10th Joint Symposium on Disaster Risk Management
September 28, 2016

Liquefaction Damage in Chiba, Japan due to the 2011 Tohoku Earthquake

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Chiba University

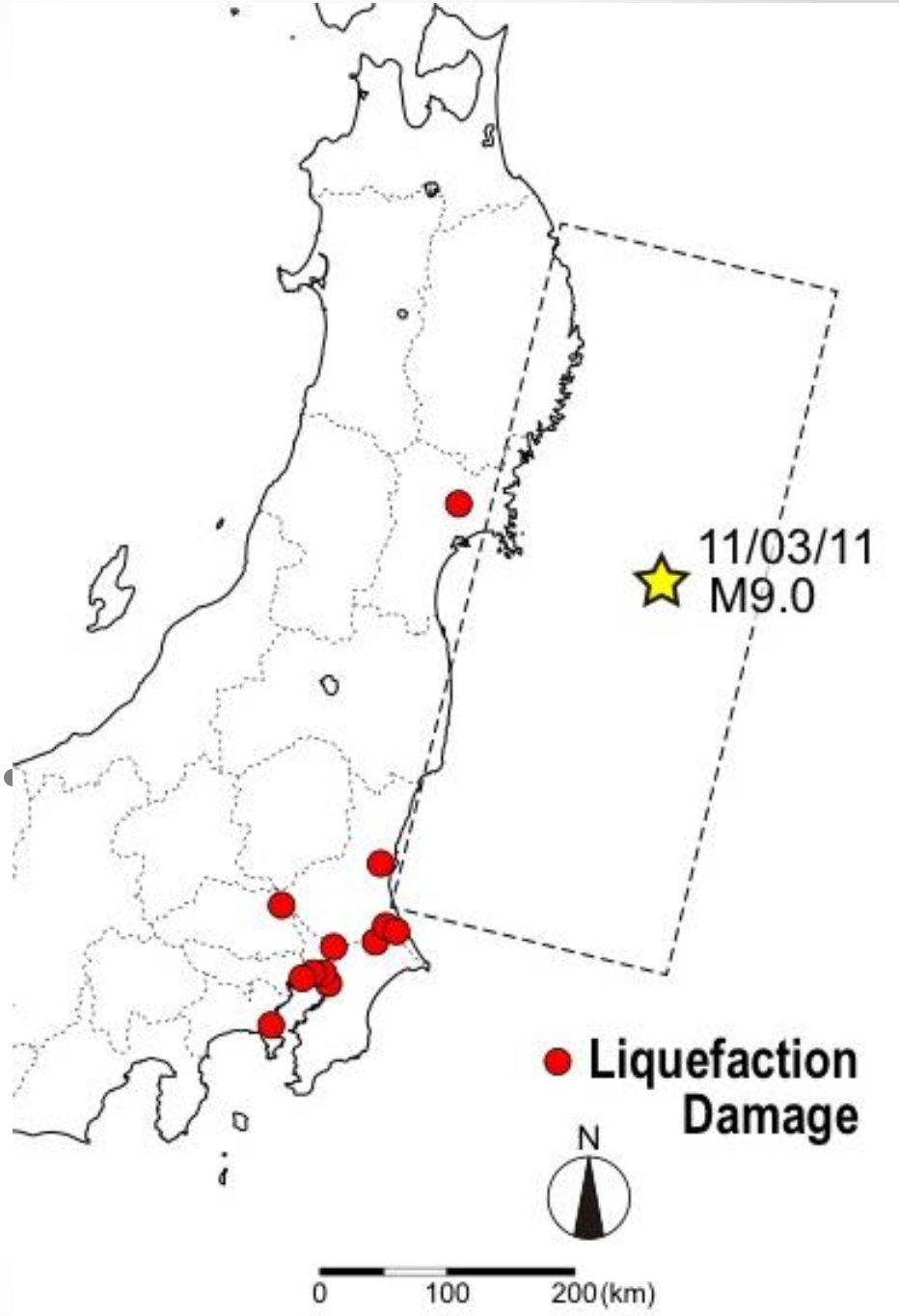
Outline

- Outline of liquefaction damage in Chiba prefecture during the 2011 Tohoku earthquake
  - Urayasu city
  - Chiba city
- Analysis of non-uniform damage distribution
  - Recorded ground motions
  - Construction of 3-D Soil Model and its Verification
  - Relation to Reclamation Process
- Countermeasures against Liquefaction
  - Demonstration Test
  - Centrifuge Shake Table Test
- Concluding Remarks

Outline of Liquefaction Damage in Chiba Prefecture

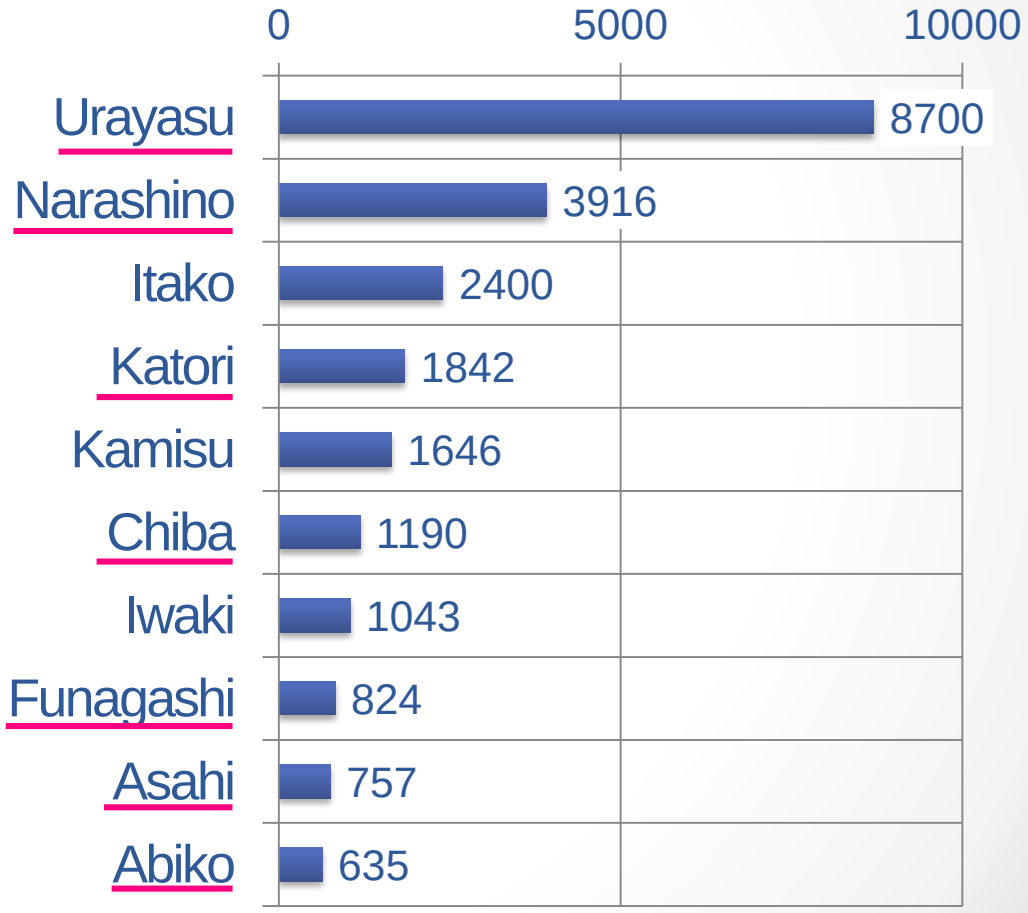
Eastern Part of Tokyo Metropolitan Area

(Animation)



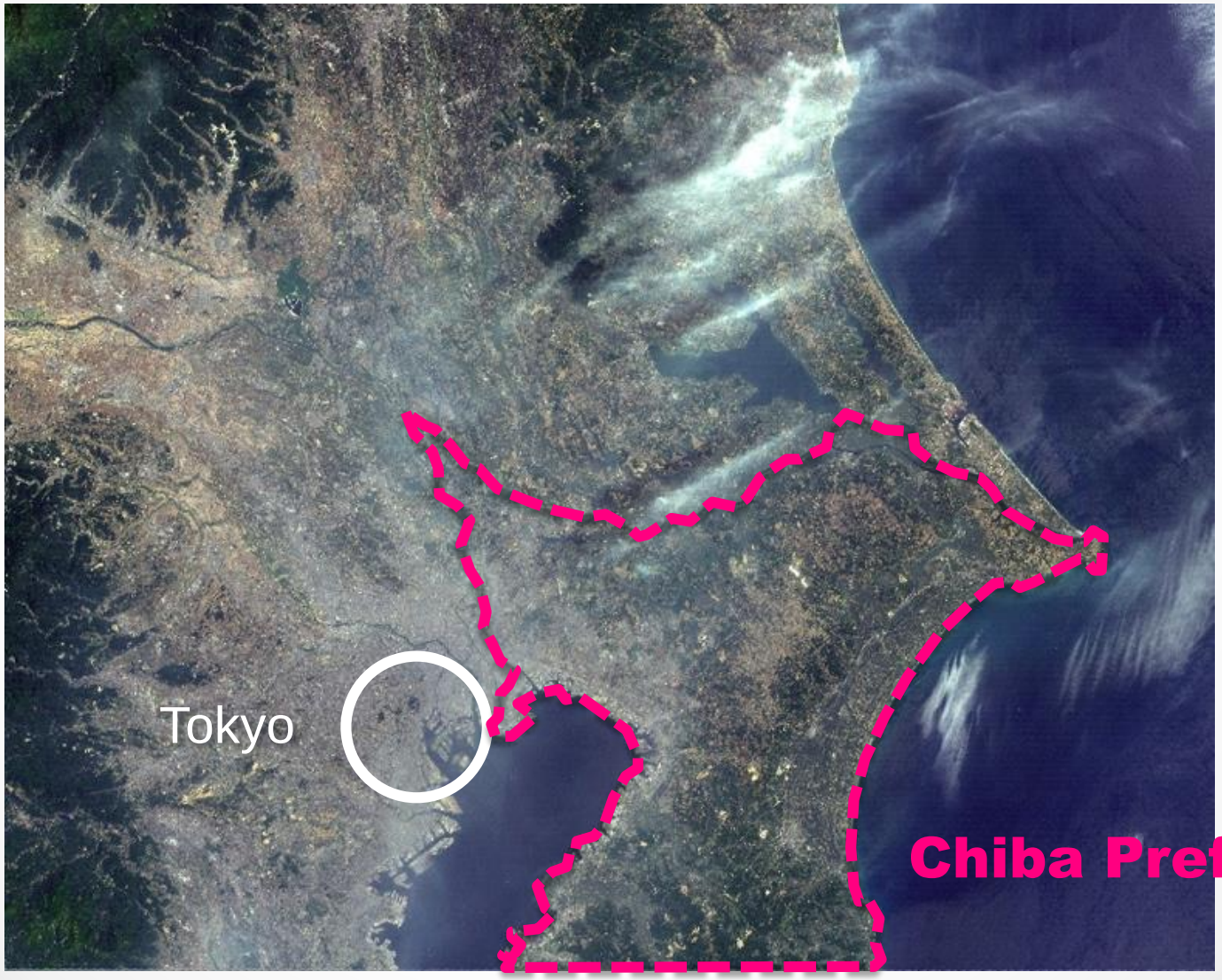
Damaged Houses due to Liquefaction

Prefecture	# of Houses
Iwate	3
Miyagi	140
Fukushima	1,043
Ibaraki	6,751
Gunma	1
Saitama	175
Chiba	18,674
Tokyo	56
Kanagawa	71
Total	26,914



MLIT (2011.9.27)

Affected Area



Affected Area

Affected Area

(Video)

Damage due to liquefaction (Photos by Urayasu city)

Damage due to liquefaction (Photos by Urayasu city)

Damage due to liquefaction (Photos by Urayasu city)

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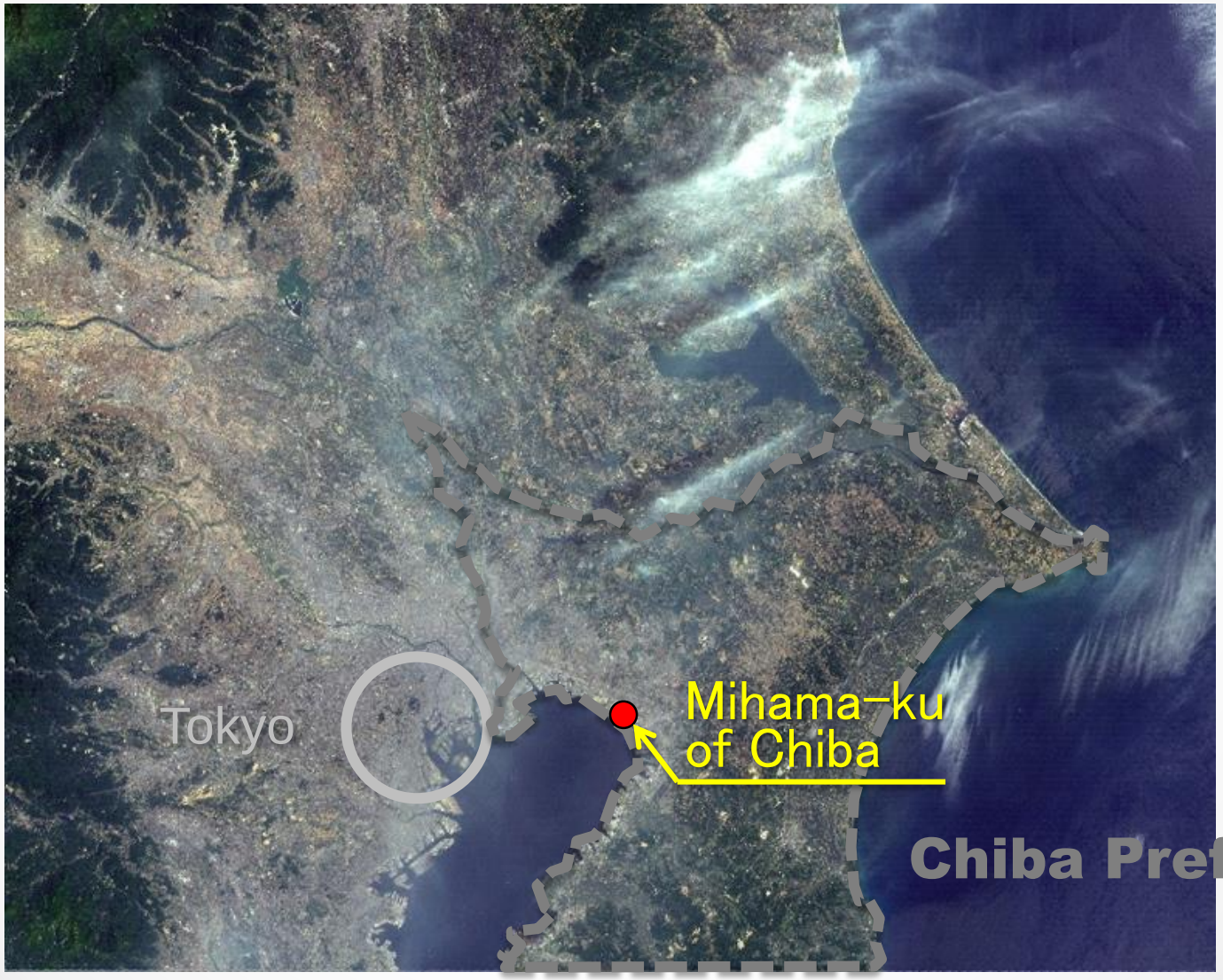
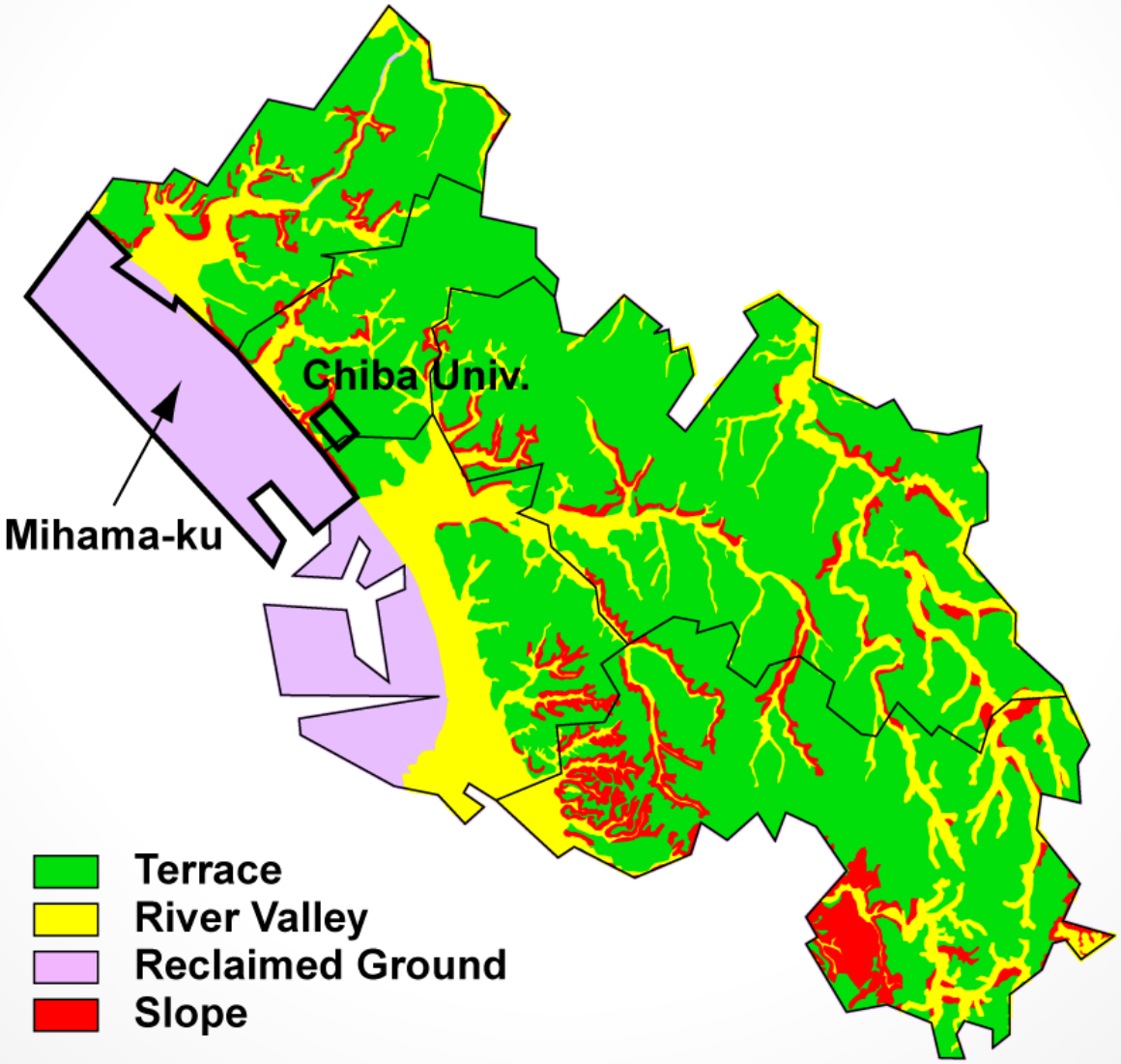
Affected Area



