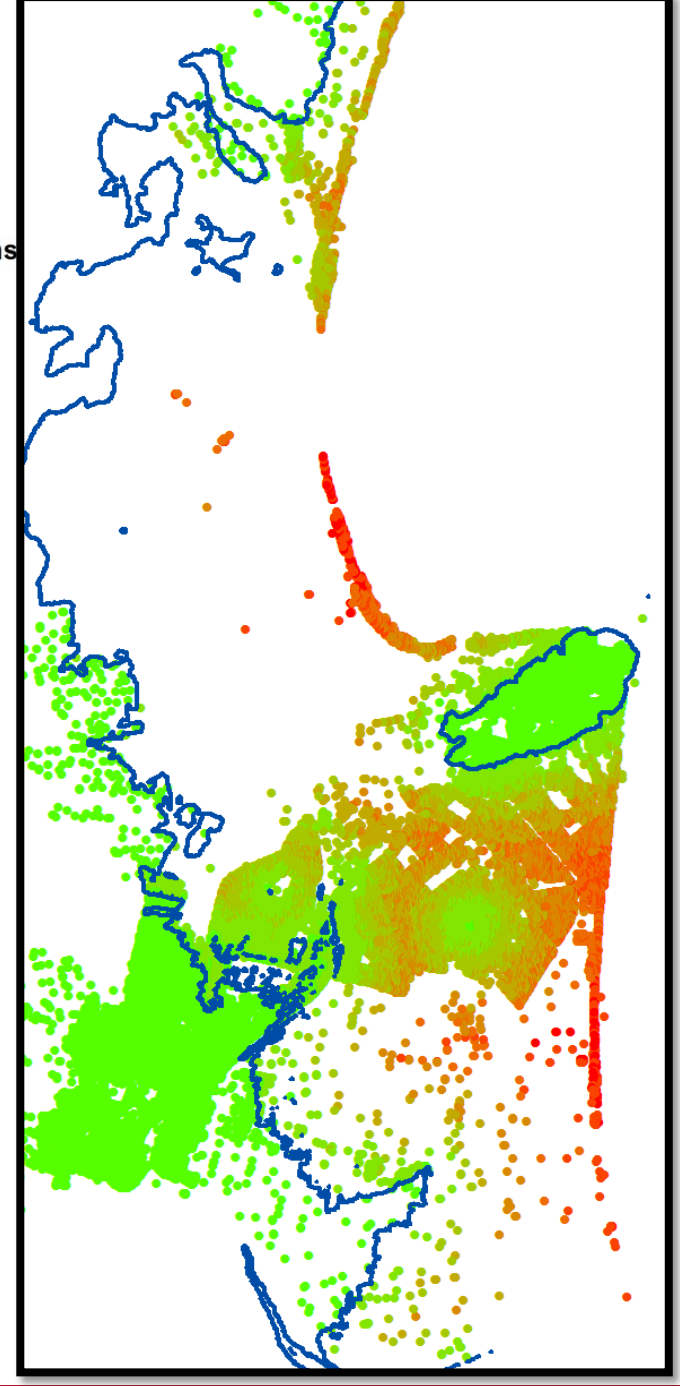


Total Evacuation Time



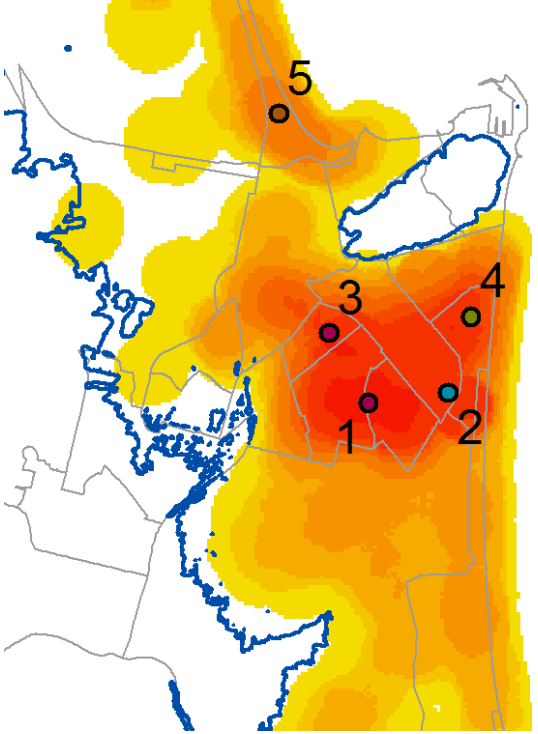






Impact of TVEB

- **Potential number of evacuees served by two example vertical evacuation buildings**



	no TVEB	TVEB #1	TVEB #2	TVEB #1+2
Safe	25,404	25,461	25,442	25,477
<38 min	17,976	21,762	20,693	23,005
>=38 min	17,964	14,120	15,208	12,861
change in >=38 min		-21%	-15%	-28%
Potential evacuees		3,844	2,756	5,103

