European Commission

Horizon 2020
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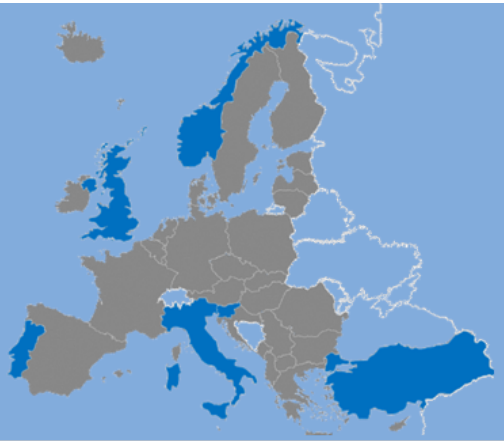


EARTHQUAKE INDUCED LIQUEFACTION RISK: HOLISTIC ASSESSMENT AND MITIGATION

Wednesday 20th June 2018 - 11:30-13:00

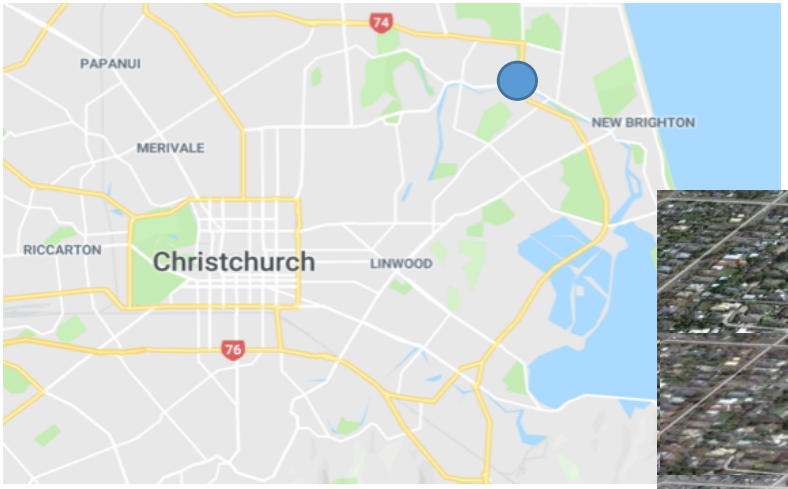
ROOM: CR2 (building M2 - Thessaloniki Concert Hall/16ECEE Conference Venue)

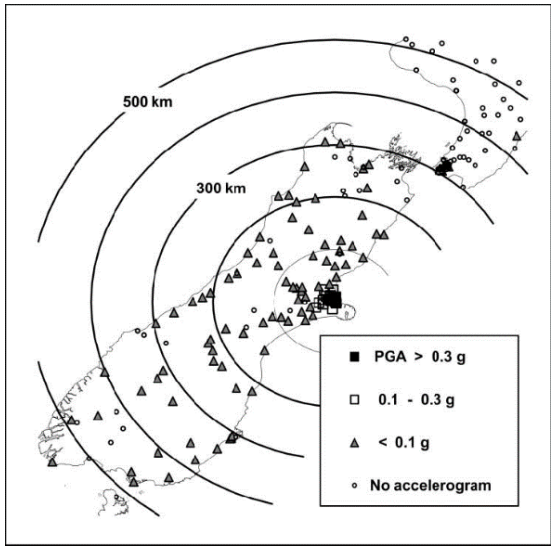
Liquefaction risk assessment: principles and observation

Giuseppe Modoni

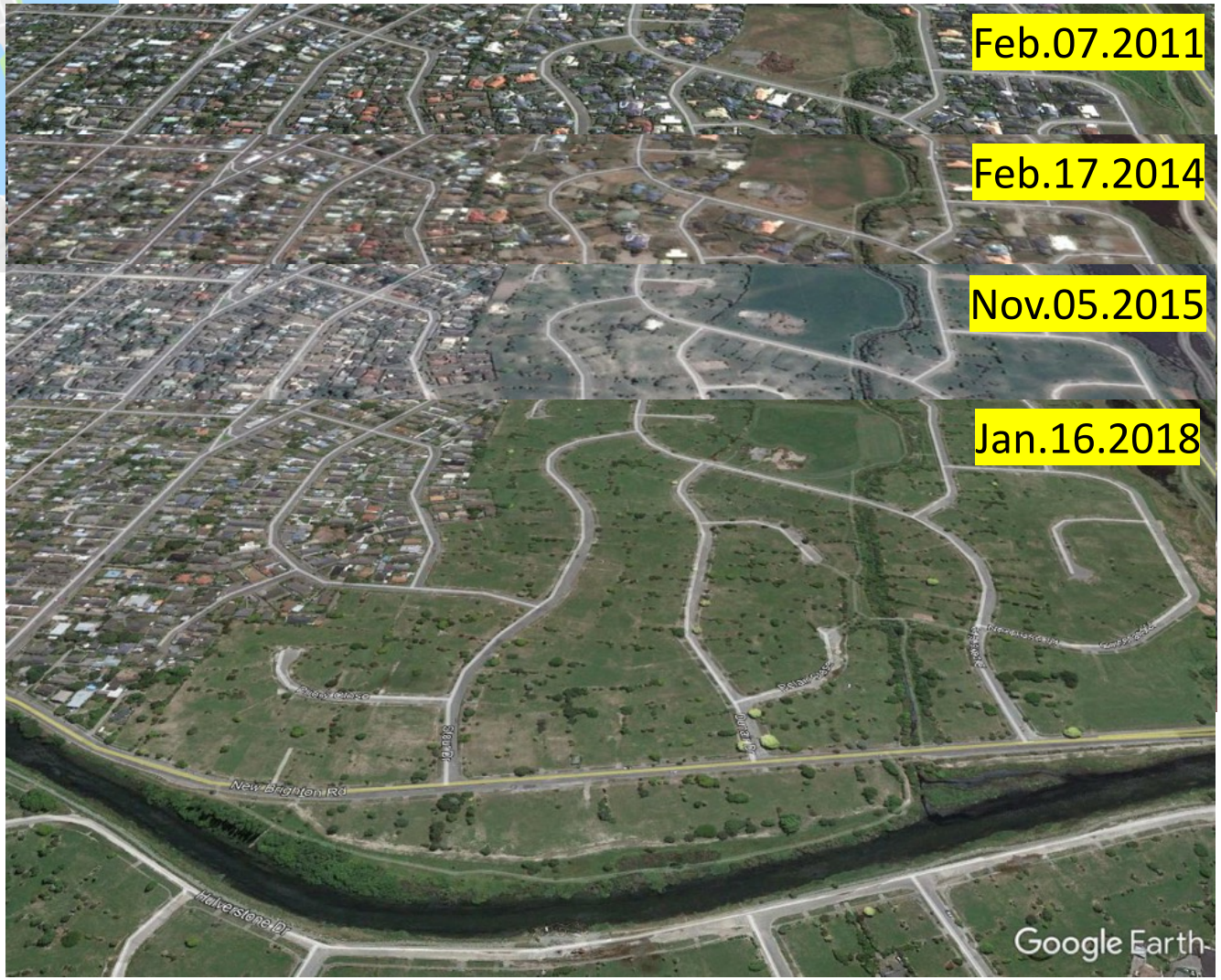
UNIVERSITY OF CASSINO AND SOUTHERN LAZIO