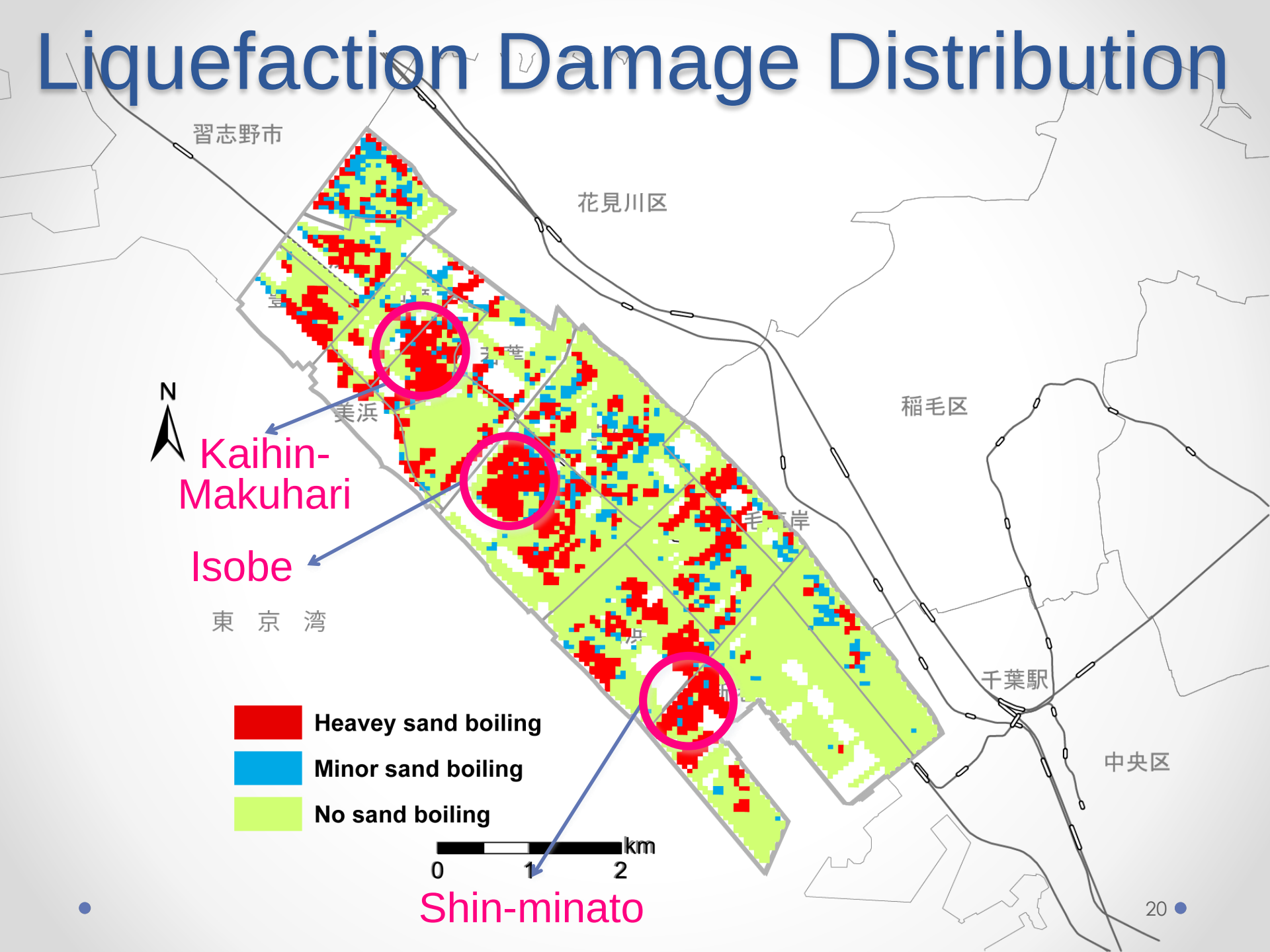
Landform Classification

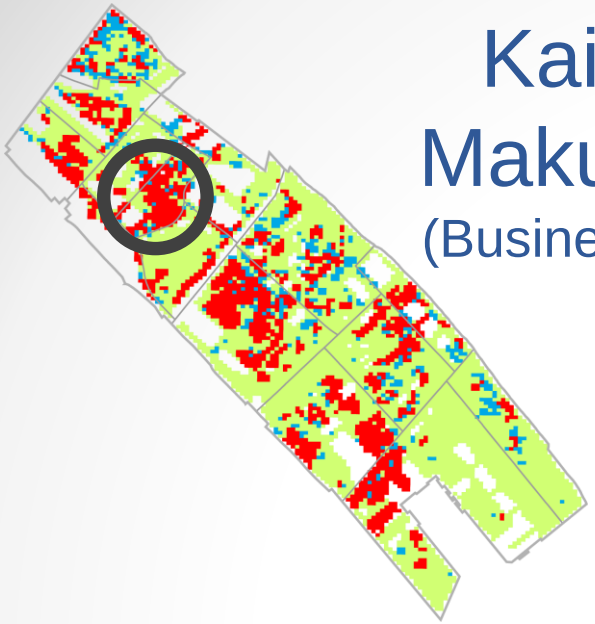
Chiba City



(Video)

Liquefaction Damage Distribution





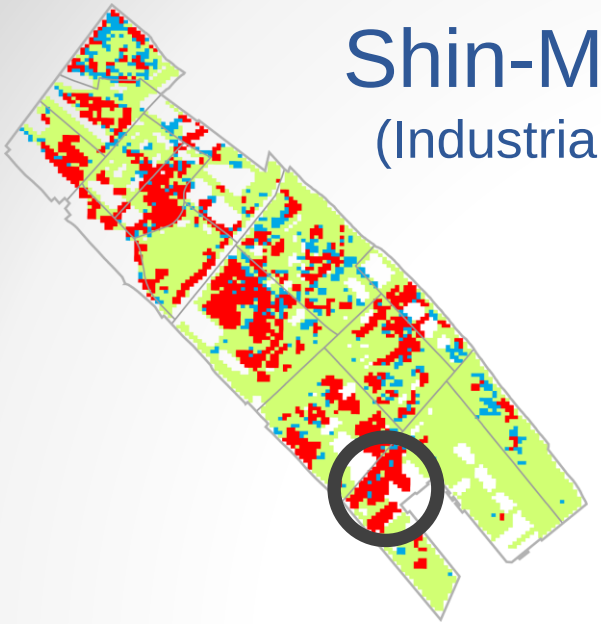
Kaihin-Makukhari
(Business Dist.)

Isobe

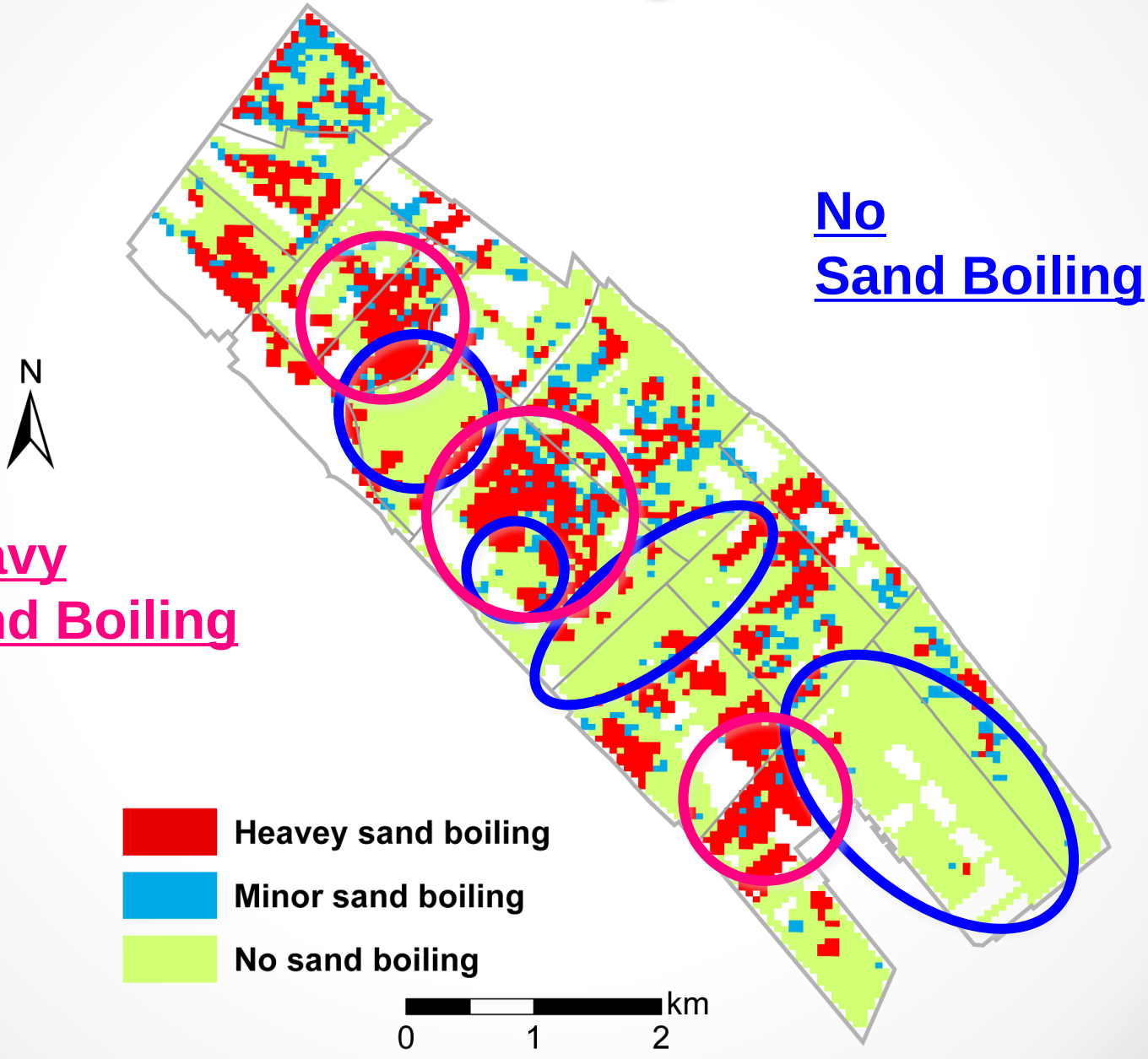
(Residential Area)

Thickness : 45cm

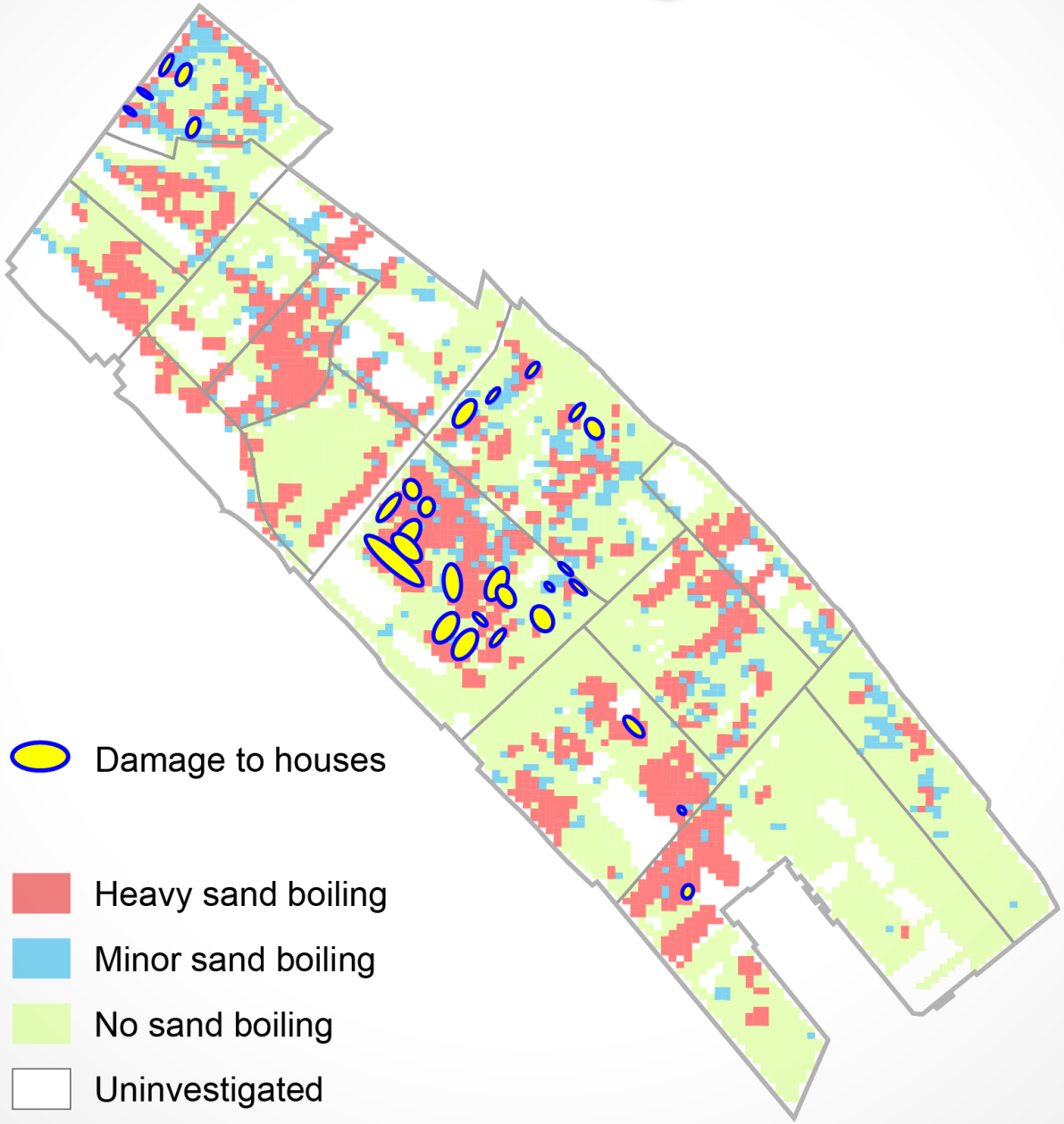
Shin-Minato
(Industrial Area)



