

ESCENARIO CATASTRÓFICO PARA LIMA Y EL CALLAO ANTE UN SISMO DE GRAN MAGNITUD (> M8.0)



XXXIV SIMPOSIO NACIONAL DE
PREVENCIÓN DE DESASTRES

“Escenario Tsunamigénico para Lima y Callao por un Sismo de Gran Magnitud”

Ing. Miguel Estrada Mendoza, PhD.

S. Koshimura, J. Morales, F. García, C. Jiménez, L. Márquez, J. Palacios, A. Quesquén



CENTRO PERUANO JAPONÉS DE
INVESTIGACIONES SÍSMICAS Y
MITIGACIÓN DE DESASTRES

FACULTAD DE
INGENIERÍA CIVIL

UNIVERSIDAD NACIONAL
DE INGENIERÍA

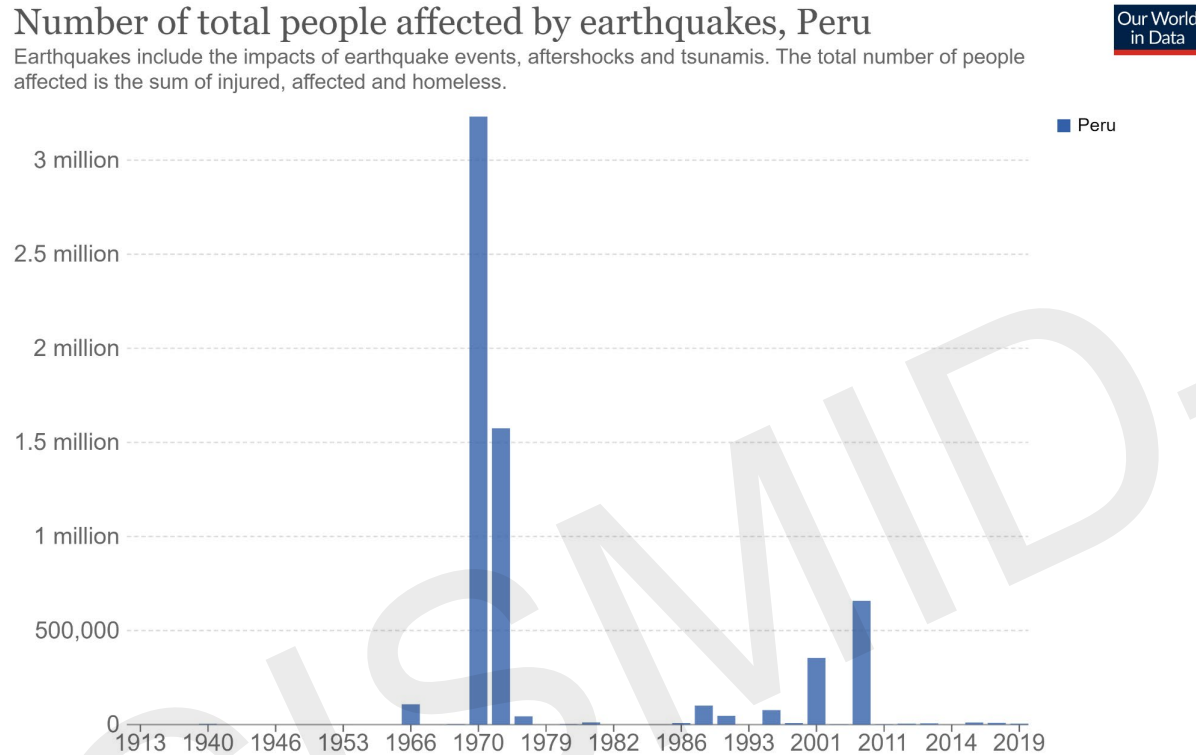


Consecuencias de los Terremotos en el Perú

Personas afectadas

Number of total people affected by earthquakes, Peru

Earthquakes include the impacts of earthquake events, aftershocks and tsunamis. The total number of people affected is the sum of injured, affected and homeless.