EARTHQUAKE INDUCED LIQUEFACTION: DESTRUCTIVE POTENTIAL





Feb.22.2011
Mw=6.2



EARTHQUAKE INDUCED LIQUEFACTION: DESTRUCTIVE POTENTIAL

SOME REMARKABLE CASE STUDIES

Christchurch
New Zeland (2010-2011)

Mw 6.2 (a_{MAX}=0.4 g - 30 sec)
dist. from epicenter 0-5 km
60 000 damaged buildings
1/3 infrastructures out of service
185 victims (0 due to liquefaction)
15 Billion US $ economic losses

Urayasu city
Japan (2011)

Mw 9.0 (a_{MAX}=0.15 g - 70 s)
dist. from epicenter 400 km
8700 damaged buildings
0 victims

Emilia Romagna
Italy (2012)

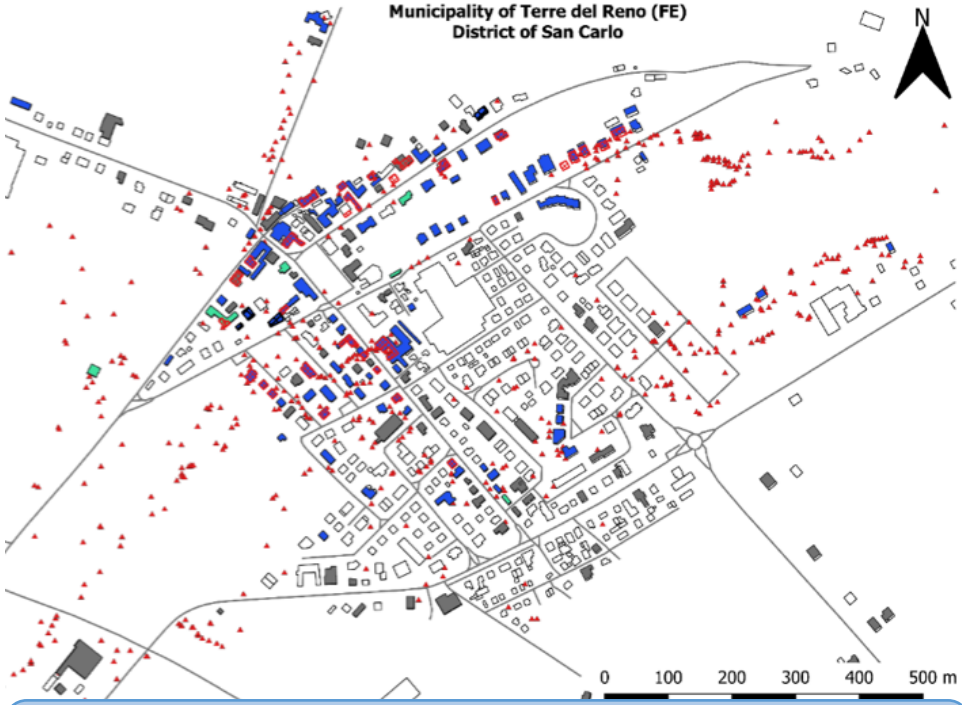
Mw 5.9 (a_{MAX}=0.29 g 20 s)
dist. from epicenter 10-50 km
12 000 damaged buildings
0 victims due to liquefaction
damage 15 Billion US $

EARTHQUAKE INDUCED LIQUEFACTION DAMAGES

Sites prone to Liquefaction (NZGS, 2016)

- River meanders and point bar deposits
- Lake shore delta deposits
- Estuarine deposits
- Beach ridge backwater deposits
- Abandoned river channels
- Former ponds, marshes, swamps
- Reclamation fills
- Tailing dams

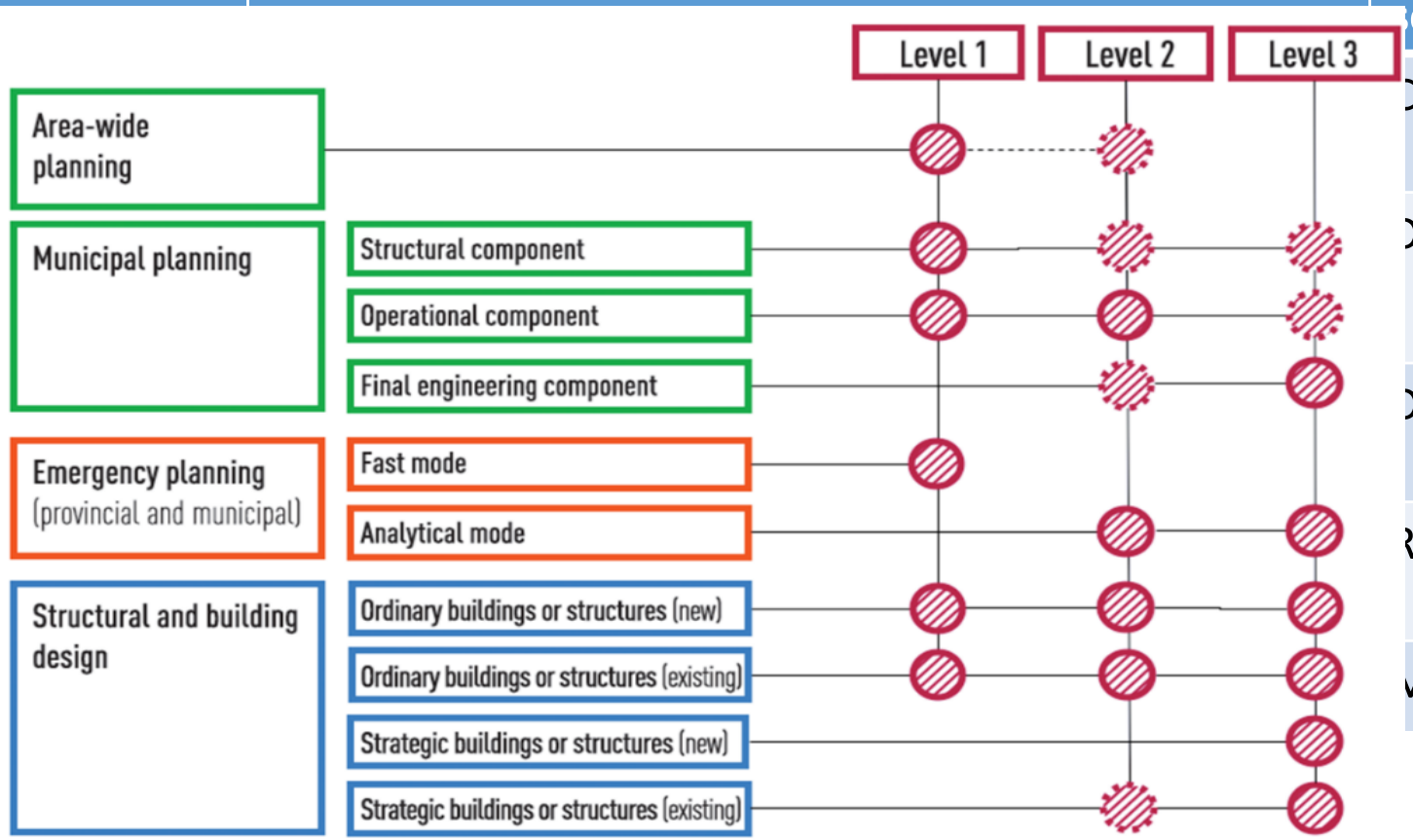
Urayasu – 2011
(Tokimatsu & Katsumata, 2012)



San Carlo – 2012 (RER-UNICAS, 2018)

SEISMIC LIQUEFACTIO RISK ASSESSMENT: WHO CARES ?