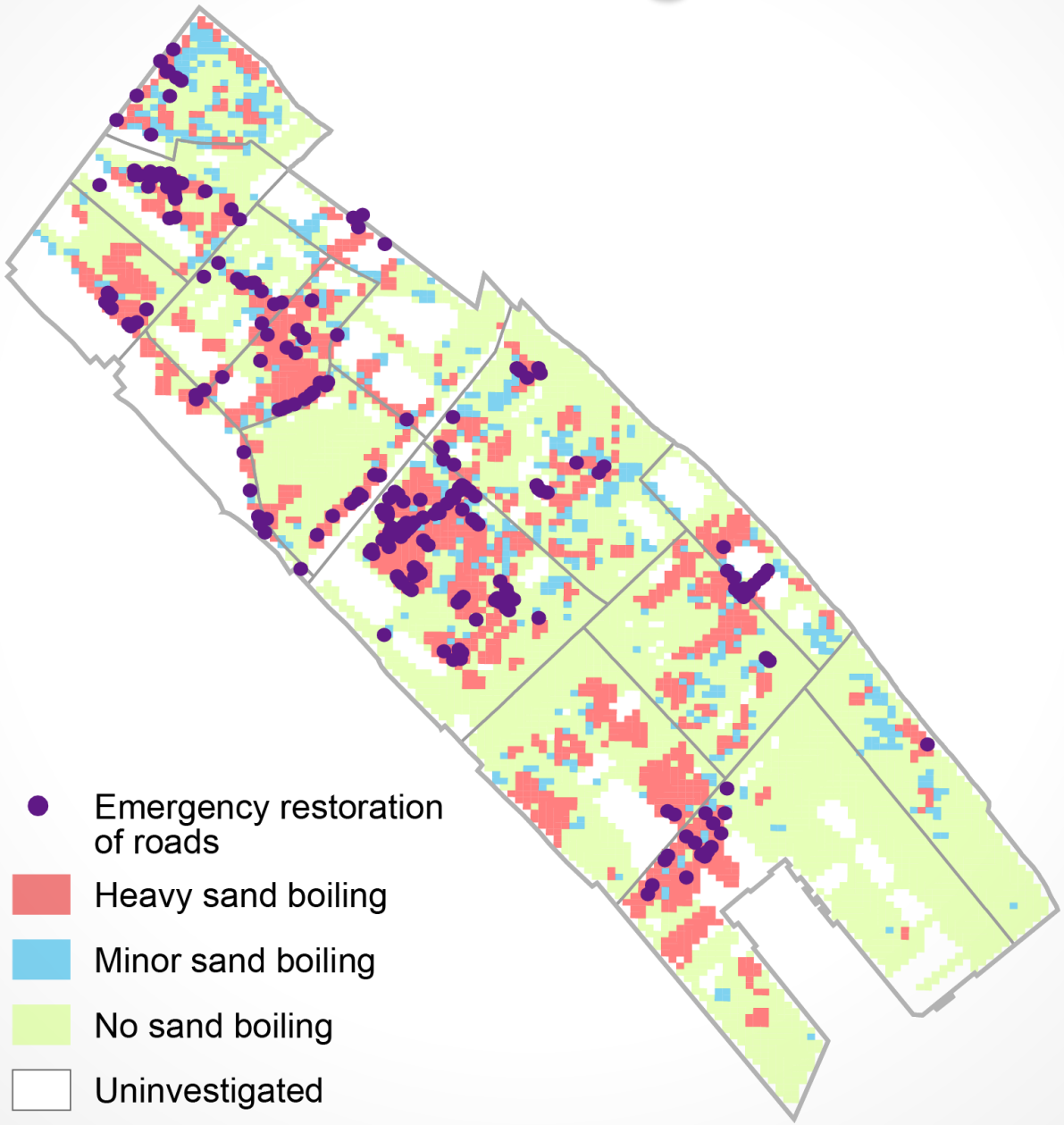
Liquefaction Damage Distribution



Liquefaction Damage Distribution



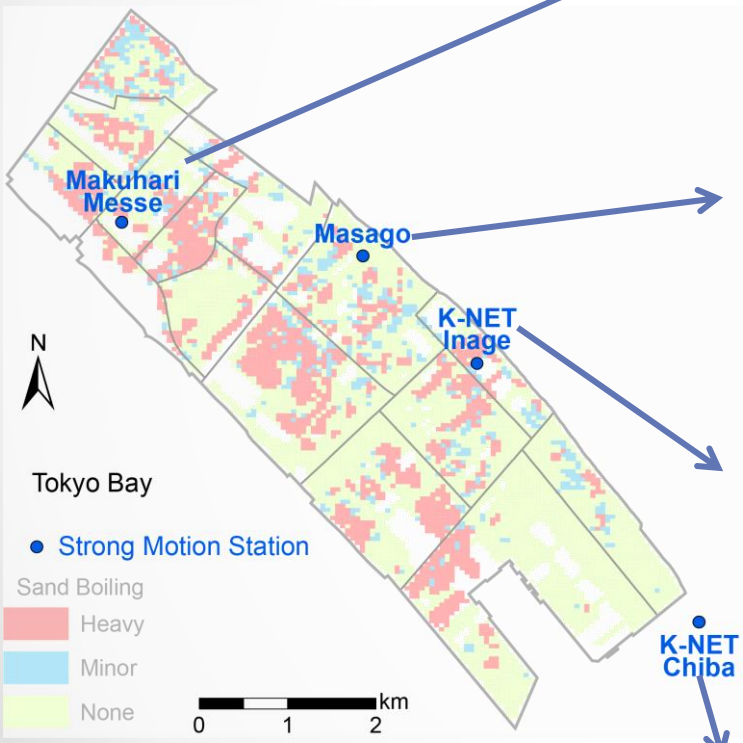
Liquefaction Damage Distribution

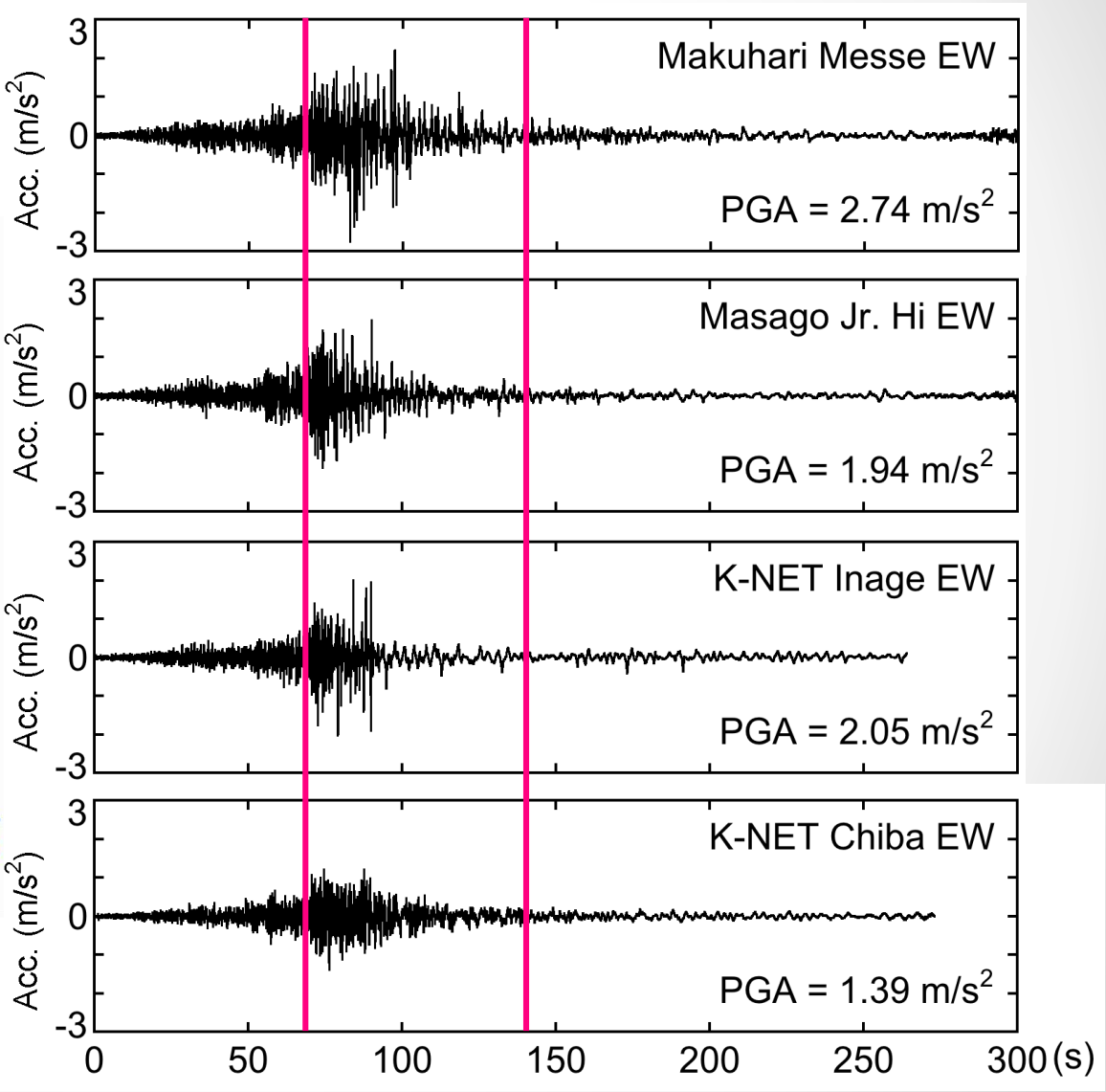


Analysis of Non-uniform Damage Distribution

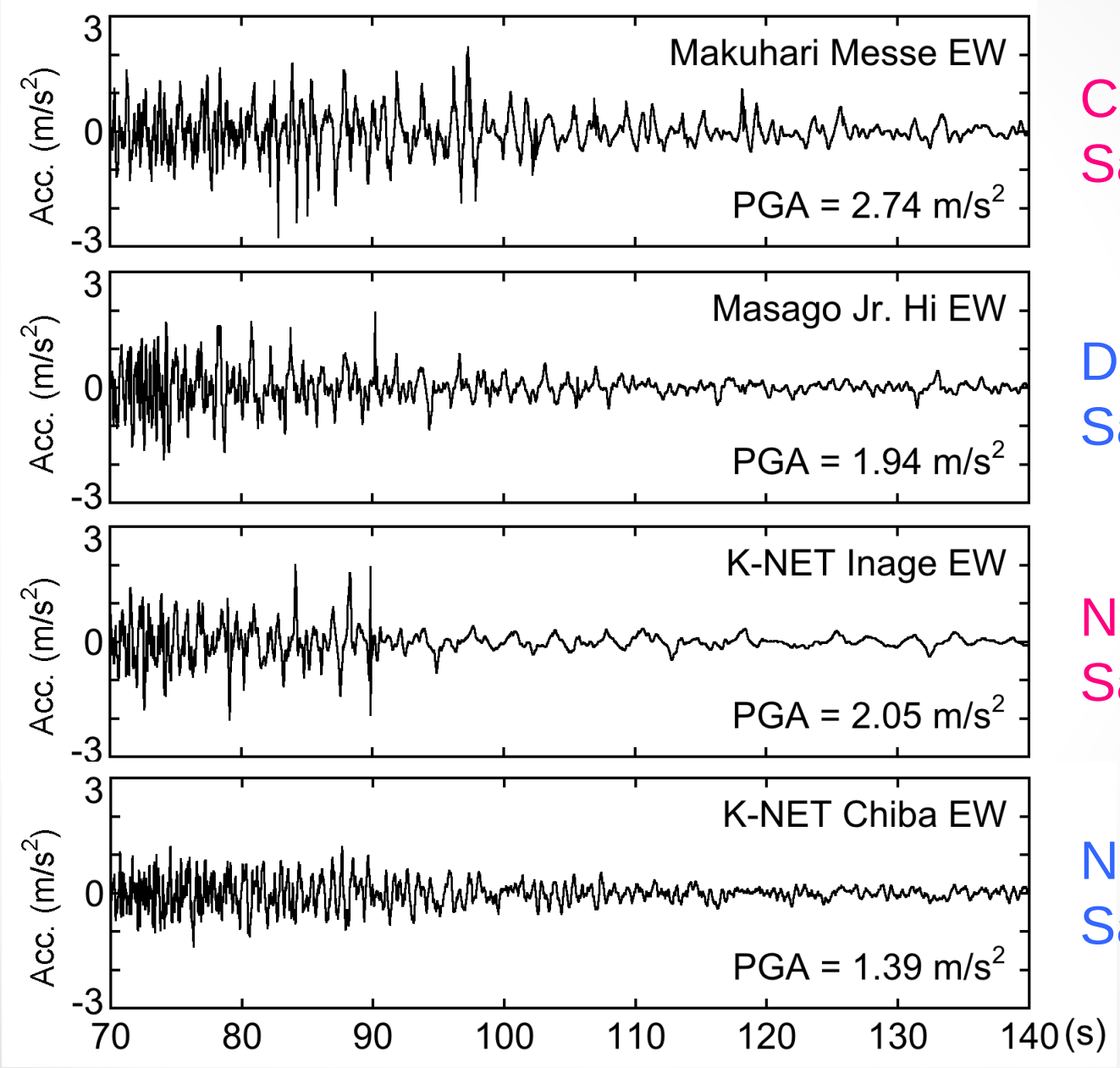
Recorded Ground Motions

Recorded Ground Motions





Recorded Ground Motions



Close to Sand Boiling

Distant from Sand Boiling

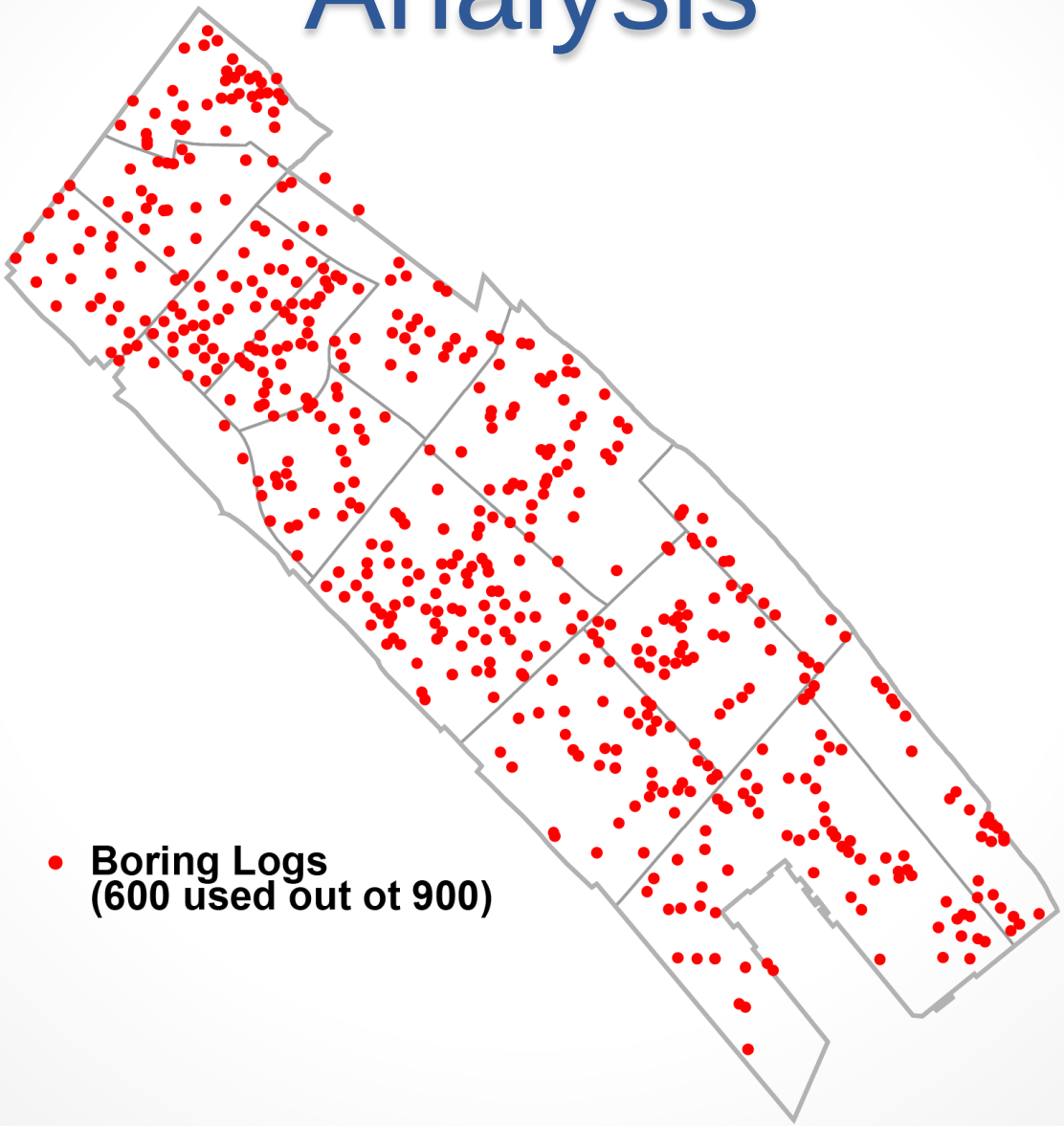
Nearby Sand Boiling

No Sand Boiling

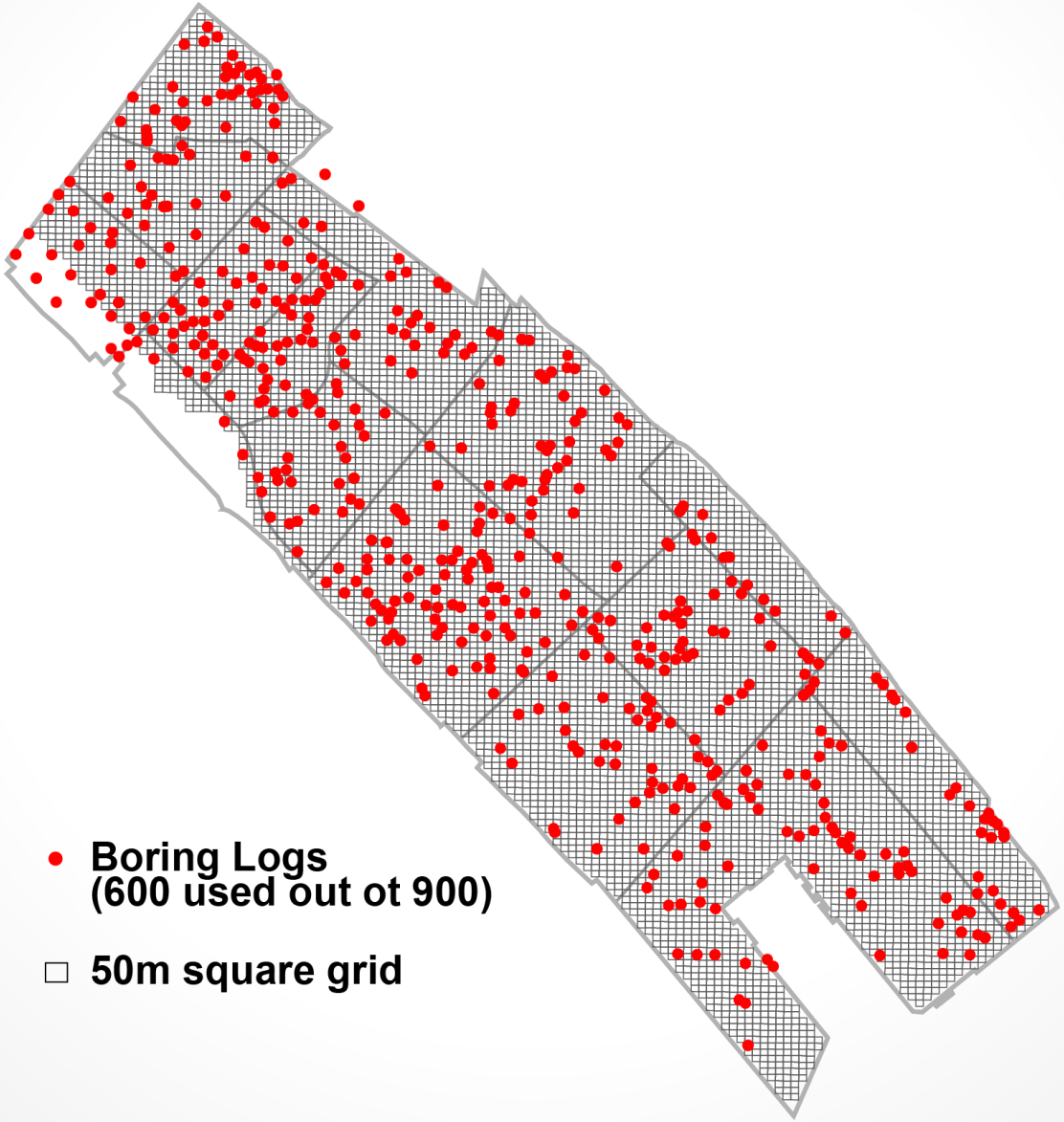
Analysis of Non-uniform Damage Distribution