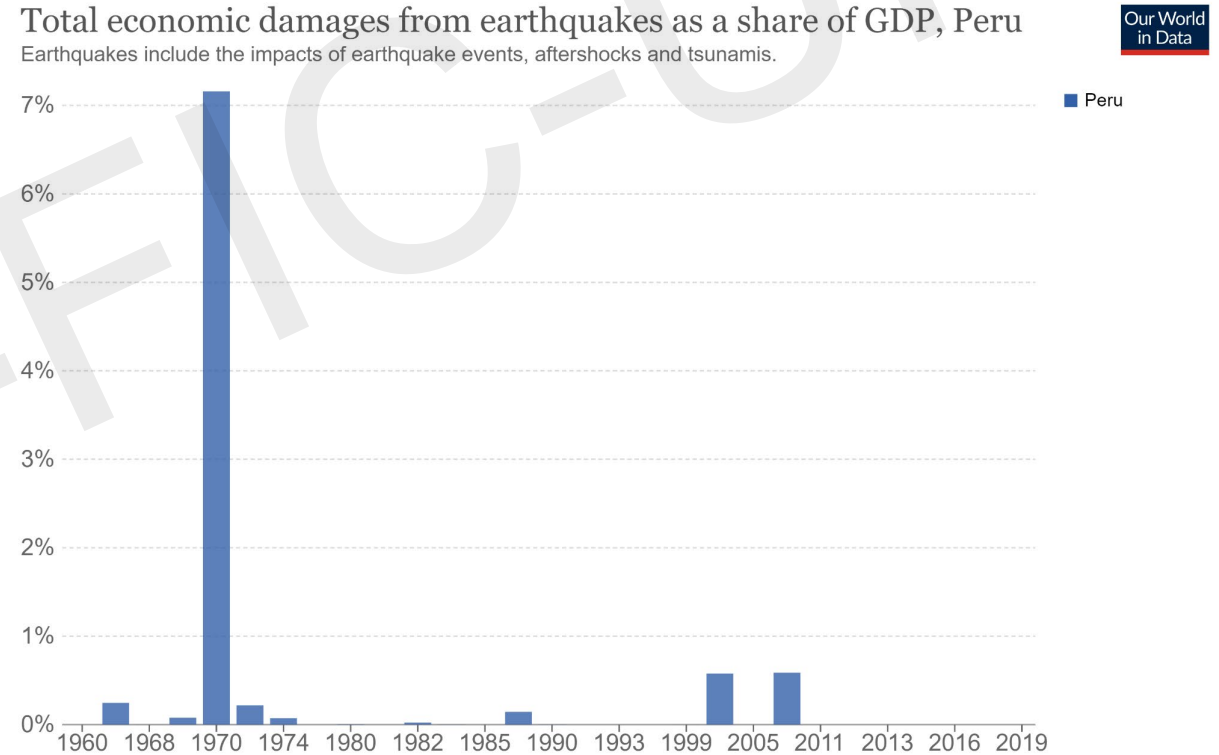


Source: Calculated by Our World in Data based on EM-DAT, CRED / UCLouvain, Brussels, Belgium – (D. Guha-Sapir)
OurWorldInData.org/natural-disasters • CC BY