Stakeholder	Requirment for risk assessment	Geographical scale
Local govern (Regional, ci		City
Owners/mar infrastructur		District/city
Emergency planners/ma		District/city
Insurance/Re companies:		Regional
Designers		Manufact

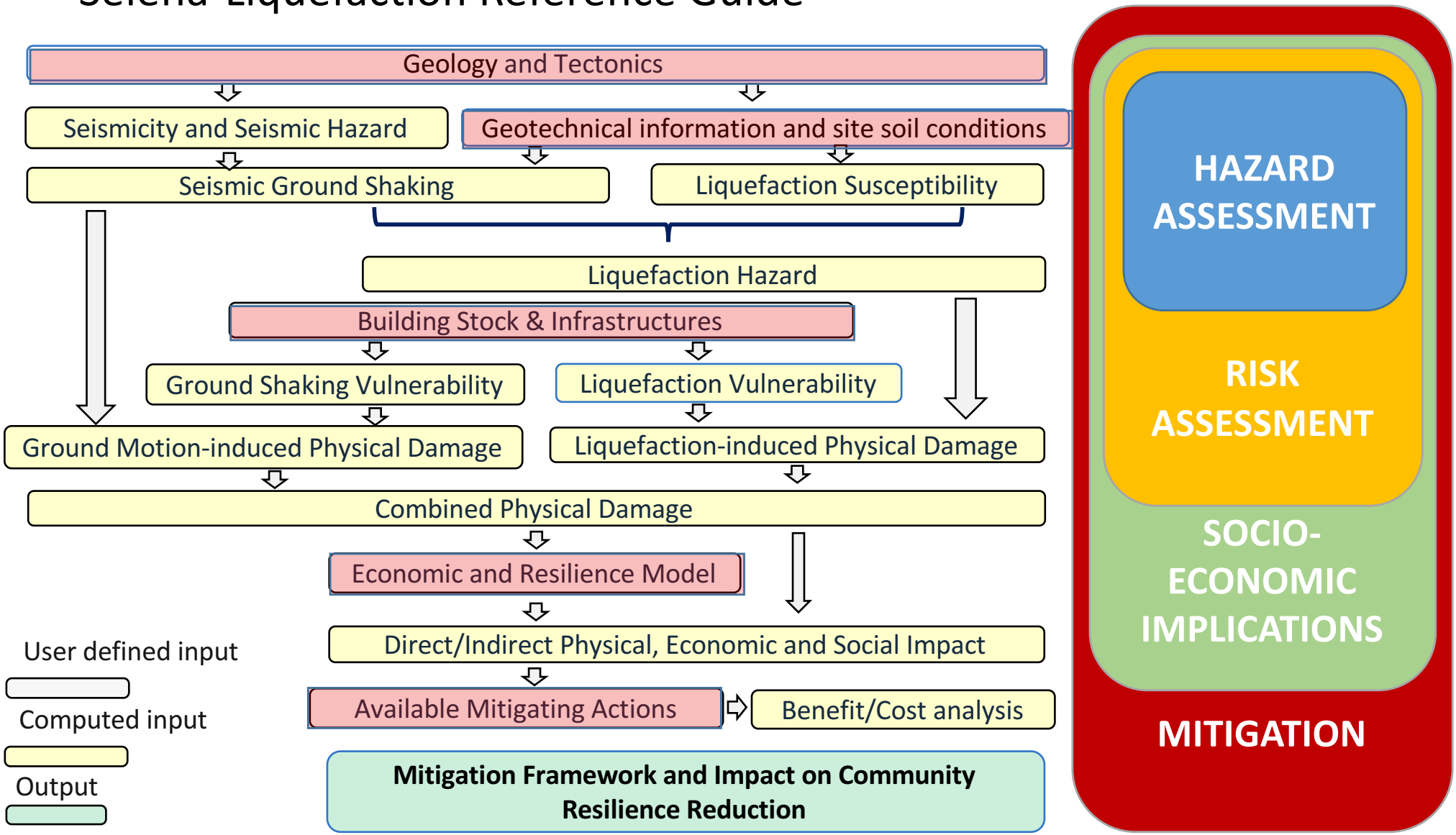


Physical asset/Economic losses/Social implications

MS -Linee guida per la gestione del territorio in aree interessate da liquefazioni (LQ) (2017)

Different geographical scale

Selena-Liquefaction Reference Guide



LIQUEFACTION RISK ASSESSMENT: GEOTECHNICAL DATABASES

Geology and Tectonics

Seismicity and Seismic Hazard

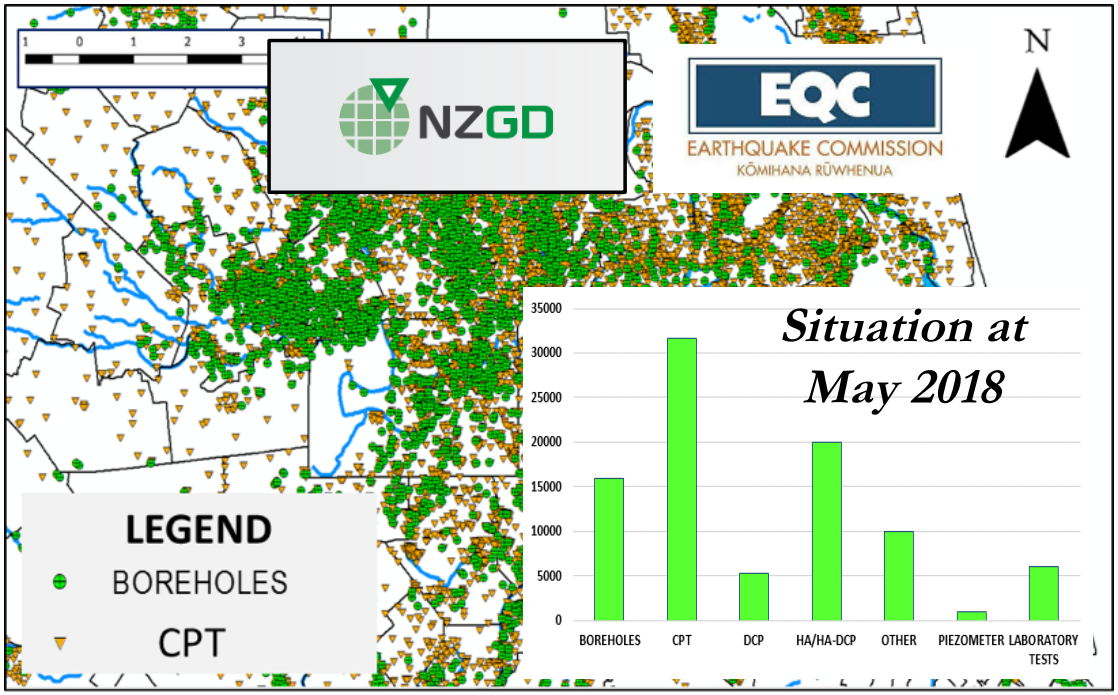
Geotechnical information, site soil conditions and GWT