Construction of 3-D Soil Model
and its Validation

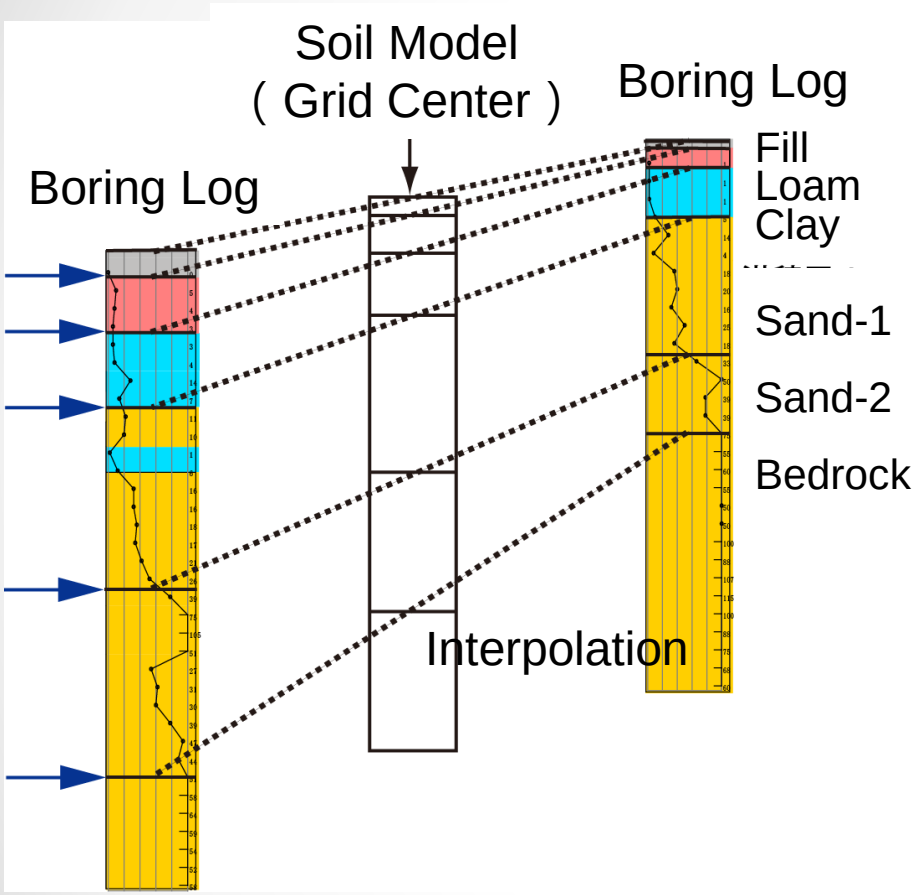
Borehole Data Used in the Analysis

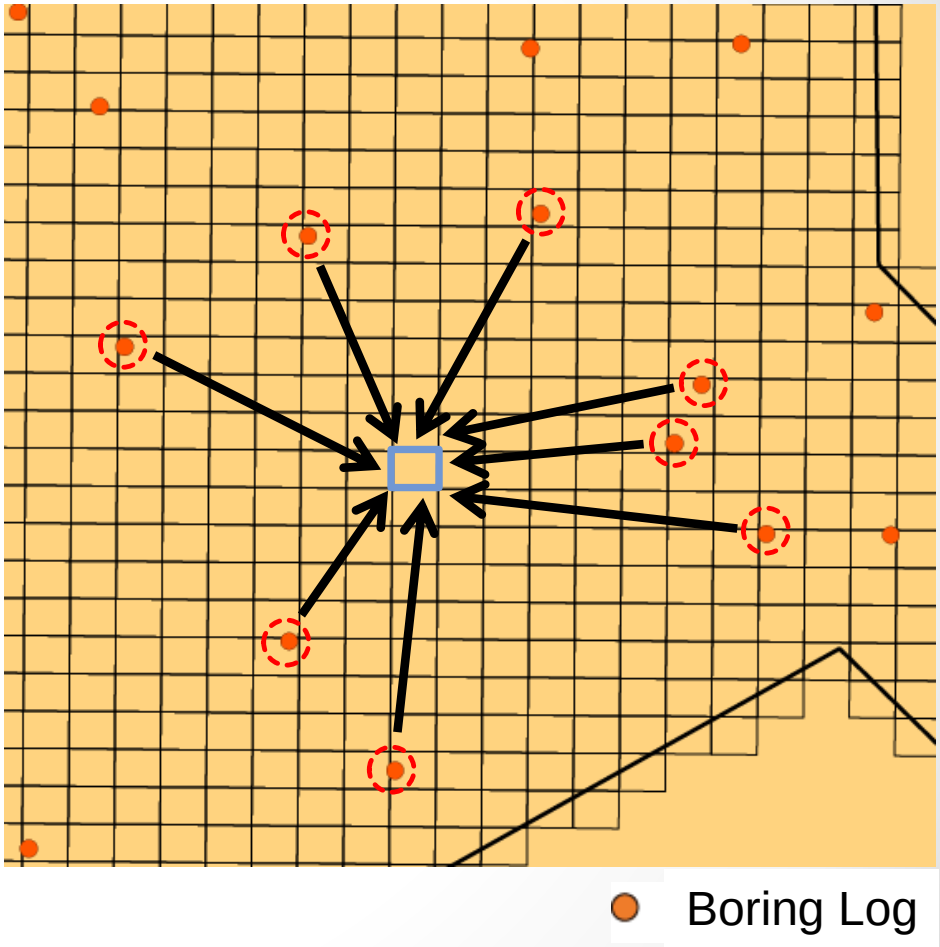


3-D Soil Model



Construction of Soil Model

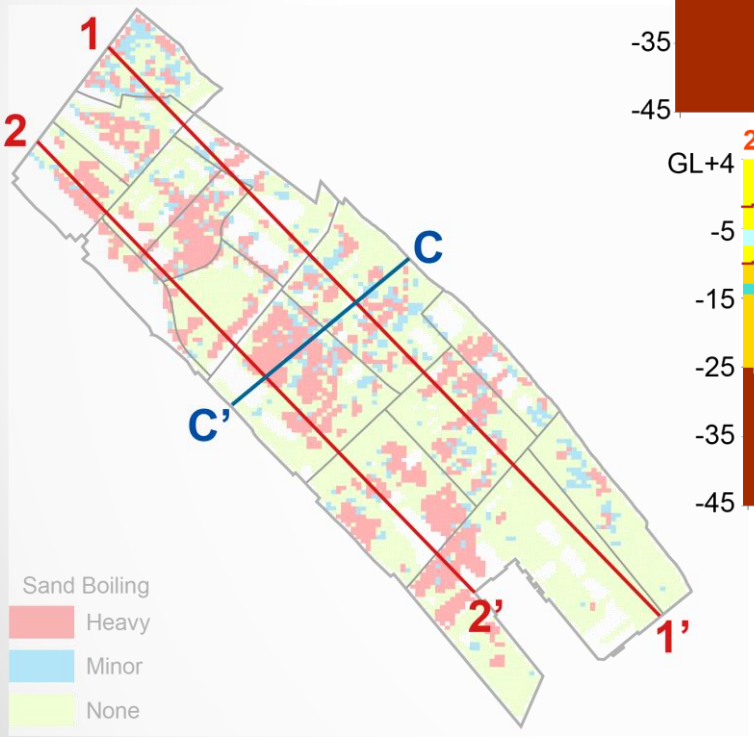


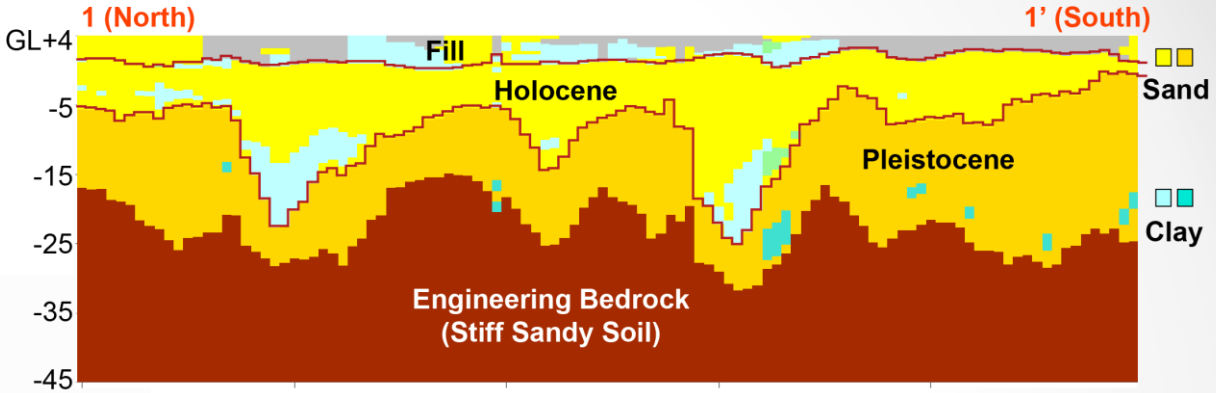


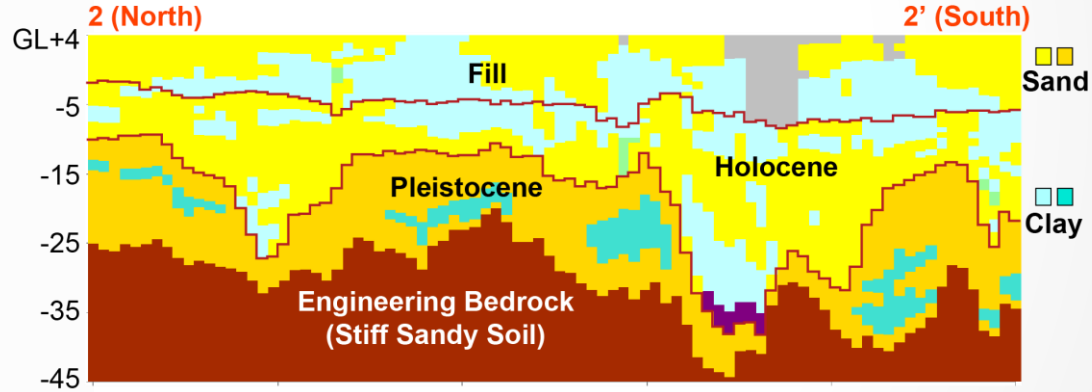
Soil Type and SPT-N :

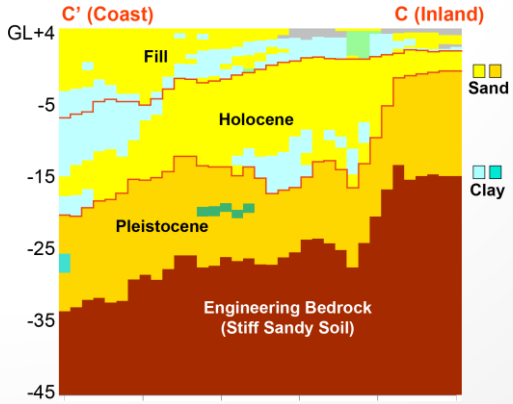
Weighted average of surrounding 8 boring logs

Soil Model

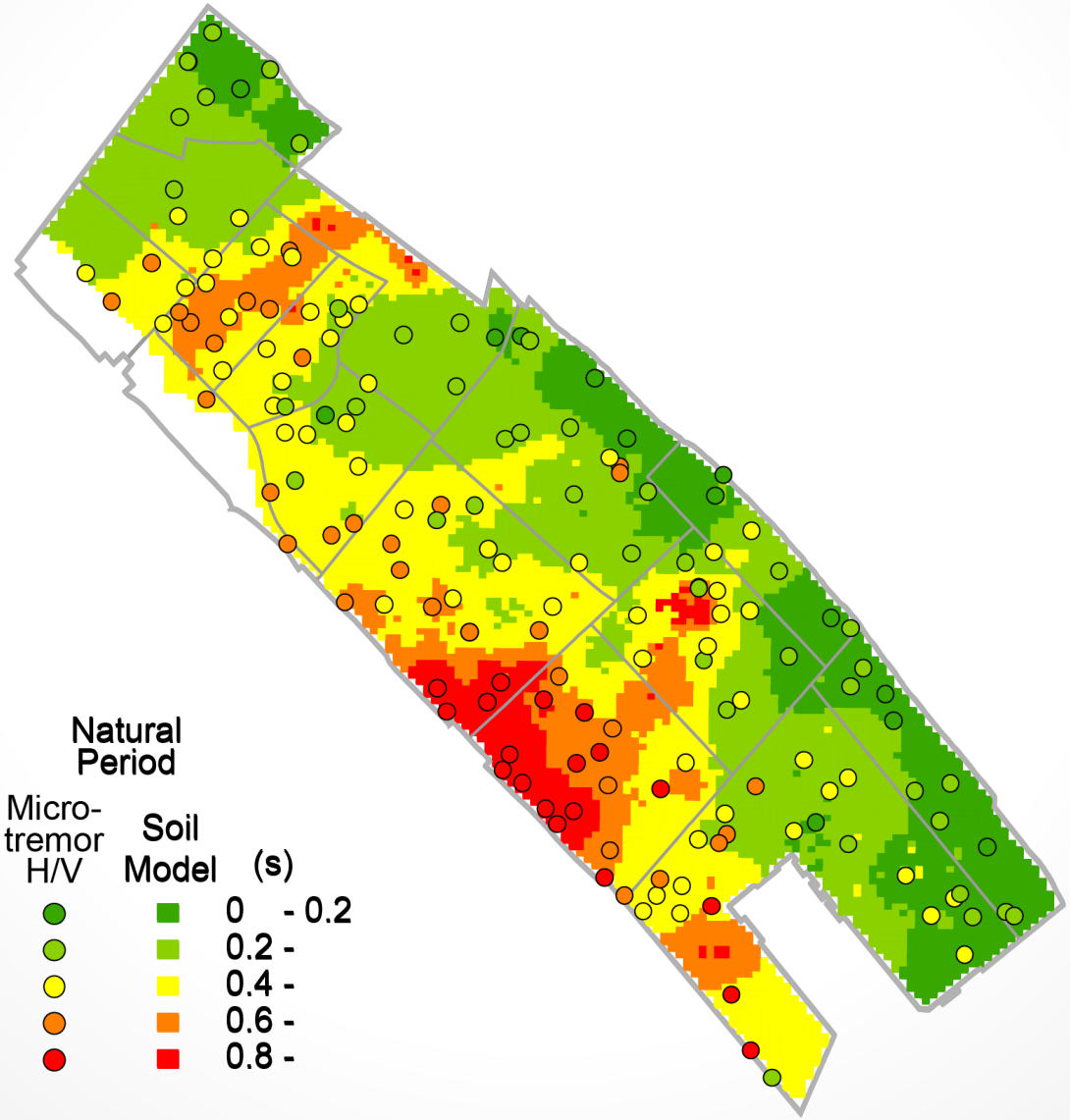

1
2
C
C'
2'
1'
Sand Boiling
Heavy
Minor
None


1 (North)
1' (South)
GL+4
-5
-15
-25
-35
-45
Fill
Holocene
Pleistocene
Engineering Bedrock
(Stiff Sandy Soil)
Sand
Clay

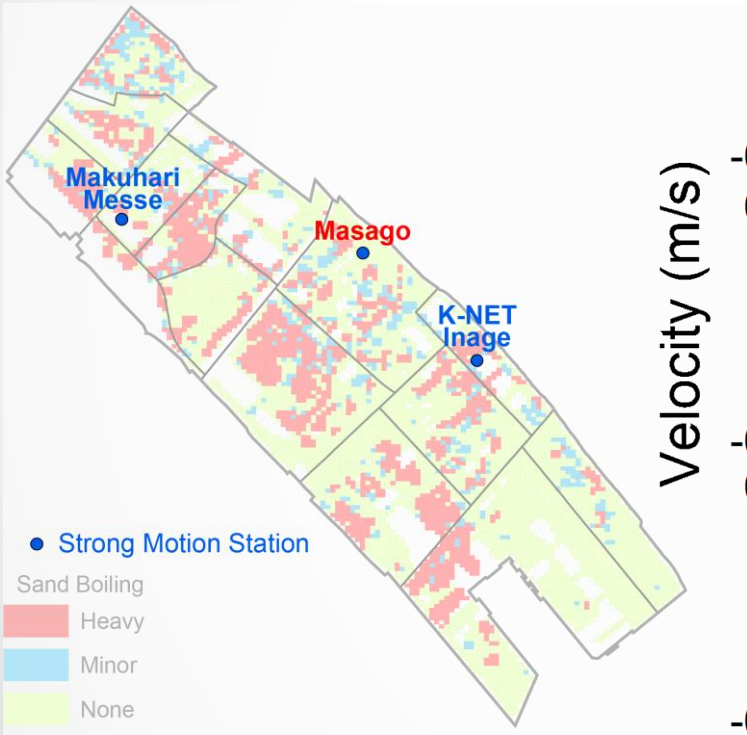

2 (North)
2' (South)
GL+4
-5
-15
-25
-35
-45
Fill
Pleistocene
Holocene
Engineering Bedrock
(Stiff Sandy Soil)
Sand
Clay