Daño Económico

Total economic damages from earthquakes as a share of GDP, Peru

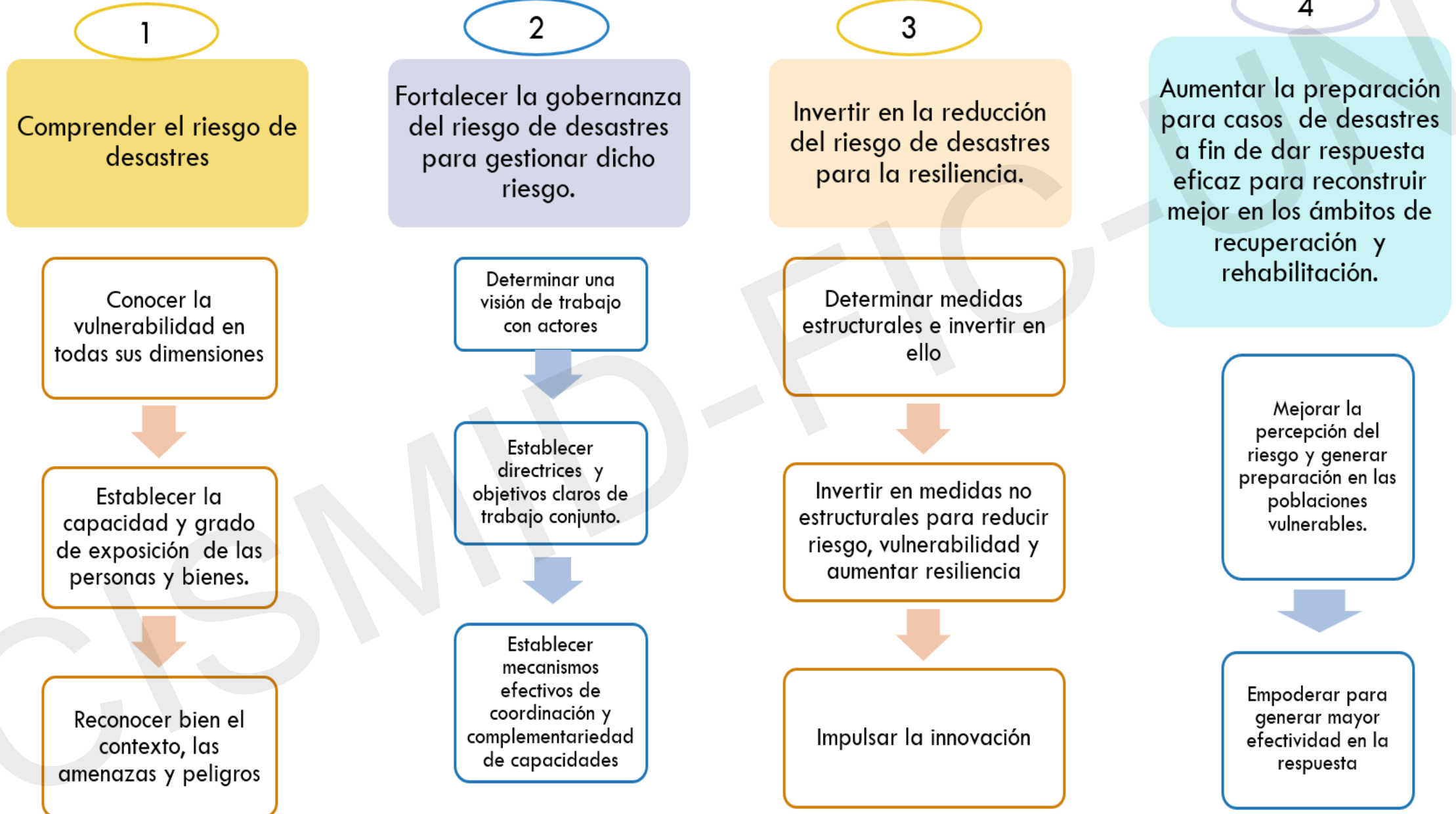
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