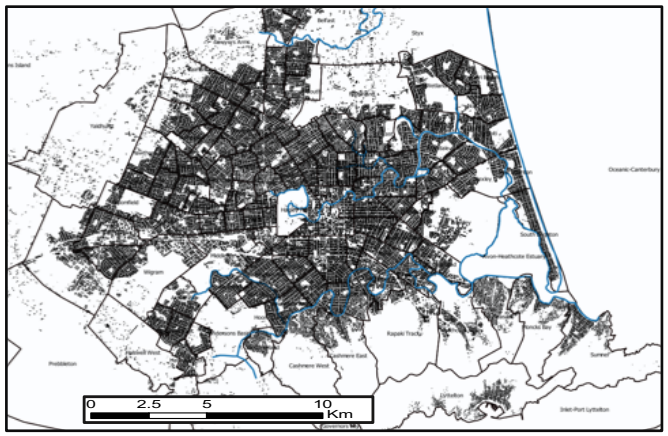
Seismic Ground Shaking

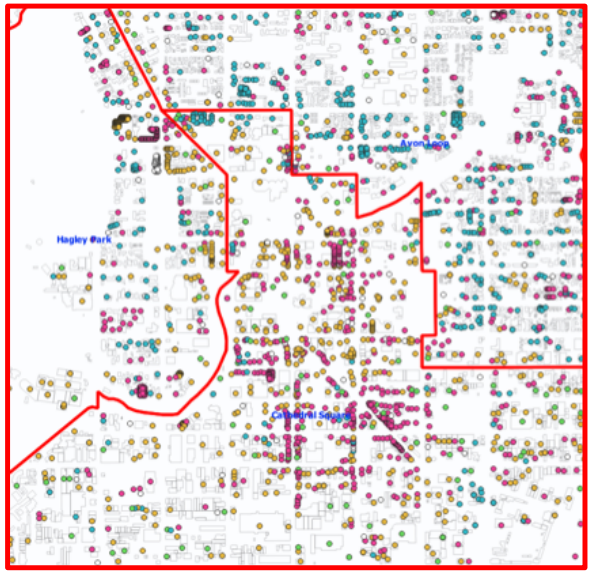
Liquefaction Susceptibility

Liquefaction Hazard

Building Stock & Infrastructures







Model buildings type

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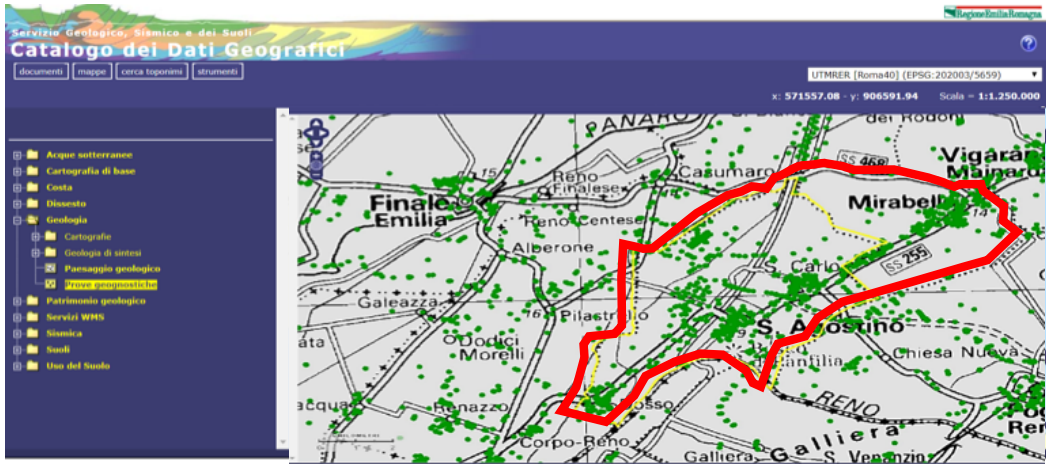
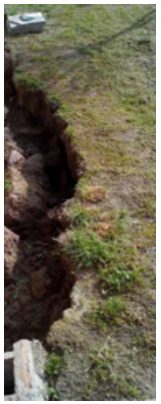


RegioneEmilia-Romagna

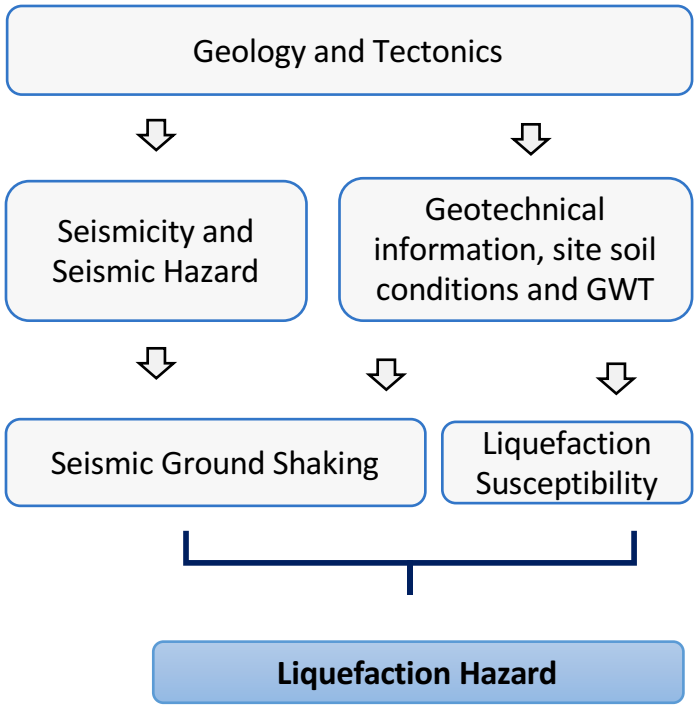
servizio geologico sismico e dei suoli

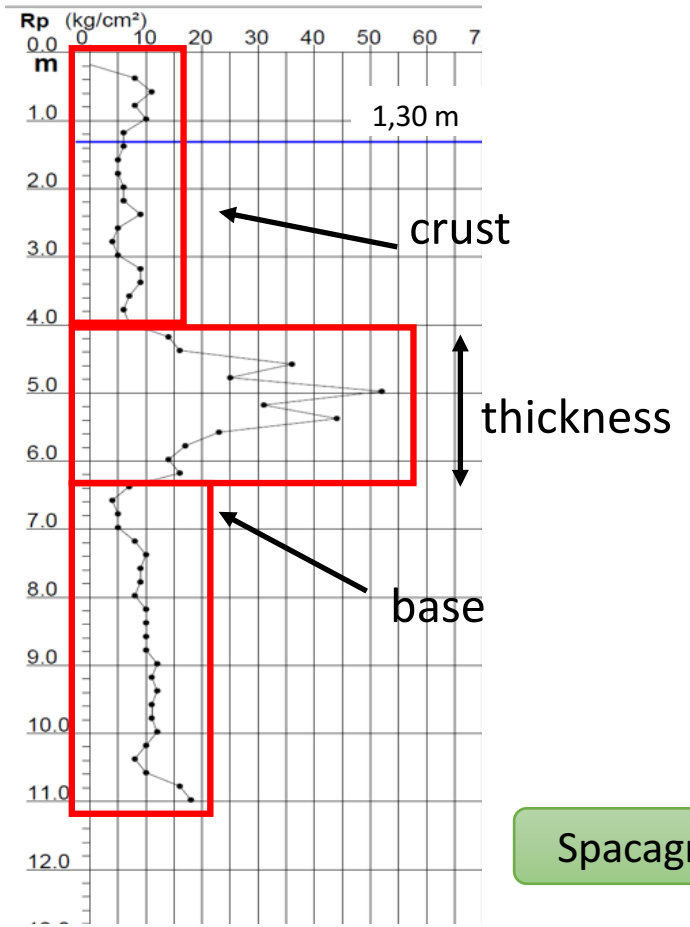
Emilia Romagna

(29410 CPT/CPTu, 12000 Boreholes, 14000 Wells, …)