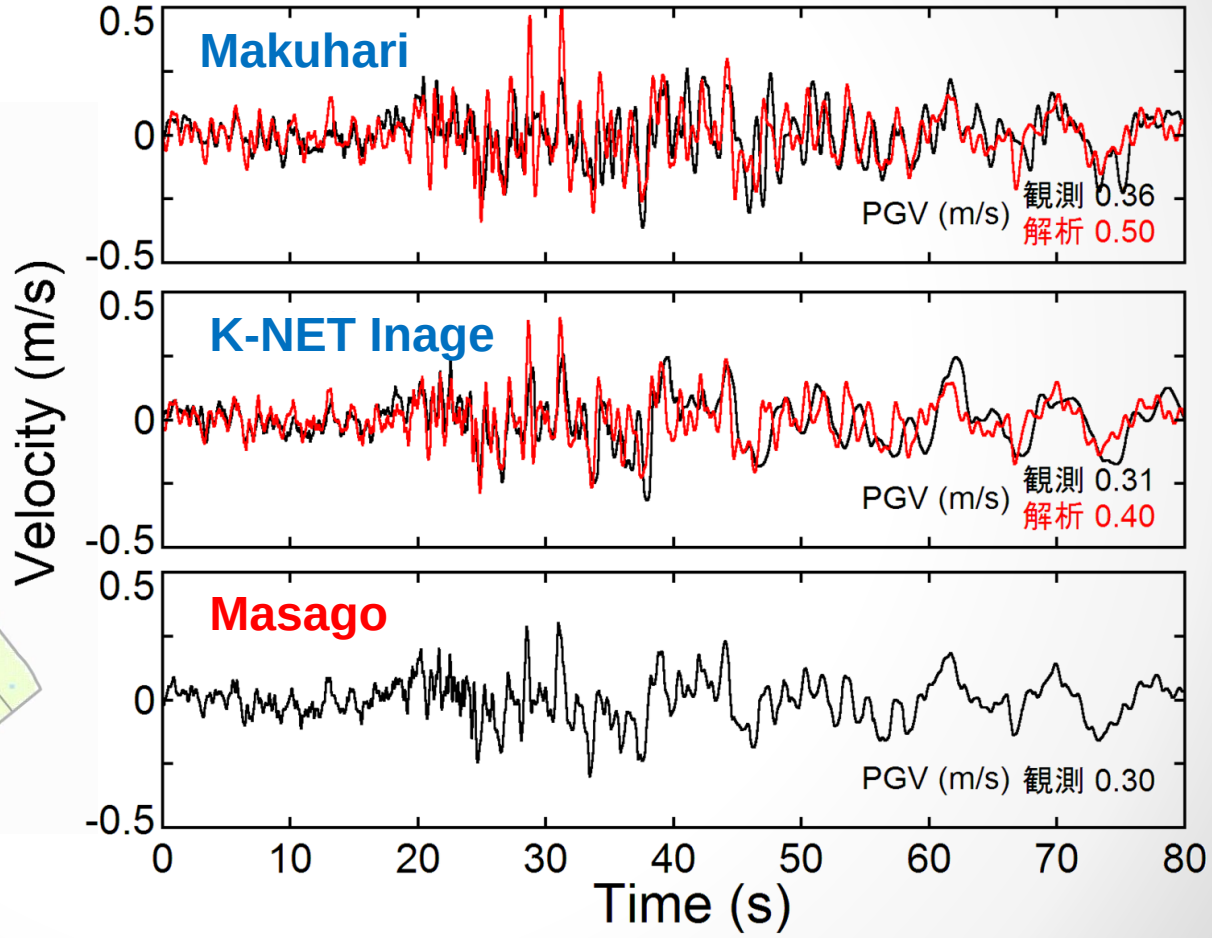

C' (Coast)
C (Inland)
GL+4
-5
-15
-25
-35
-45
Fill
Holocene
Pleistocene
Engineering Bedrock
(Stiff Sandy Soil)
Sand
Clay

Validation of Soil Model (1)

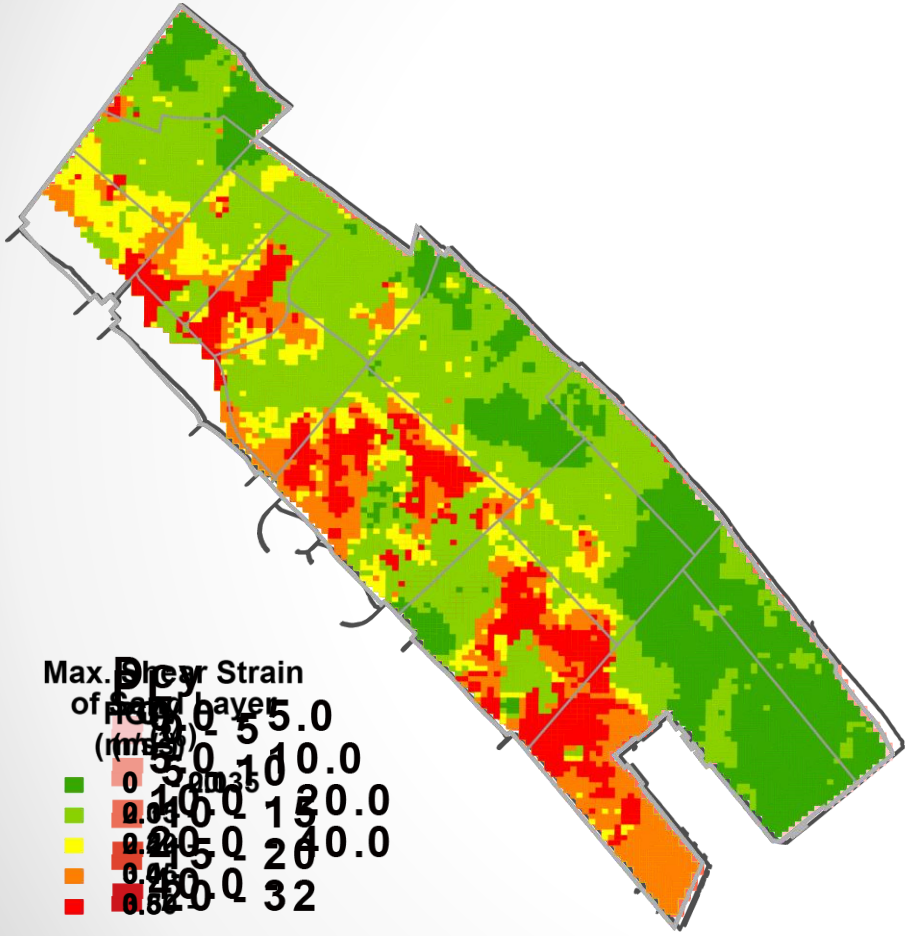


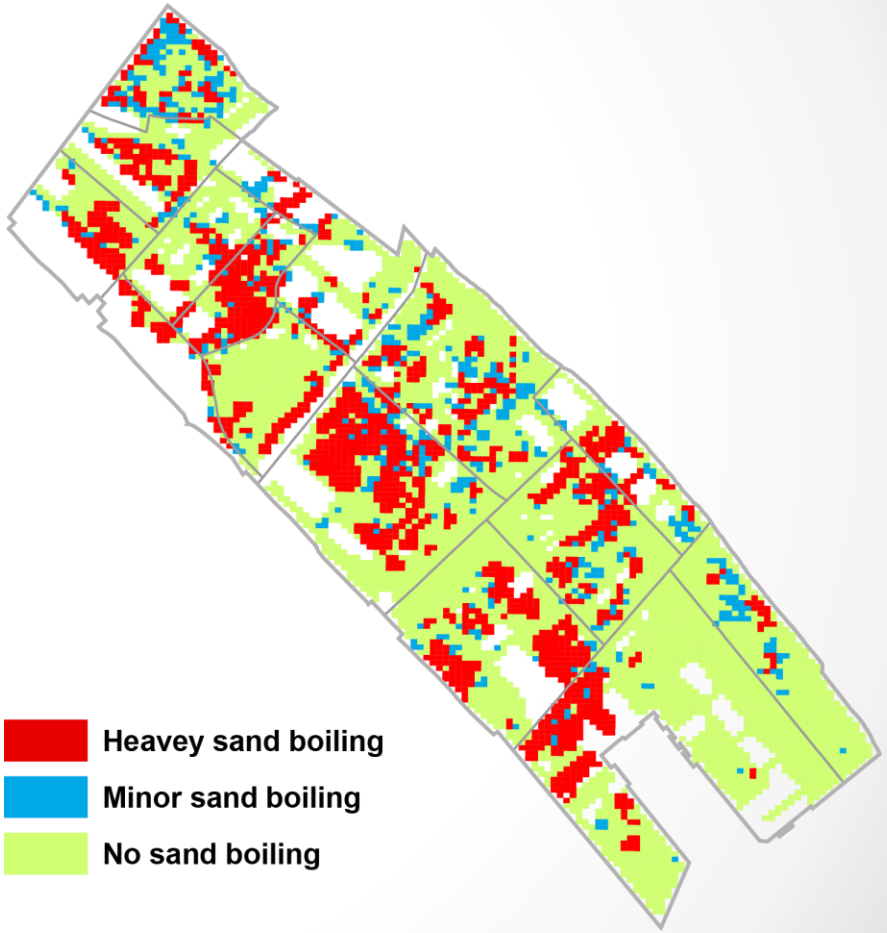
Validation of Soil Model (2)





Non-uniform Damage Distribution





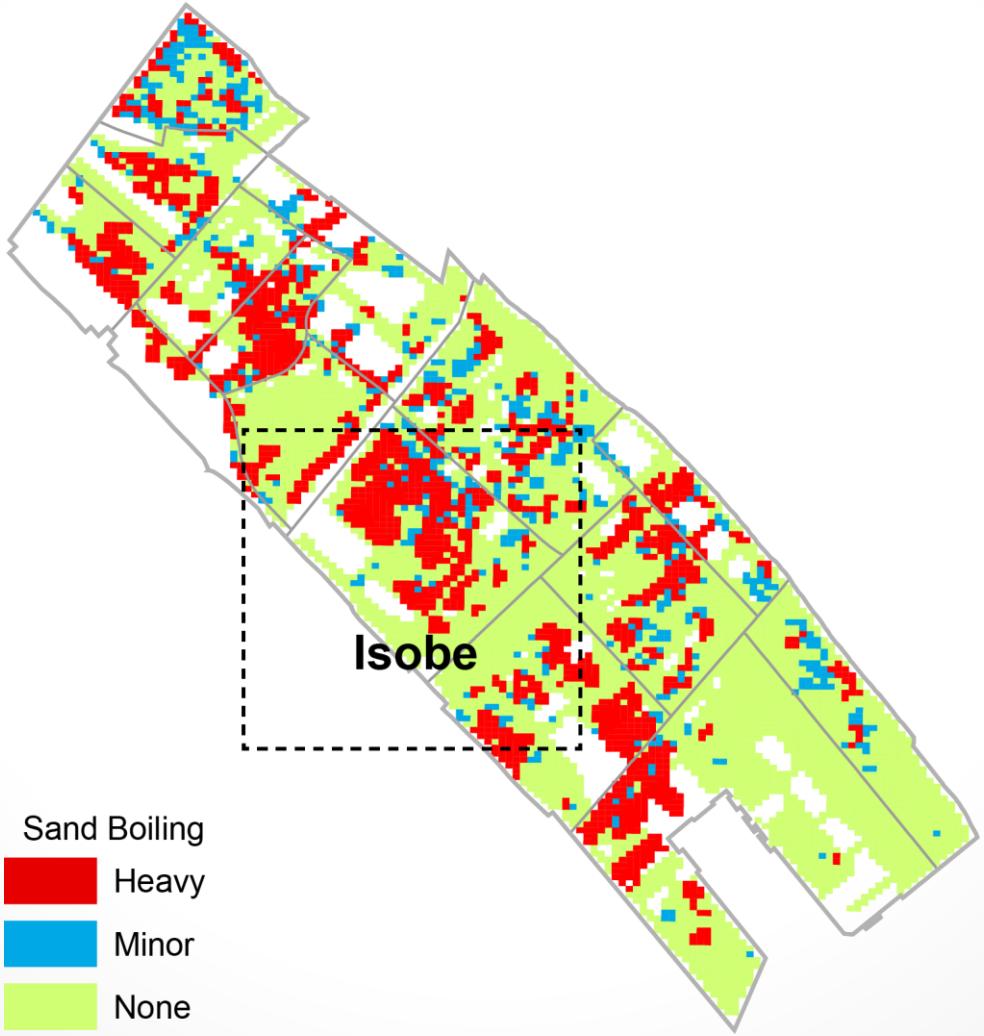
Analysis of Non-uniform Damage Distribution

Relation to Reclamation Process

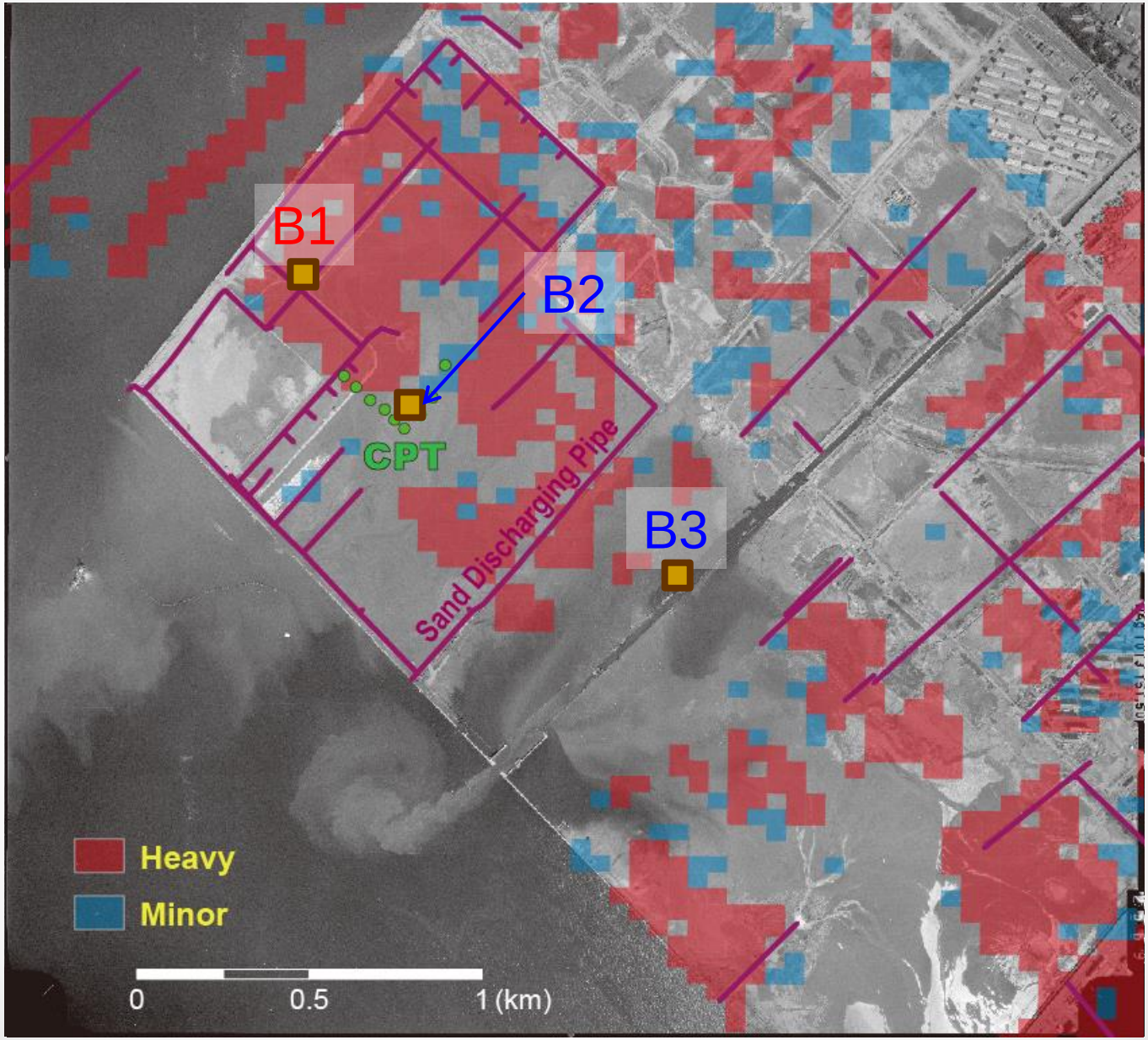
(Video)