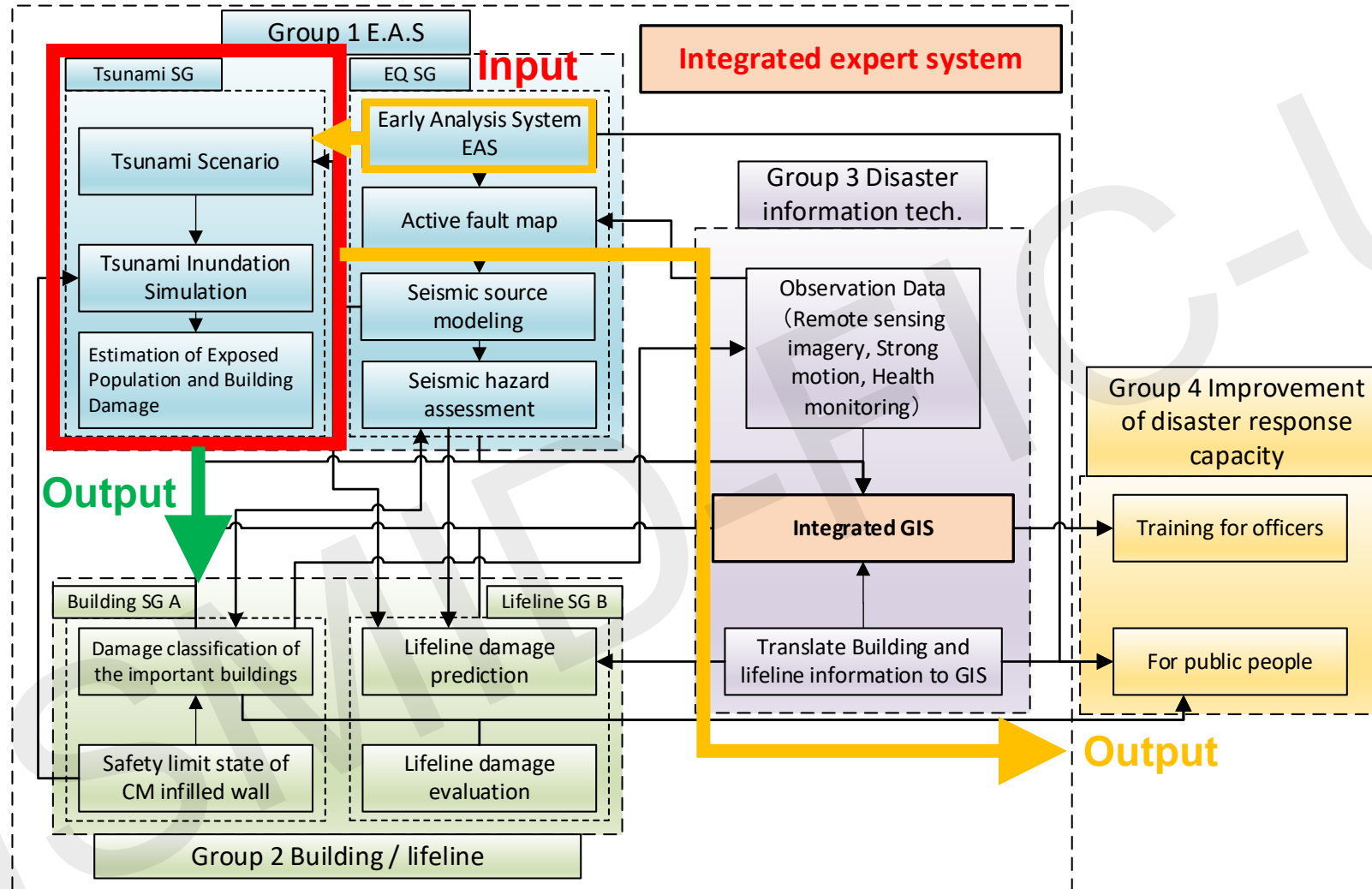
Source: Calculated by Our World in Data based on EM-DAT, CRED / UCLouvain, Brussels, Belgium – (D. Guha-Sapir)
OurWorldInData.org/natural-disasters • CC BY