LIQUEFACTION RISK ASSESSMENT: INDEXS VS DAMAGE





Zone	*Soil Behavior Type*	I_c
1	*Sensitive, fine grained*	N/A
2	*Organic soils – clay*	> 3.6
3	*Clays – silty clay to clay*	2.95 – 3.6
4	*Silt mixtures – clayey silt to silty clay*	2.60 – 2.95
5	*Sand mixtures – silty sand to sandy silt*	2.05 – 2.6
6	*Sands – clean sand to silty sand*	1.31 – 2.05
7	*Gravelly sand to dense sand*	< 1.31
8	*Very stiff sand to clayey sand**	N/A
9	*Very stiff, fine grained**	N/A

Spacagna et al. (2018)

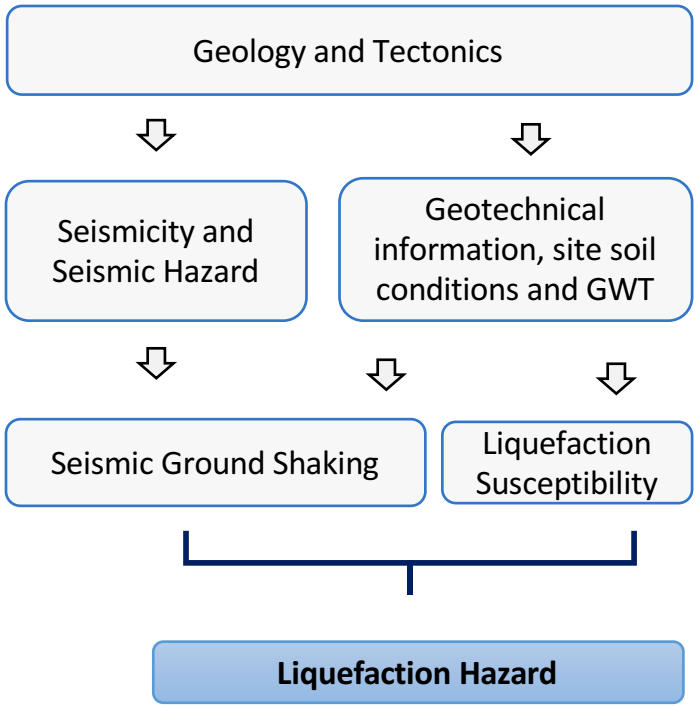
$$I_c = ((3.47 - \log Q_t)^2 + (\log F_r + 1.22)^2)^{0.5}$$

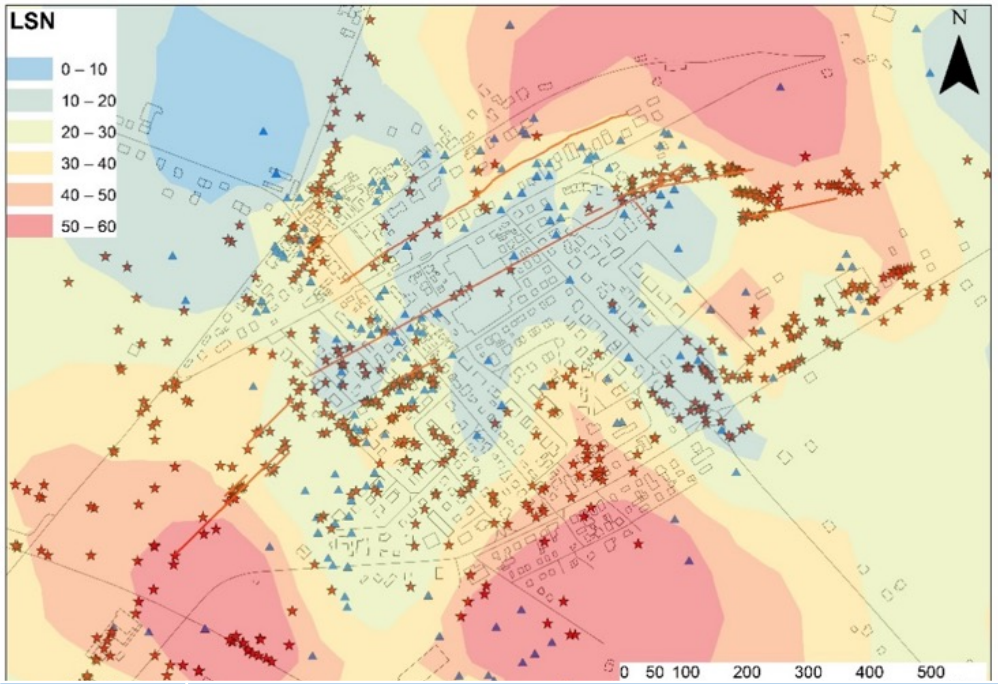
where:

Q_t = normalized cone penetration resistance (dimensionless)
= $(q_t - \sigma_{vo})/\sigma'_{vo}$

F_r = normalized friction ratio, in %
= $(f_s/(q_t - \sigma_{vo}))$ x 100%

LIQUEFACTION RISK ASSESSMENT: INDEXS VS DAMAGE





LPI range	Liquefaction risk
0-10	Little to no expression of liquefaction, minor effects
10-20	Minor expression of liquefaction, some sand boils
20-30	Moderate to severe expresion of liquefaction, settlement can cause structural damage
40-50	Major expression of liquefaction, undulations and damage to ground surface, severe total and differential settlement of structures
>50	Severe damage, extensive evidence of liquefaction at surface, severe and differential settlements affecting structures, damage to services