提供：磯辺街づくり研究会

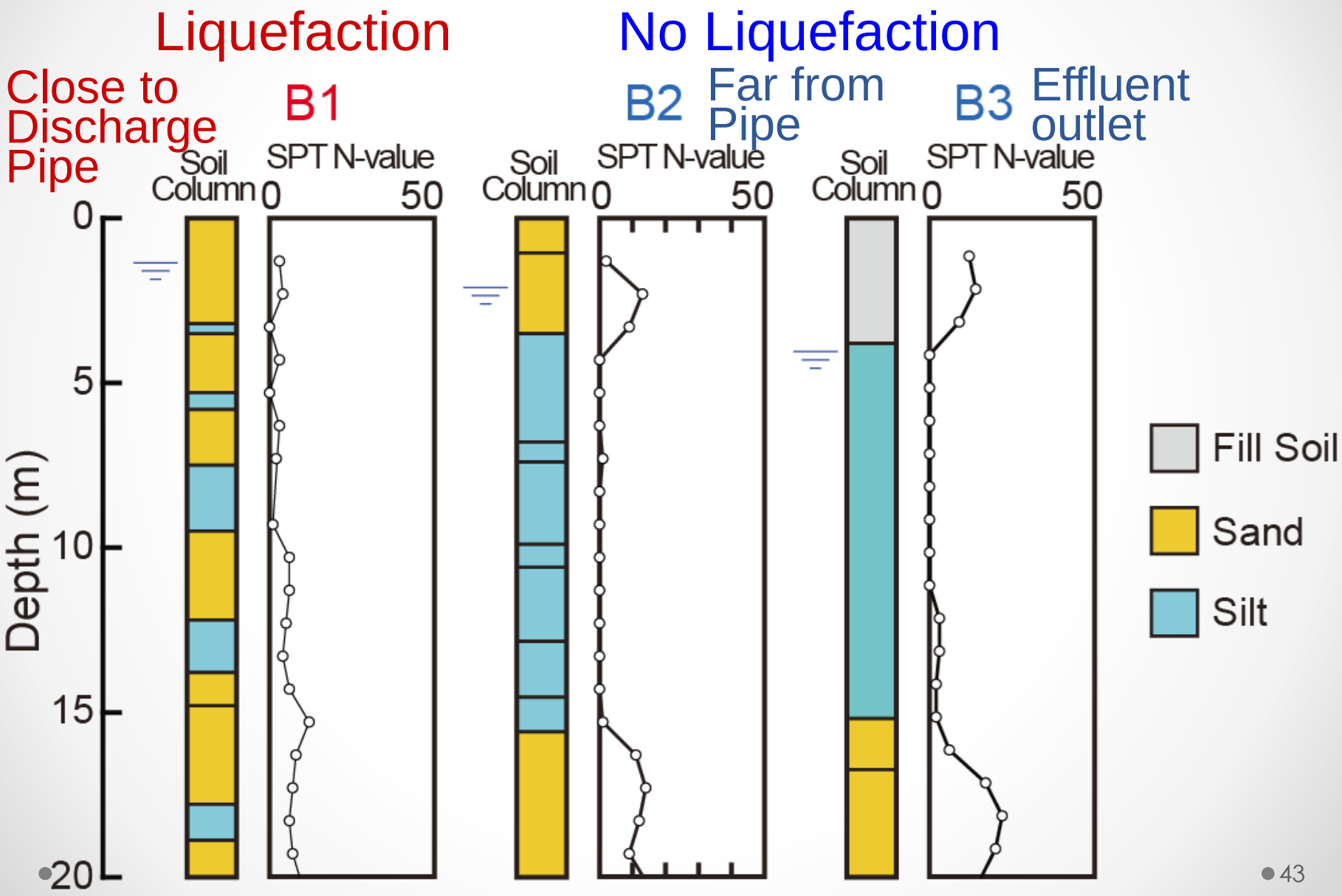
Isobe District
(Residential Area)



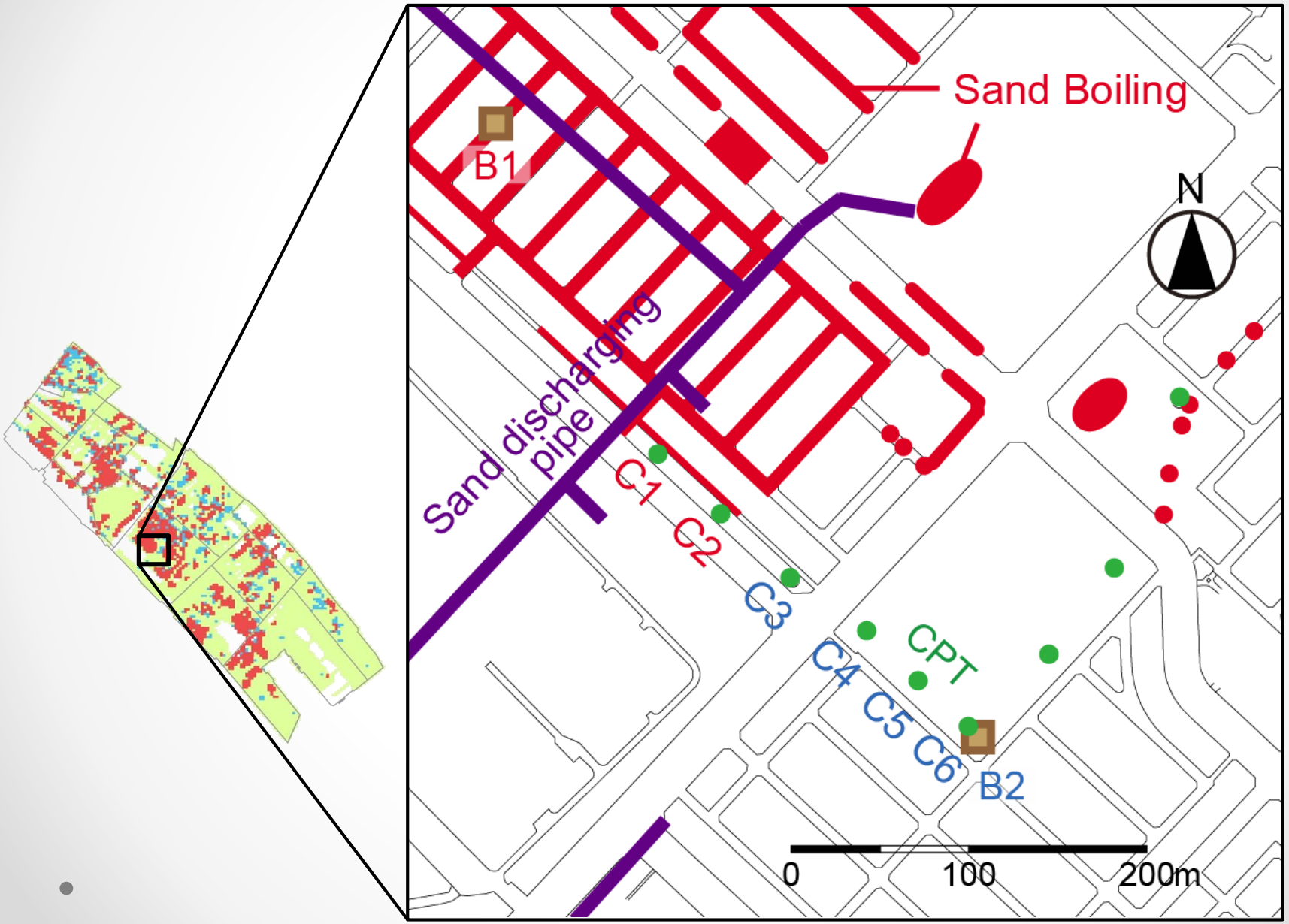
Isobe District (Aerial Photo in 1972)



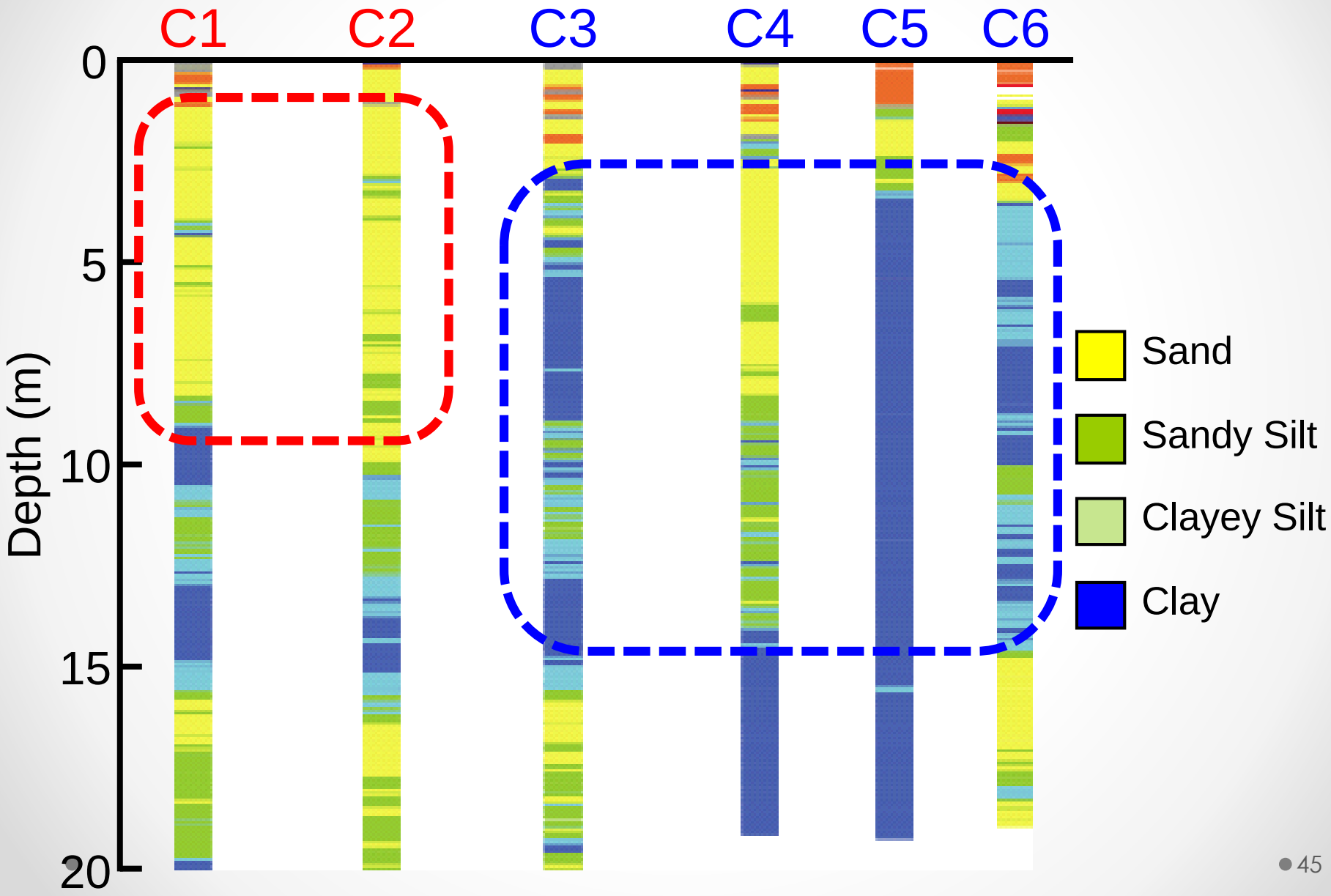
Soil Profile at B1, B2 and B3



CPT near Sand Discharging Pipe



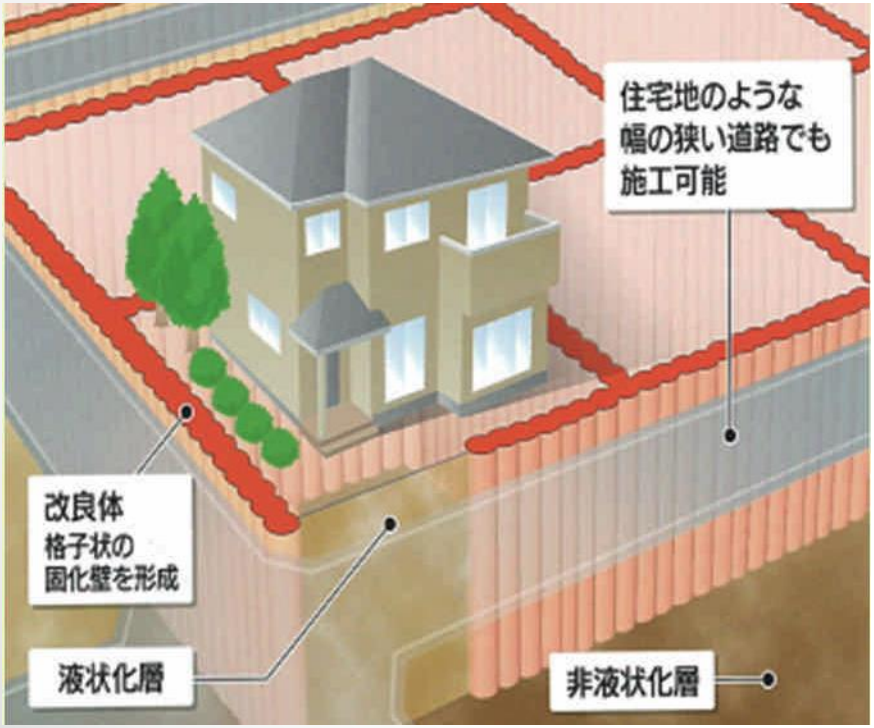
CPT near Sand Discharging Pipe



Countermeasures Against Liquefaction for Existing Residential Areas

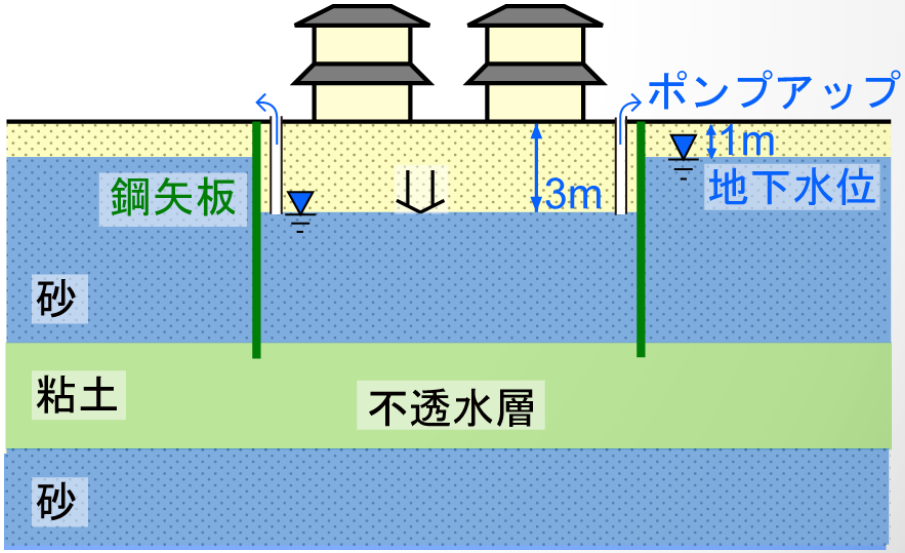
Typical Countermeasures for Existing Residential Area

Grid Form Ground Imprv.
(Urayasu city)



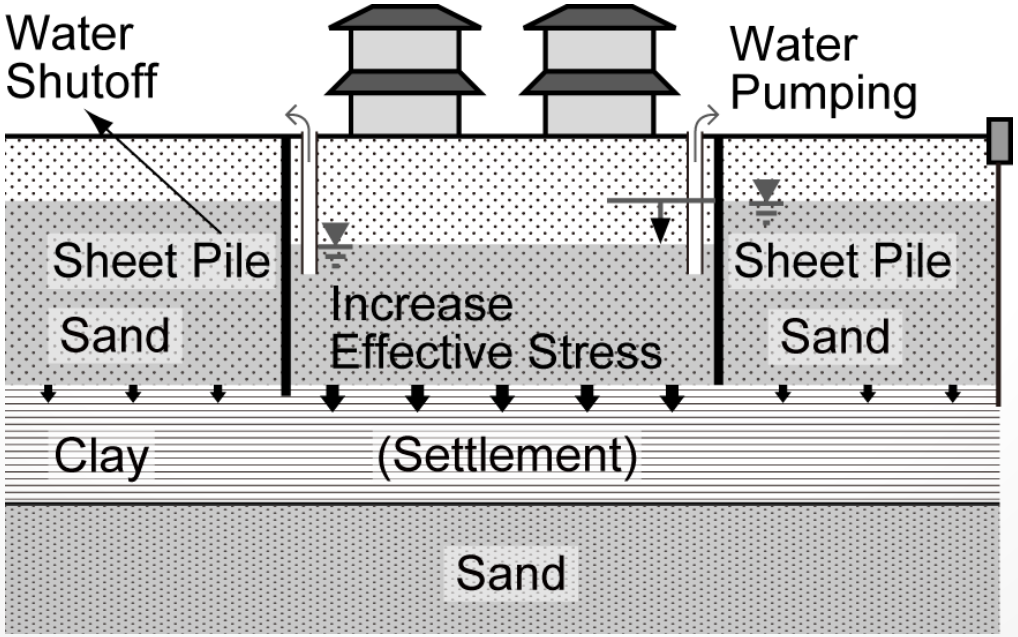
http://jgs-chubu.org/download/syn4/pdf/23/23_3_1.pdf

Dewatering
(Chiba city)