TSUNAMI RESILIENT BUILDINGS AND VERTICAL EVACUATION

Tsunami Vertical Evacuation (TVE)

- **Evacuation to safety above flow height within expected inundation zone**
- **Intended for local events**
- **Additional option – inland or high ground are best**
- **Upper floors of high-rise buildings**
  - **every-day use (e.g. office blocks, hotels)**
- **Structures built specifically for evacuation**
  - **(e.g. towers)**
- **Artificially constructed raised ground**
  - **(e.g. berms, hills)**
- **Japan; Indonesia; Hawaii, Washington (U.S.)**

FEMA P646A, 2009

Available codes for tsunami resilient construction

- Update to scope, calculations in 2016
- Japan: Cabinet office (2005)
  - Update to reduce load factors, refine calculation
- Adoption of FEMA guidelines in Chile
- EU funded project: EU-wide code to include tsunami resistant design

FEMA P646

- LOADS: Hydrostatic / dynamic, buoyant, impulsive, uplift; debris dam/impact; gravity
- Design elevation = 1.3 * modelled maximum tsunami elevation + 3 m
- Combinations of tsunami loads, but not EQ+TS loads
- General attributes of tsunami-resistant structures:
  - Strong systems with reserve capacity to resist extreme forces
  - Open systems to allow water to flow through
  - Ductile systems, to resist forces without failure
  - Redundancy, to allow partial failure without progressive collapse
- Design recommendations for individual components:
  - Columns to be designed to withstand lateral loads, and to be of a circular shape
  - Plan orientation of shear walls to minimise load
  - Floor systems to be designed to reduce buoyant forces

2016 ASCE 7 Tsunami Loads and Effects Subcommittee

- Current FEMA guidelines for vertical evacuation facilities only

- New ASCE guidelines to apply to large public, commercial, and special-occupancy buildings
  - design guidelines for non-structural systems
  - hazard assessment and inundation analysis procedures
  - vertical evacuation refuges: immediate occupancy for maximum credible tsunami (1 in 2,500 yr)
  - Simple method and site-specific method to calculate tsunami flow depth and velocity at a site
  - Structural measures to reduce loads
  - Prescriptive foundation design to resist scour

- Estimated economic impact of tsunami-resistant design: additional 2% of the cost of seismically-engineered buildings

Japanese vertical evacuation guidelines

- Government designation guidelines (2005)
  - Structure and planning aspects

- Structural requirements
  - Constructed post-1981, Reinforced Concrete or SRC
  - Earthquake damage did not prevent use in tsunami
    - Scour, debris, glazing, contents, cladding

- Height requirement driven by expected inundation depth
  - 3 m depth = 4 storeys or higher

- A few overtopped, many almost overtopped at low tide
  - Revised height requirements (min. 5 storeys)
  - Proposed to decrease force estimates in design loading


870
people


380
people


200
people
宮城県気仙沼合同庁舎


120
people


44
people


公立志津川病院


330
people

Observed damage

- **Fire damage – floating oil, debris**
  - **Need to fire-proof buildings, government action to prevent large leaks in tsunami**

Fire Damage at Kadonowaki School, Ishinomaki City

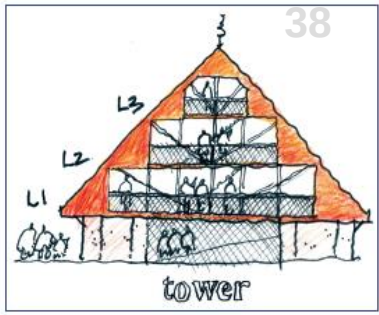
Refuge access

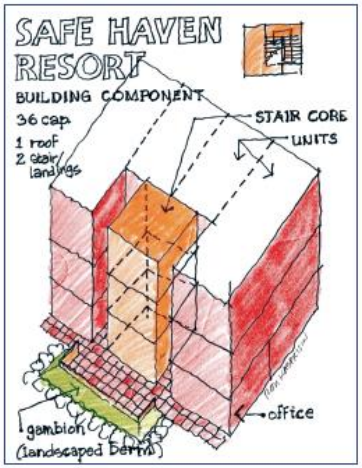
- **Options**
  - External stairs direct to roof
  - All-hours staffing (security, hospitals)
  - Residents / staff open buildings
  - Allowable forced entry
  - Local resident representative key-holders
- **Issues**
  - Places responsibility on staff
  - Allowing forced entry?
  - Legal / liability for occupants / damage to building
- **Explore feasibility for NZ case-by-case**