CHRISTCHURCH EARTHQUAKE CASE STUDY

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Liquefaction Susceptibility

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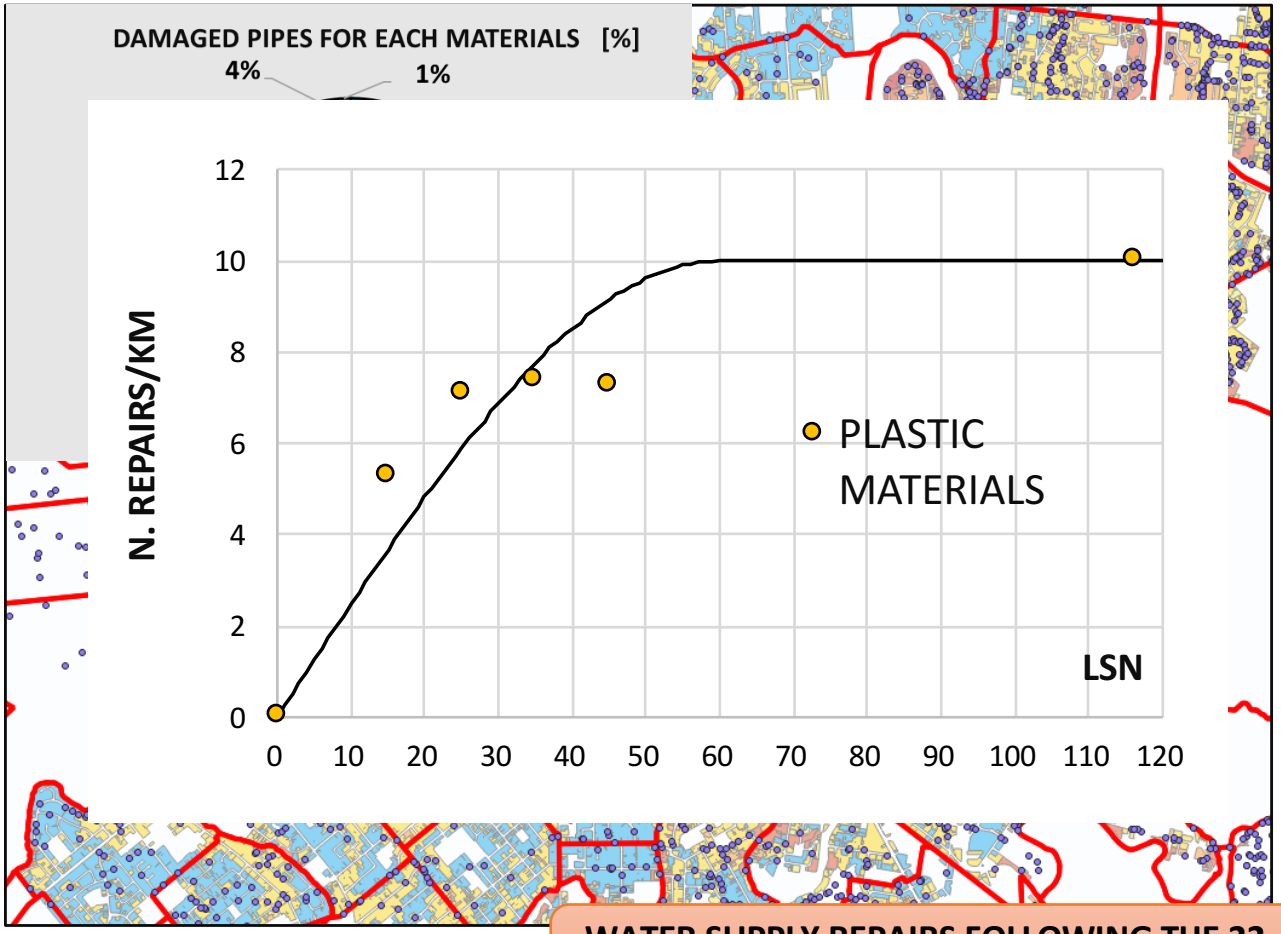
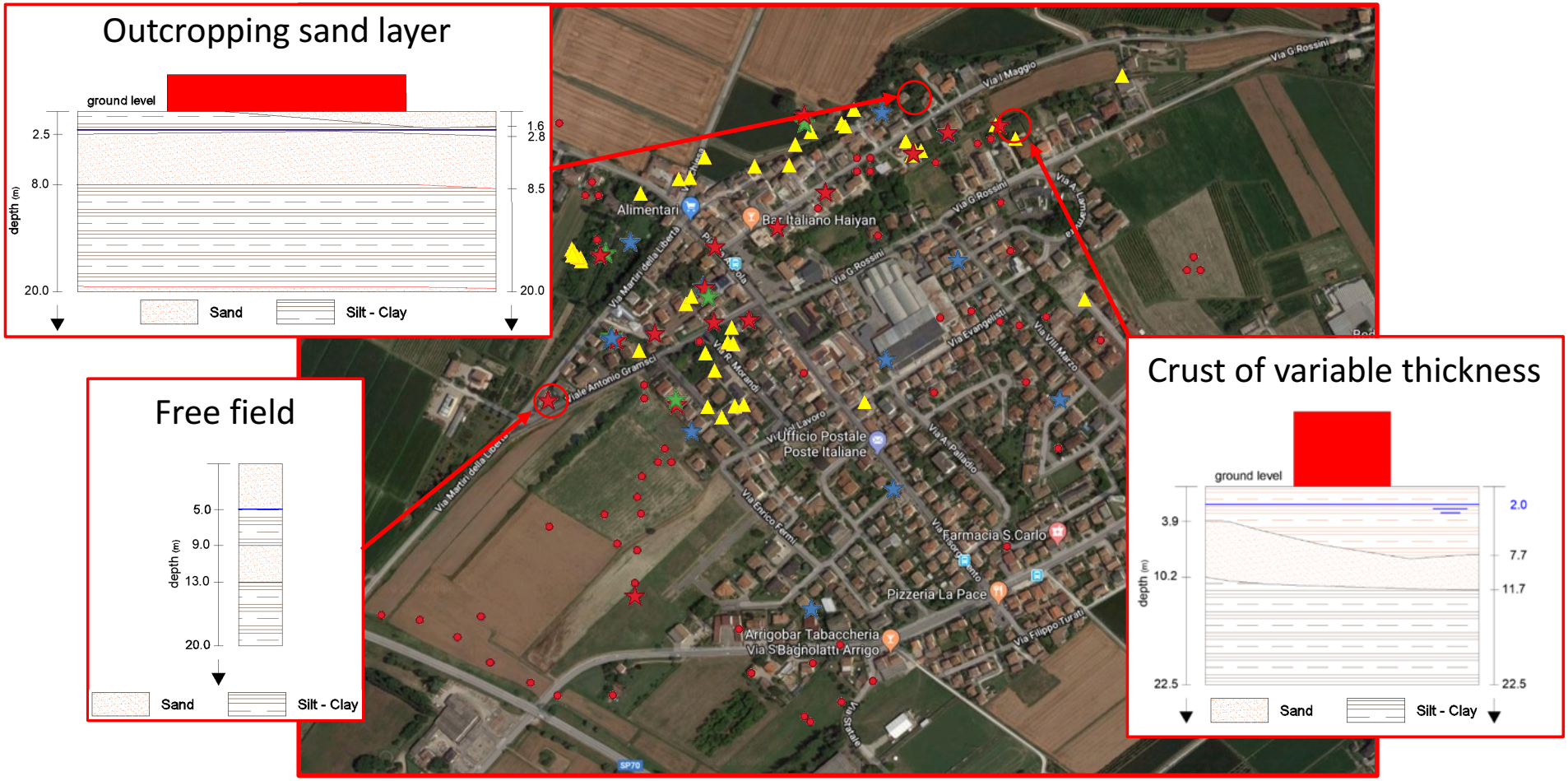
EXAMPLE FOR VALIDATION