Fuente: Our World in Data: <https://ourworldindata.org/natural-disasters>

Prioridades de SENDAI (2015)



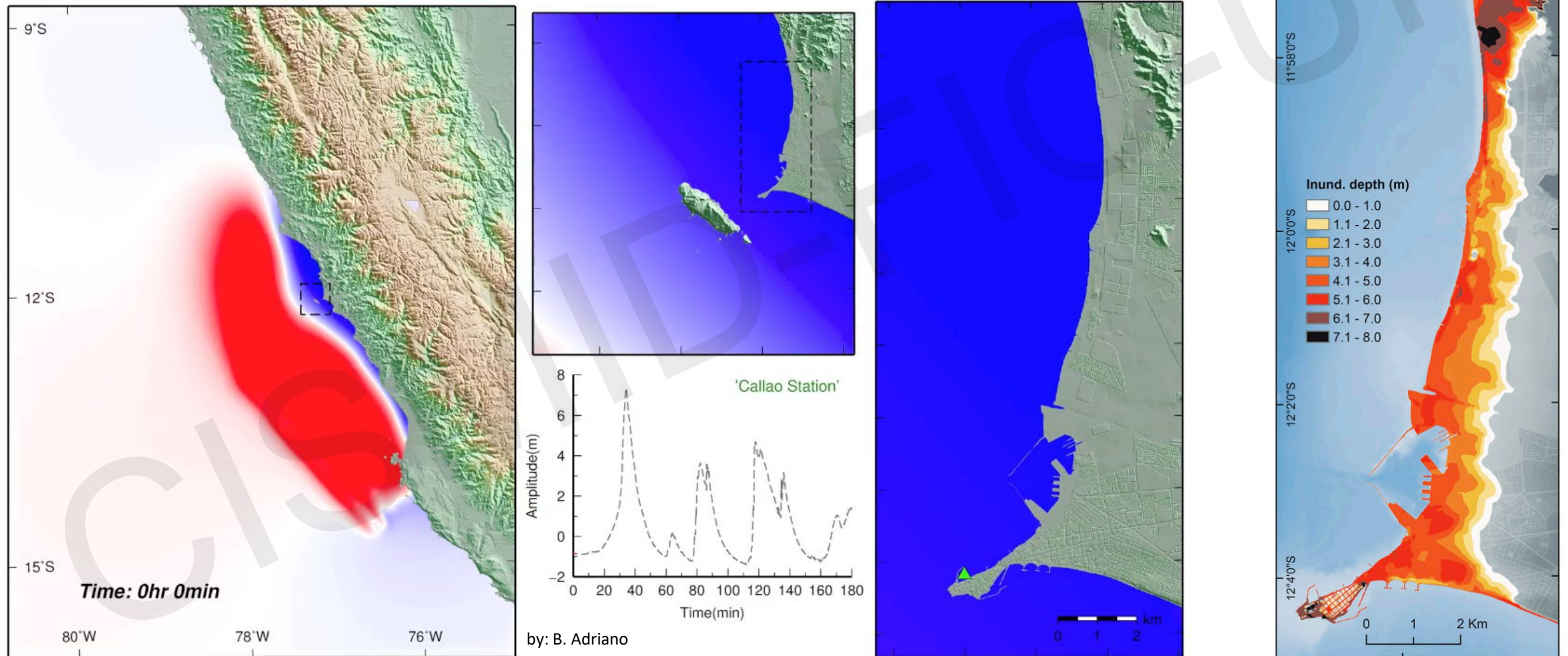
SATREPS Project Structure



Enhance the Peruvian capacity of the earthquake disaster management of officers and stake-holders with the integrated expert system.

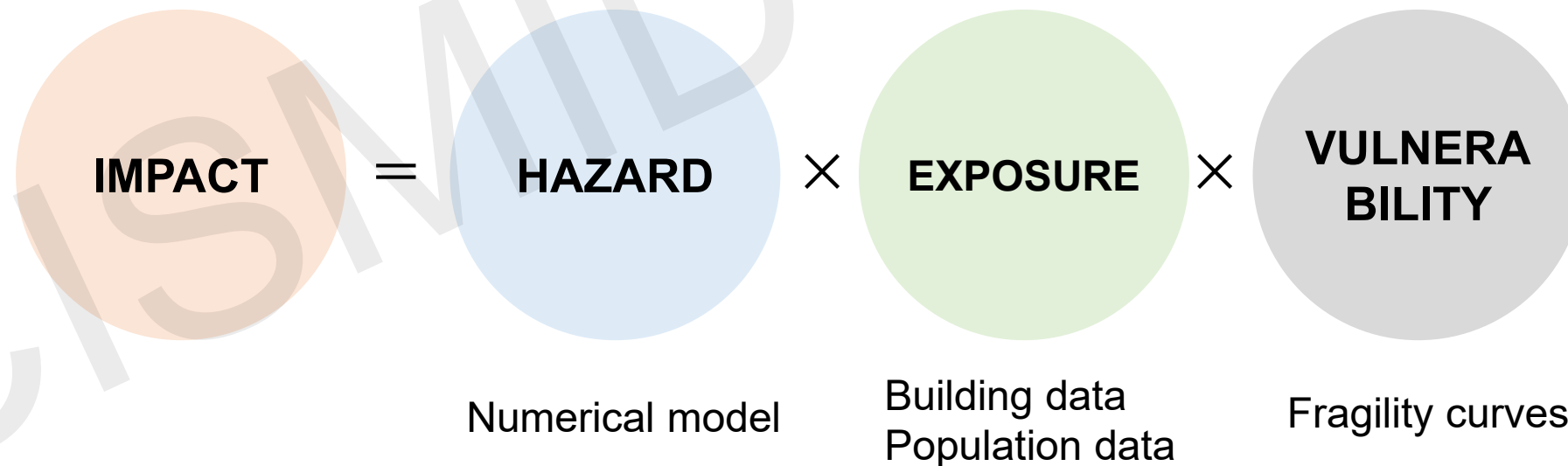
Potential Tsunami Inundation Scenarios

Tsunami Simulation and Envelope of Maximum Inundations (Mas et al. 2014)