Vertical evacuation issues

PROJECT SAFE HAVEN:

TSUNAMI VERTICAL EVACUATION ON THE WASHINGTON COAST





- Owner agreement – leverage community interest
  - Corporate social responsibility, employee responsibility
  - Community identified buildings, approached government / owners

- Community planning, discussions, awareness
  - Access, liability, training community with staff / owners
  - Awareness of facility use – confidence in strength, welfare
  - Ownership of evacuation plans, local knowledge of best routes

Vertical Evacuation

- **Low consideration of buildings for evacuation in unprompted question – 15% of all respondents**

- **Explored factors that might encourage & discourage use**

Factor	Percentage of respondents
(–) Doubts about safety / height	43%
(–) Slow access / being trapped	20%
(–) Panic / over-crowding	19%
(–) Visible damage / debris	14%
(+) Described as safe / reinforced	34%
(+) If safest option in time available	24%
(+) If there was easy access	12%

Evacuee welfare

- Potential that refuge will be in use for days, not hours
  - Debris, standing water
  - Plan for 1-2 days
  - Shelter, food, water, comm. at welfare centres, not immediate refuge
  - Requires dedicated storage on upper floors or day-to-day building use
- Welfare may help to reduce no. of people leaving too early
  - Influence on future response (Sharma et al., 2009)

Signage

- Consistent signs but extremely inconsistent placement
  - New buildings only

- NZ signage standard

Potential update to NZ signage?

CHALLENGES AND OPPORTUNITIES

Challenges and Opportunities

- **Both… little memory about recent major tsunami**
- **Encourage positive evacuation behaviour**
  - **Encourage immediate evacuation**
  - **Reduce expectancy of siren / official warning in local-source**
- **Improve evacuation modelling**
  - **Understanding of warning response and evacuation behaviour**
  - **Account for vulnerable individuals and groups (e.g., poor mobility)**
  - **Implement in route AND refuge planning**

Challenges and Opportunities

- **Consistency in evacuation mapping**
  - Style, number of zones
- **Coordinated evacuation exercises**
  - Monitor, review, improve
  - Schools and businesses
- **Vertical evacuation into guidelines, link to land-use planning**
  - Design (structural and non-structural)
  - Latest (and forthcoming) guidelines
  - Placement, required capacity refuges
  - Regular purpose, funding, legal issues

REFERENCE SLIDES

Achieving consistency in evac planning

- RP of largest zone should never be lower than RP of subduction zone
- 3 zones. Choice made by EMs. Consistency is important across NZ. Guidelines allow for just 2 zones if local source is not larger wave height than Dist/Reg.
- Calibration of orange zone at a threat level – choice of return period is local choice, but needs to be noted as to what
- Dropping to 2 zones everywhere: must evacuate to full local source each time there is an evac. Results in such a big evacuation each time, that EM are more cautious about calling one (WA, US)
- Going to more zones (more complexity): more difficult for public comprehension and memory

Land-use planning uncertainty

- Explanation of translating EP curve uncertainty to mapped inundation.
  - The key is understanding of the EP curve
    - Explain multiple runs, generation of frequency and severity
  - Map mean, LQ, UQ wave height at coast onto inundation through propagation of wave height inland, or ideally by mapping every montecarlo run directly to inundation
- For LU planning
  - The uncertain area often doesn't get mapped, instead shown as single hard line.
  - 1. what is acceptable RP for building/use class. Political decision. Must be taken first.
  - 2. what level of uncertainty are you happy to tolerate: controls uncertainty around mean, which is to be mapped.

Evacuating people with disabilities

- Familiarise with planning tools that have already been developed by reputable organizations
- Ensure representation by the disabled community throughout the planning process
- Identify the needs of the community
- Facilitate/aid self-identification and preparation
- List resources to assist people with disabilities
- Train first responders in the needs of persons with disabilities
- Build strong relationships with government agencies that work with disabled people