Dewatering as a Countermeasure

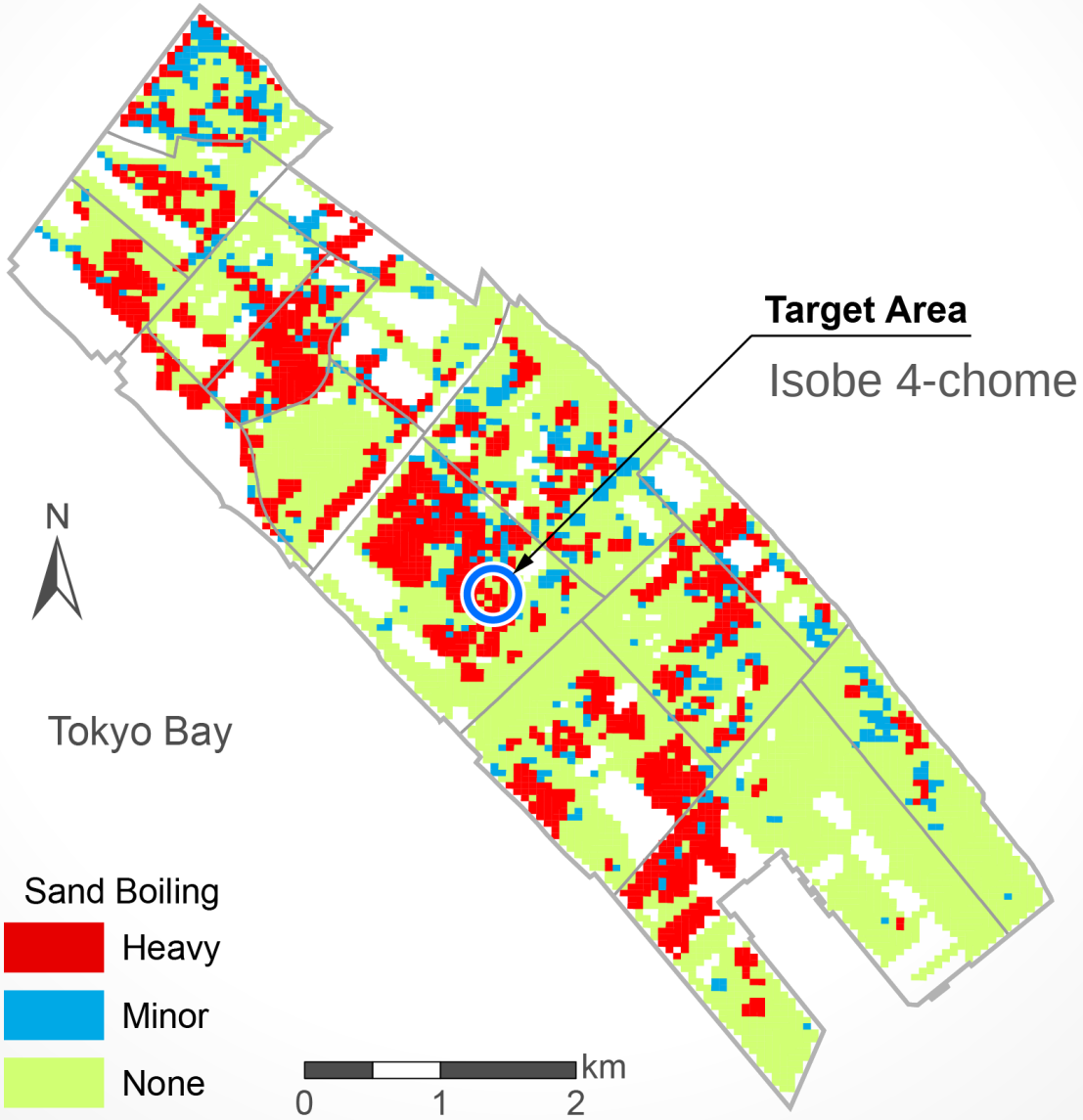
- The local government (Chiba City) decided to take measures against future liquefaction damage in the existing residential areas: Dewatering.
- We are involved in the project.



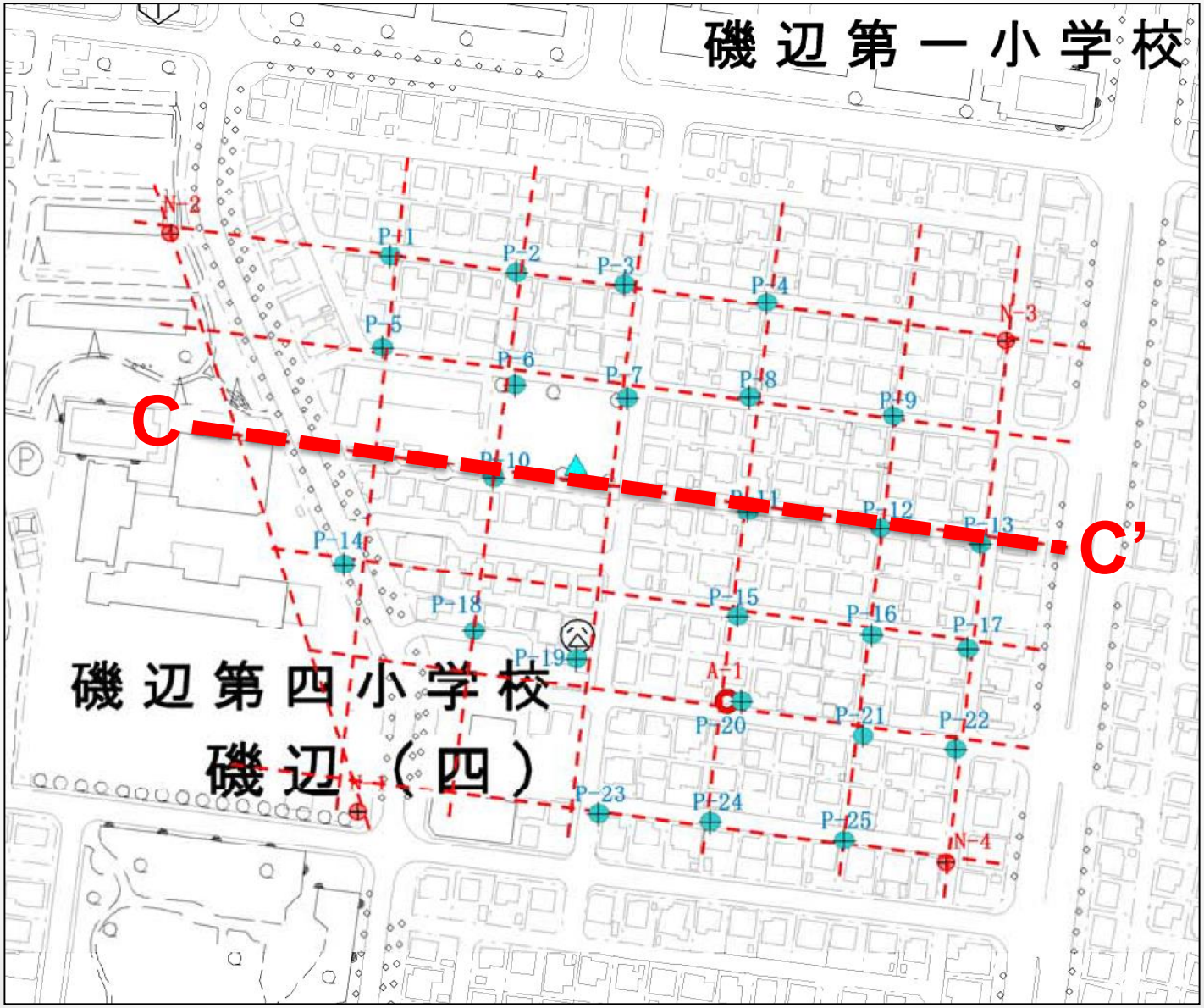
Countermeasures Against Liquefaction

Demonstration Test

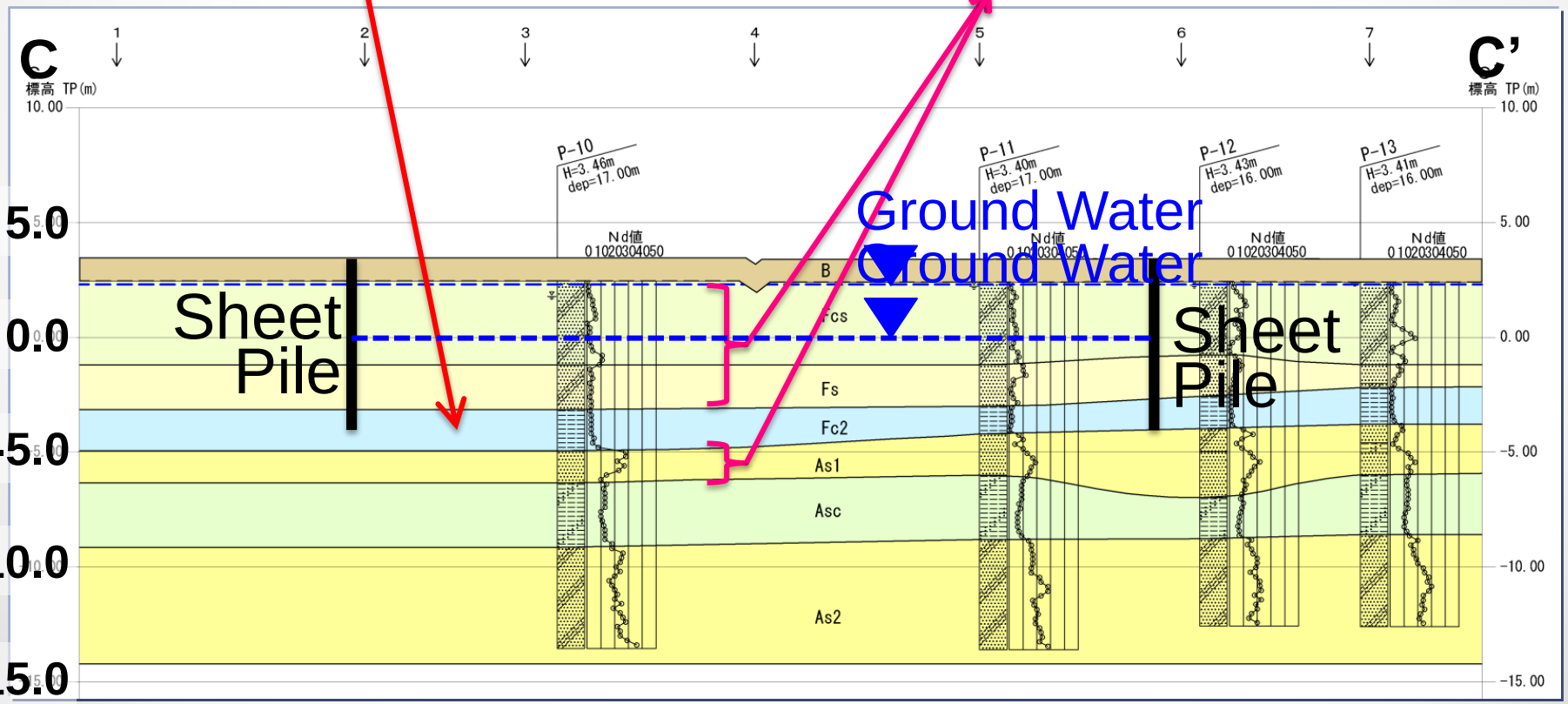
Target(Model) Area



Target Site

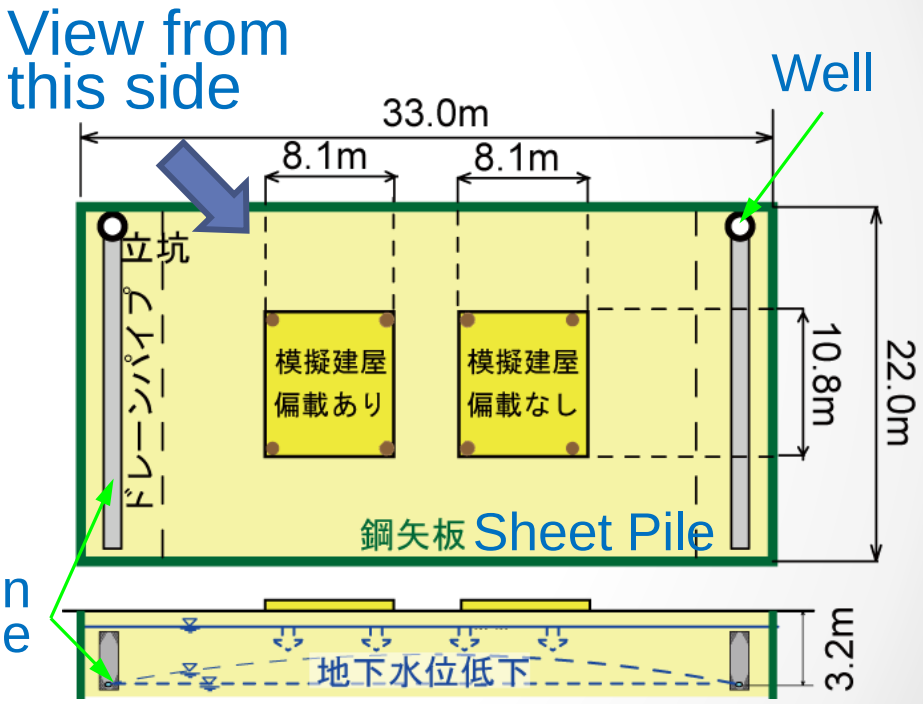

磯辺第一小学校
N-2
P-1
P-2
P-3
P-4
N-3
P-5
P-6
P-7
P-8
P-9
C
P-10
P-11
P-12
P-13
C'
P-14
P-15
P-16
P-17
P-18
P-19
磯辺第四小学校
A-1
C
P-20
P-21
P-22
磯辺（四）
P-23
P-24
P-25
N-4

Soil Profile (C-C')