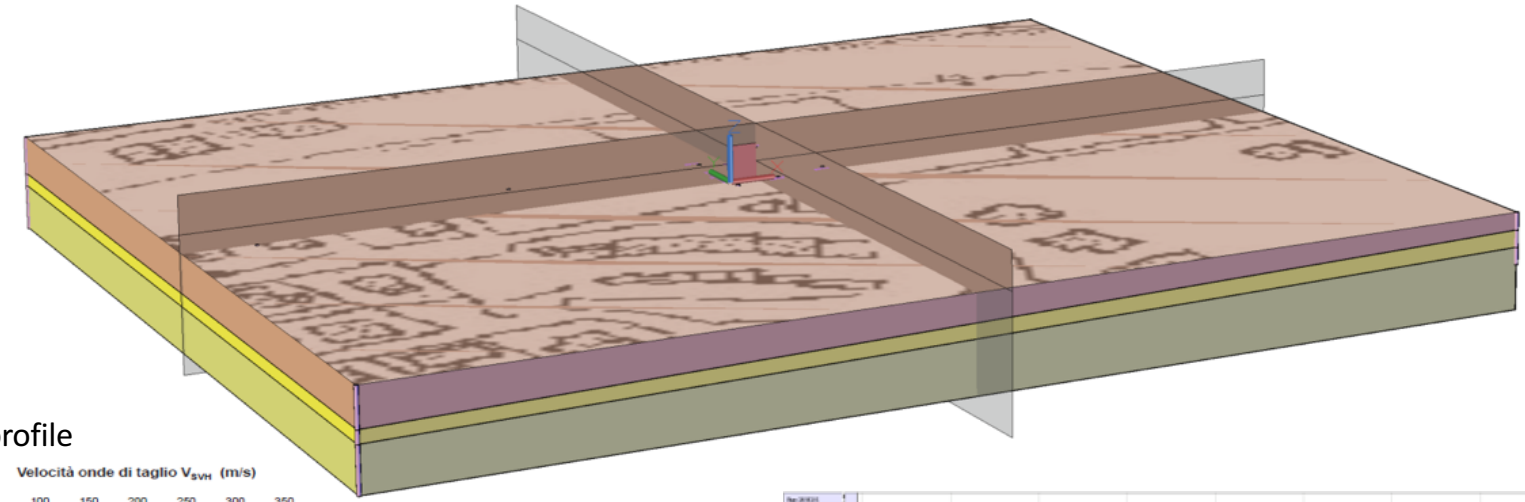
WATER SUPPLY REPAIRS FOLLOWING THE 22 FEBRUARY 2011 EARTHQUAKE



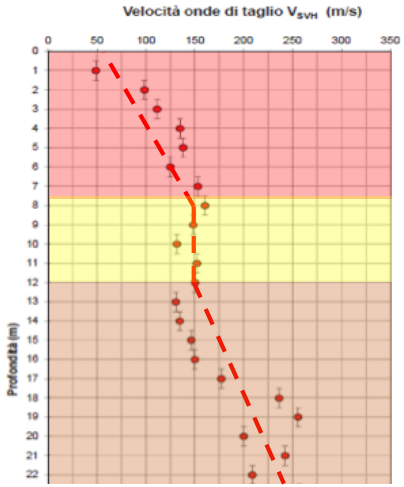
San Carlo village (Google Earth)

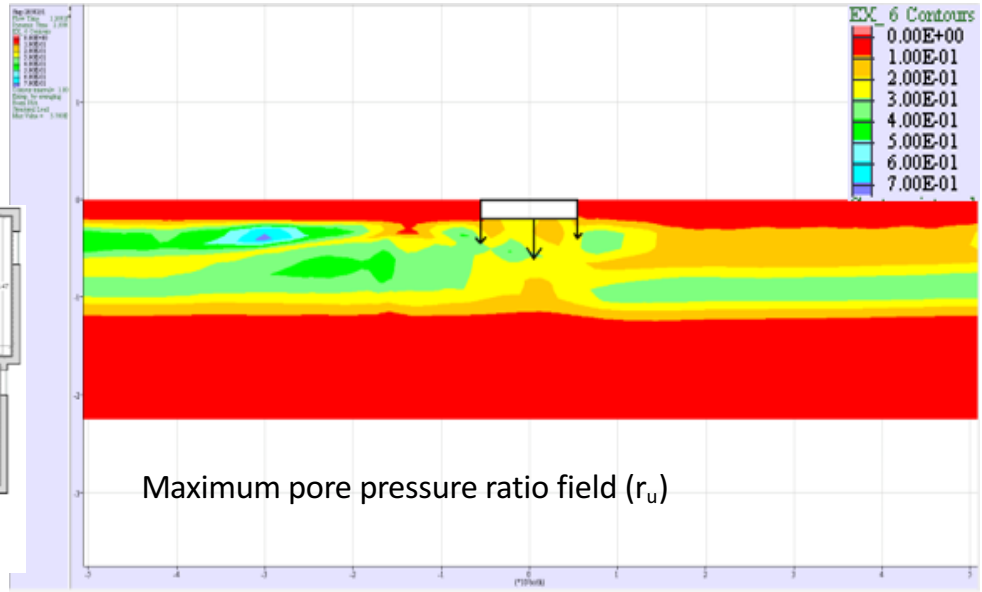
Data coming from RegioneEmilia-Romagna

3D subsoil profile:



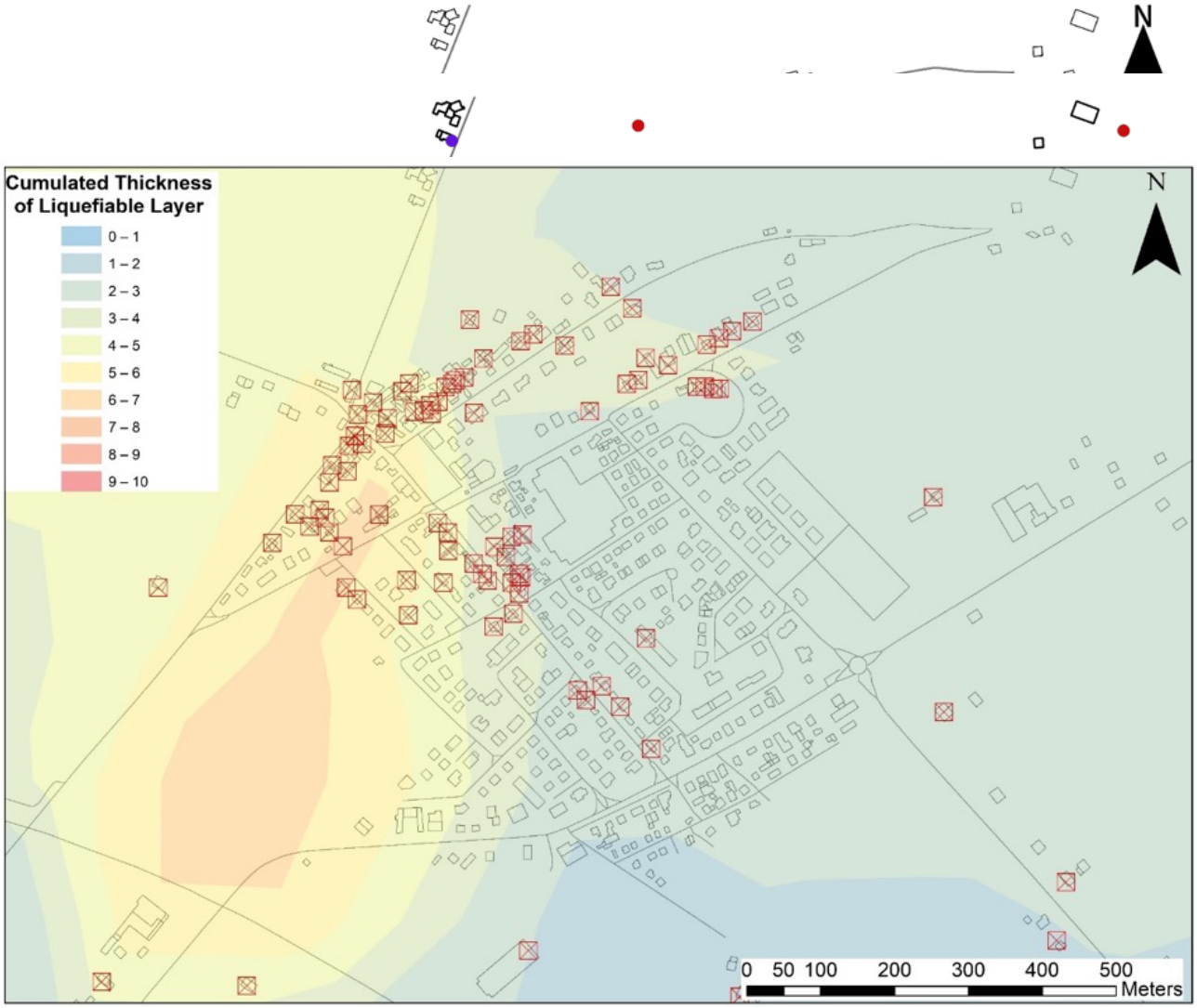
CPTS profile

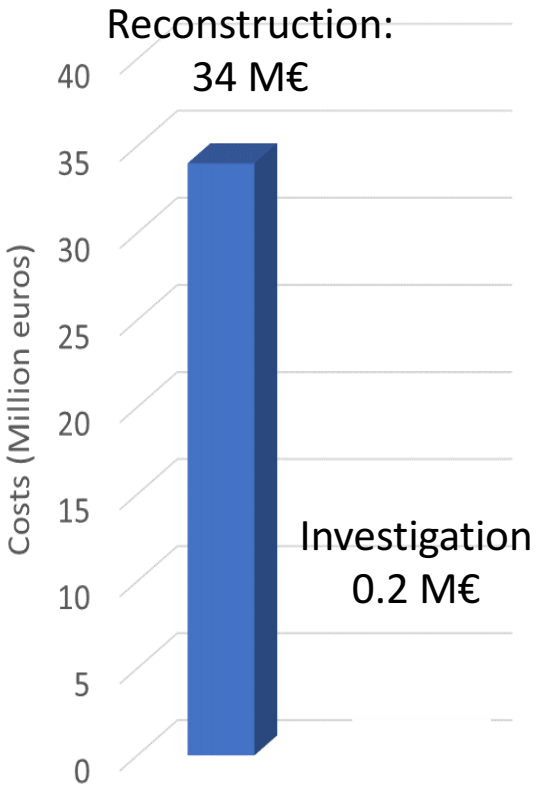




Maximum pore pressure ratio field (r_u)

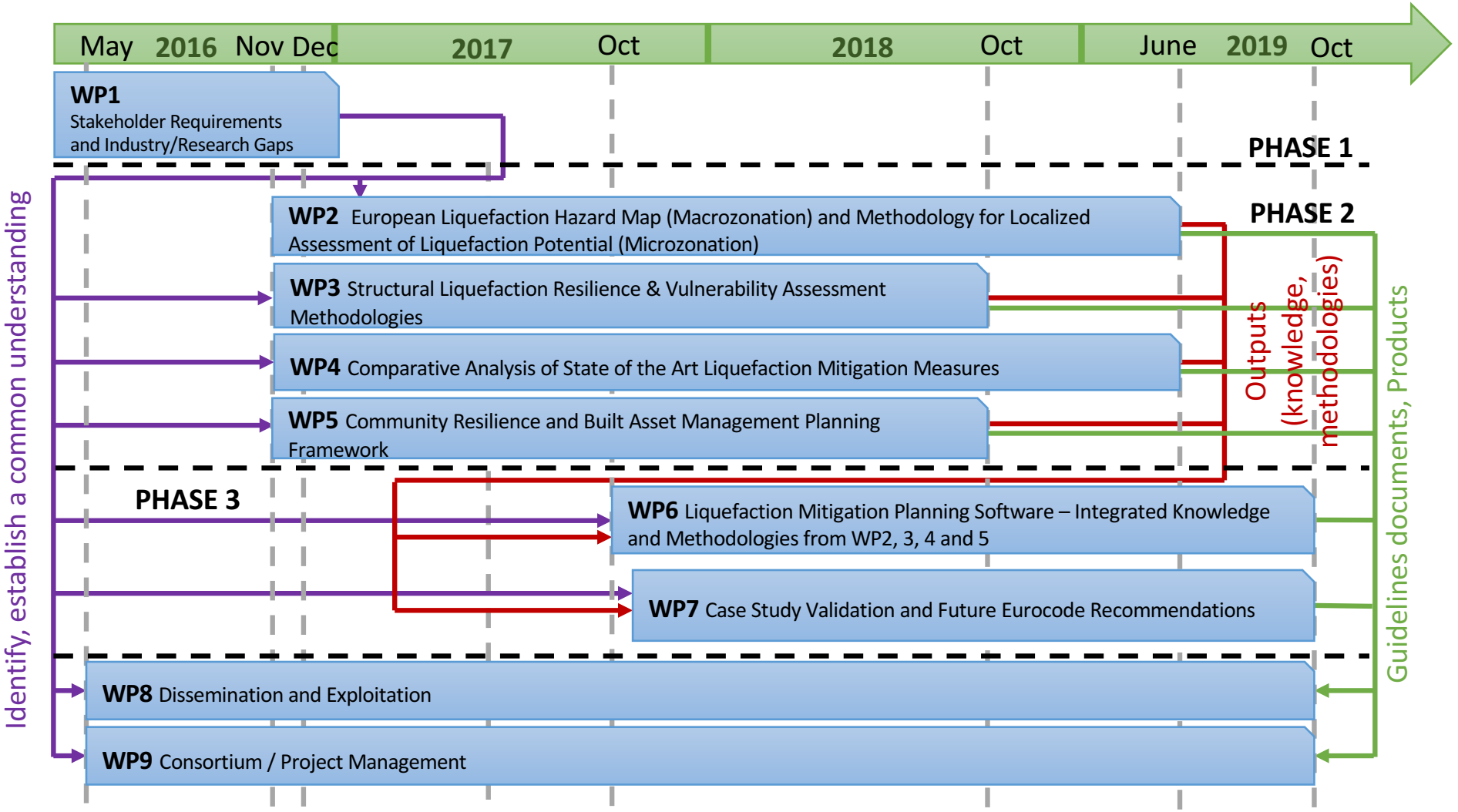
San Carlo (Emilia)





Volume of liquefiable soil below repaired buildings
67000 m^3

LIQUEFACT



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16TH EUROPEAN CONFERENCE ON EARTHQUAKE ENGINEERING THESSALONIKI 18 - 21 JUNE 2018

EARTHQUAKE INDUCED LIQUEFACTION RISK: HOLISTIC ASSESSMENT AND MITIGATION

Liquefaction risk assessment: principles and lessons from case studies
Giuseppe Modoni (University of Cassino)

Assessment of liquefaction risk at different geographical scales
Carlo G. Lai (University of Pavia)

Ground improvement to mitigate the liquefaction potential
Alessandro Flora (University of Napoli):

Liquefaction vulnerability of structures and infrastructures on liquefiable deposits: part I
Maxim Millen & Xavier Romão (University of Porto)

Empirical damage and liquefaction fragility curves
Marco di Ludovico (University of Napoli)

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