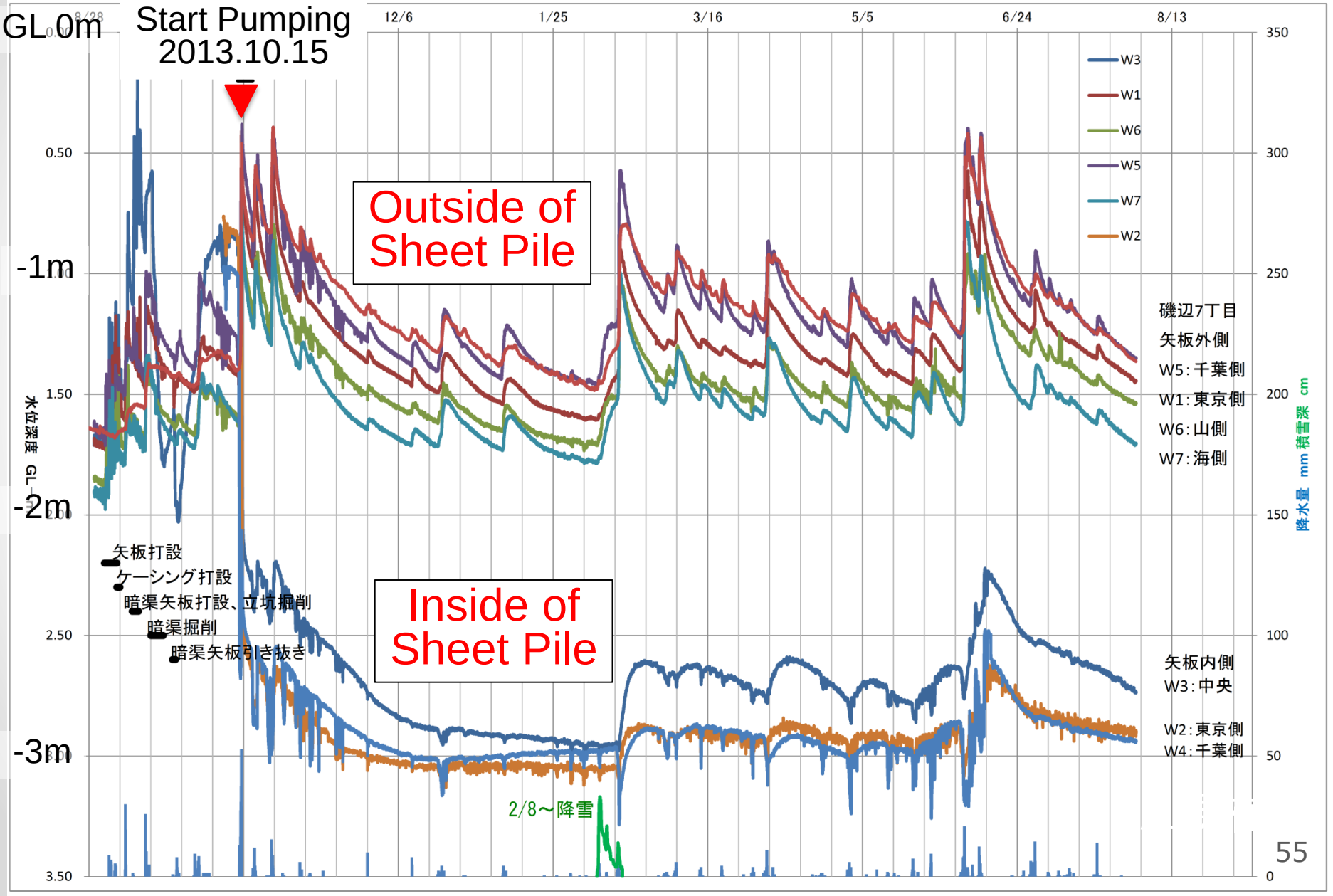
Demonstration Test of Dewatering

Residential House Models

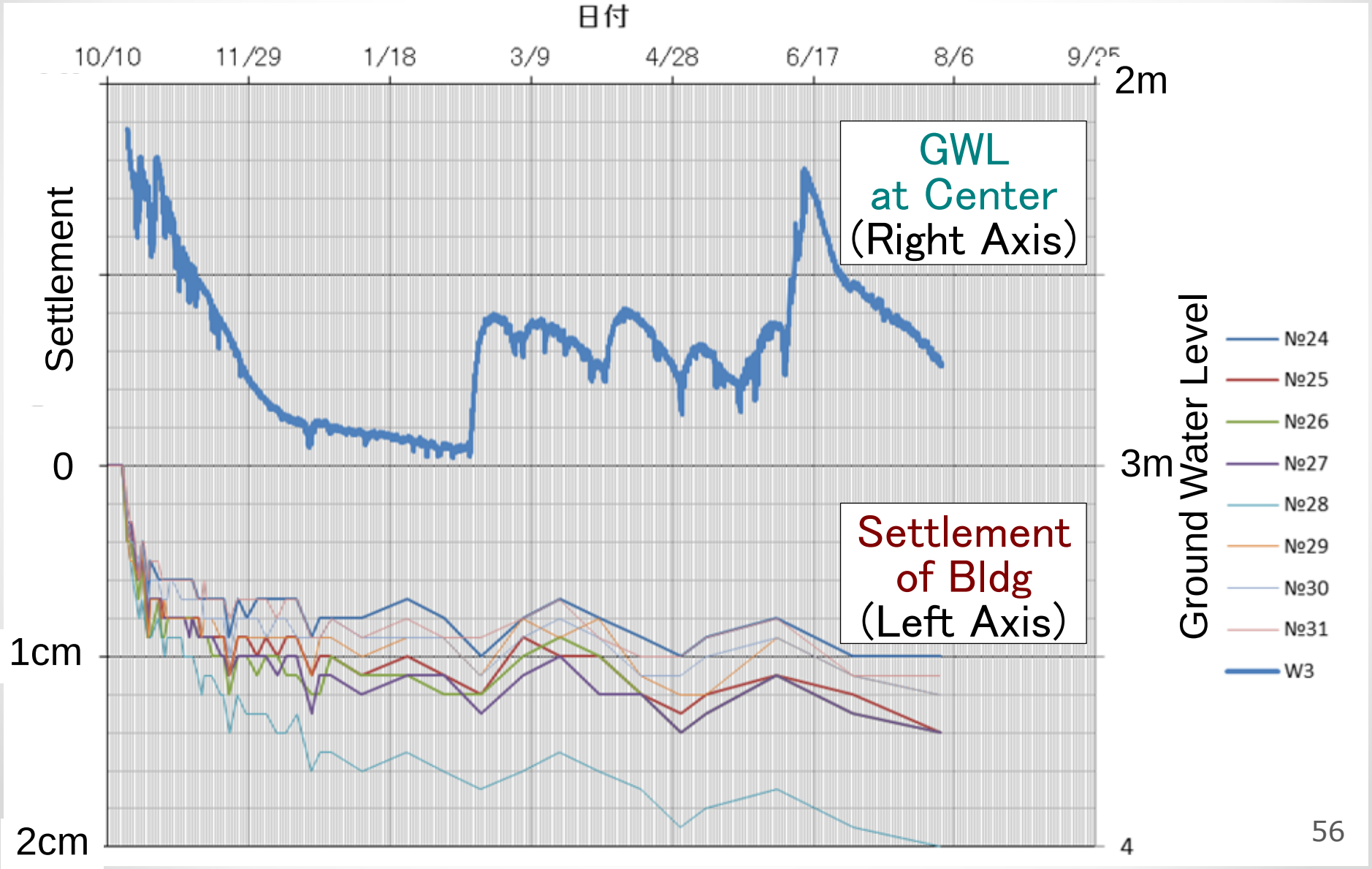


Upper: Plan, Lower: Section

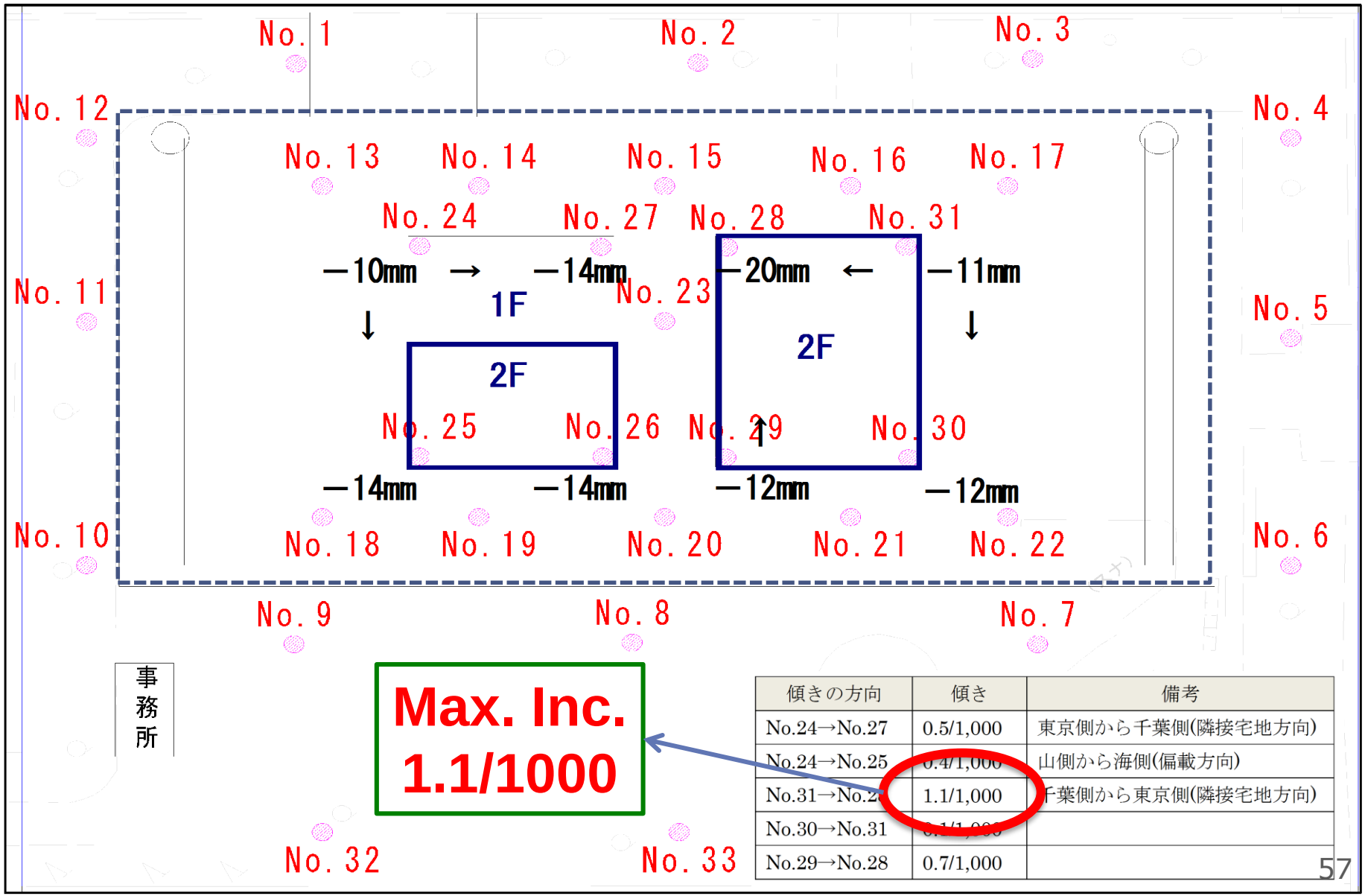
Ground Water Level Observation



Settlement of Model Bldgs



Differential Settlement



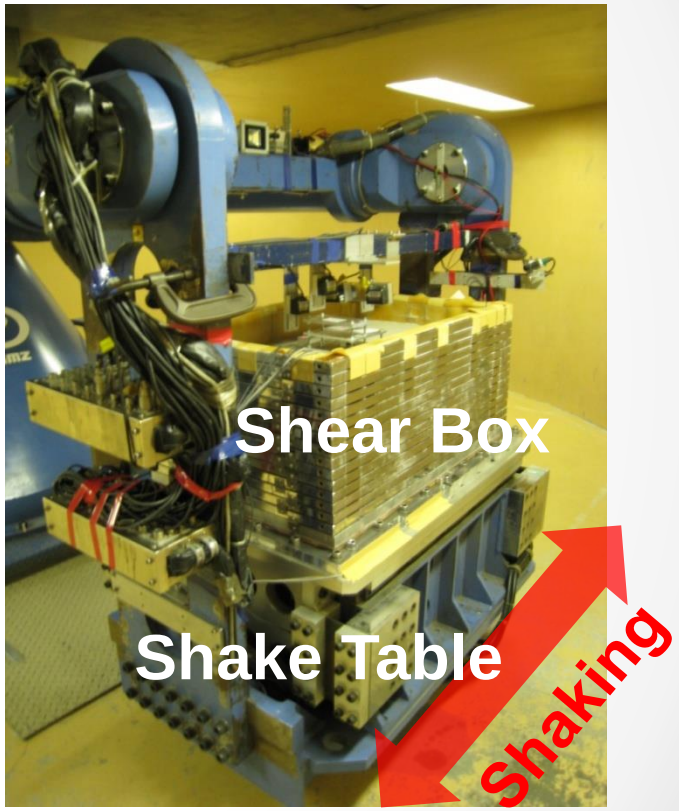
傾きの方向	傾き	備考
No.24→No.27	0.5/1,000	東京側から千葉側(隣接宅地方向)
No.24→No.25	0.4/1,000	山側から海側(偏載方向)
No.31→No.2[illegible]	1.1/1,000	千葉側から東京側(隣接宅地方向)
No.30→No.31	[illegible]	
No.29→No.28	0.7/1,000	

Countermeasures Against Liquefaction

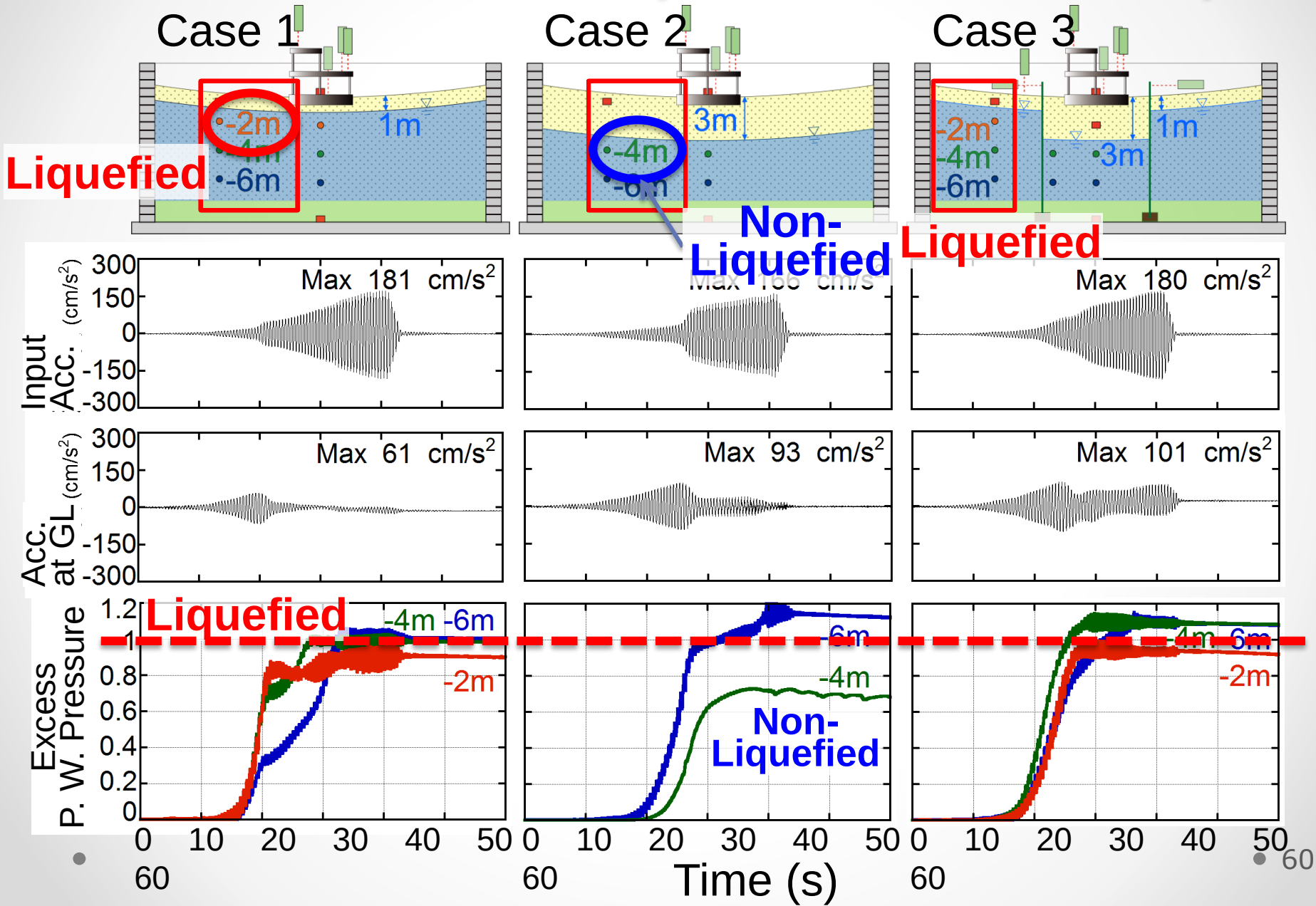
Centrifuge Shake Table Test

Centrifuge Model Test

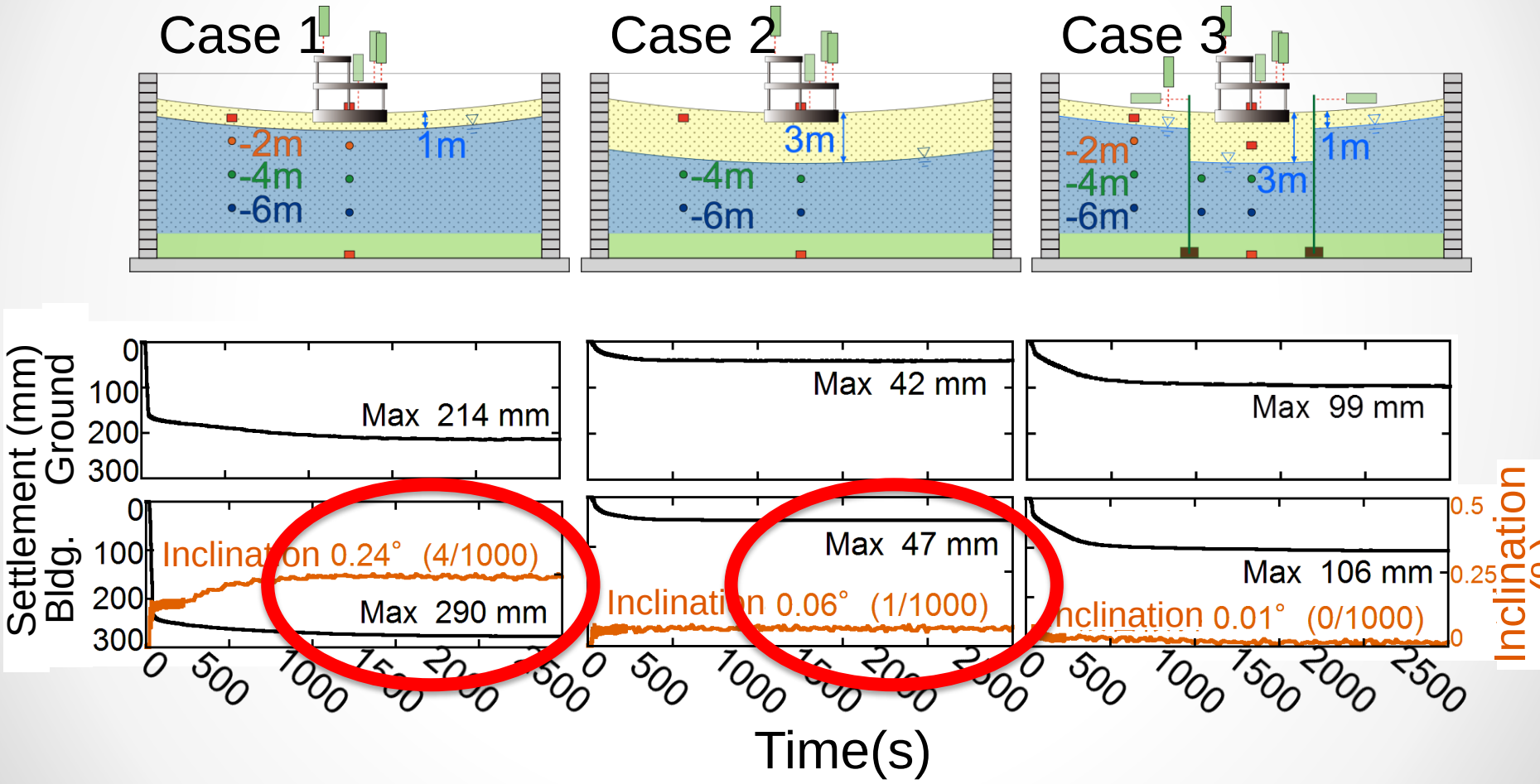
- The objective is to evaluate the effectiveness of dewatering against liquefaction during an earthquake in the target site.
- The ground motion that was experienced in this area during Tohoku earthquake was applied.



Test Results (Excess PWP)



Test Results (Differential Settlement)



Settlement / inclination are suppressed.

Concluding Remarks

- Extensive liquefaction was observed in the area along the coast of Tokyo bay during 2011 Tohoku earthquake.
- We have carried out a survey of liquefaction damage in the form of sand boiling extensiveness, throughout Mihama ward of Chiba city.
- The resulting damage distribution was found to be non-uniform by a great deal.
- The cause of non-uniformity can be considered as a result of the reclamation process of hydraulic filling.
- The local government is taking measures against liquefaction damage due to future earthquakes.

(Video)

If time permits.