Objective : Developing a Capability of Tsunami Inundation and Damage Forecast for Lima, Peru

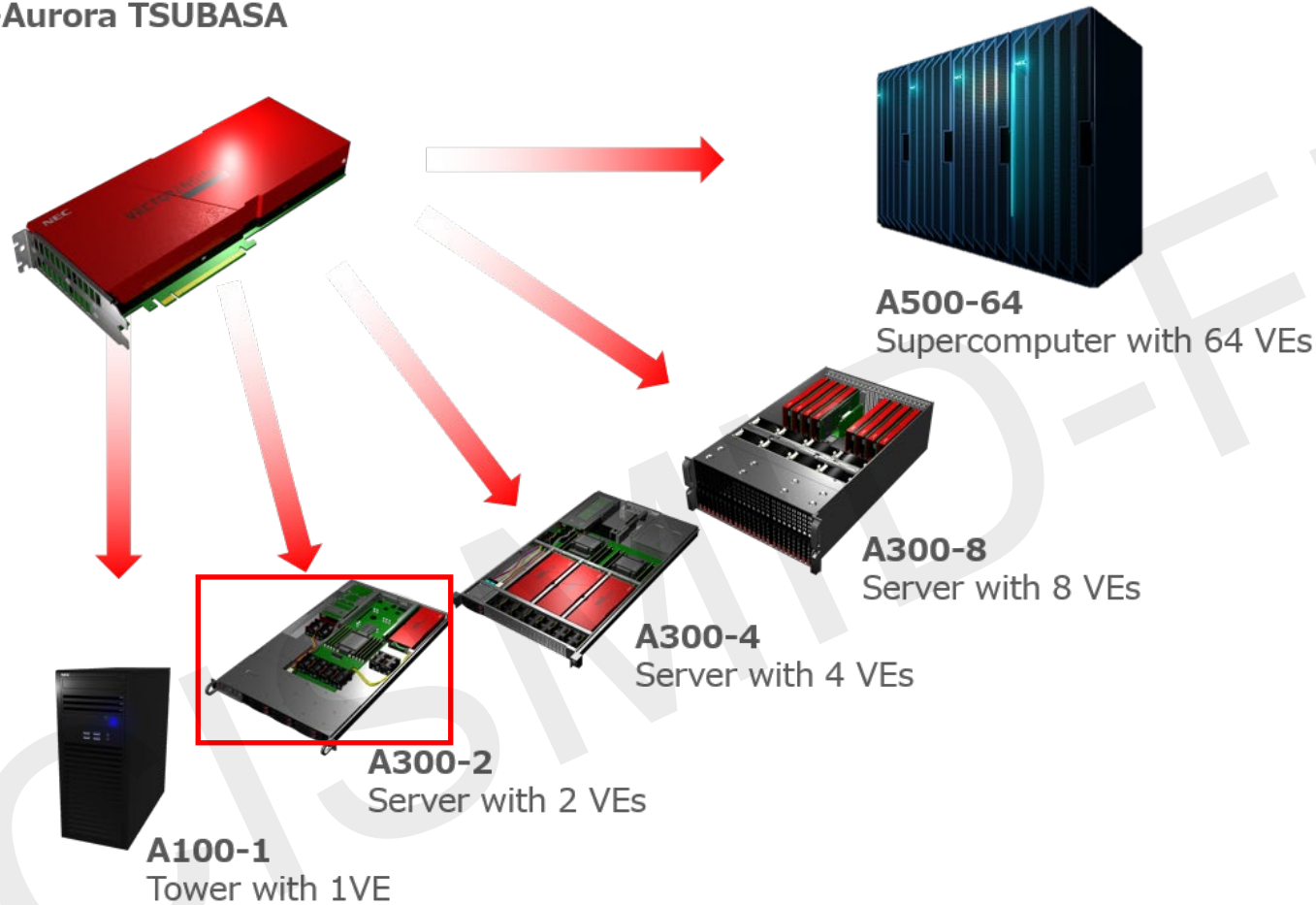
- ✓ High-Performance Computing
- ✓ High-Resolution Bathymetry/Topography Data
- ✓ Exposure Data and Analysis
- Vulnerability : Tsunami Fragility Curves



Computing Platform

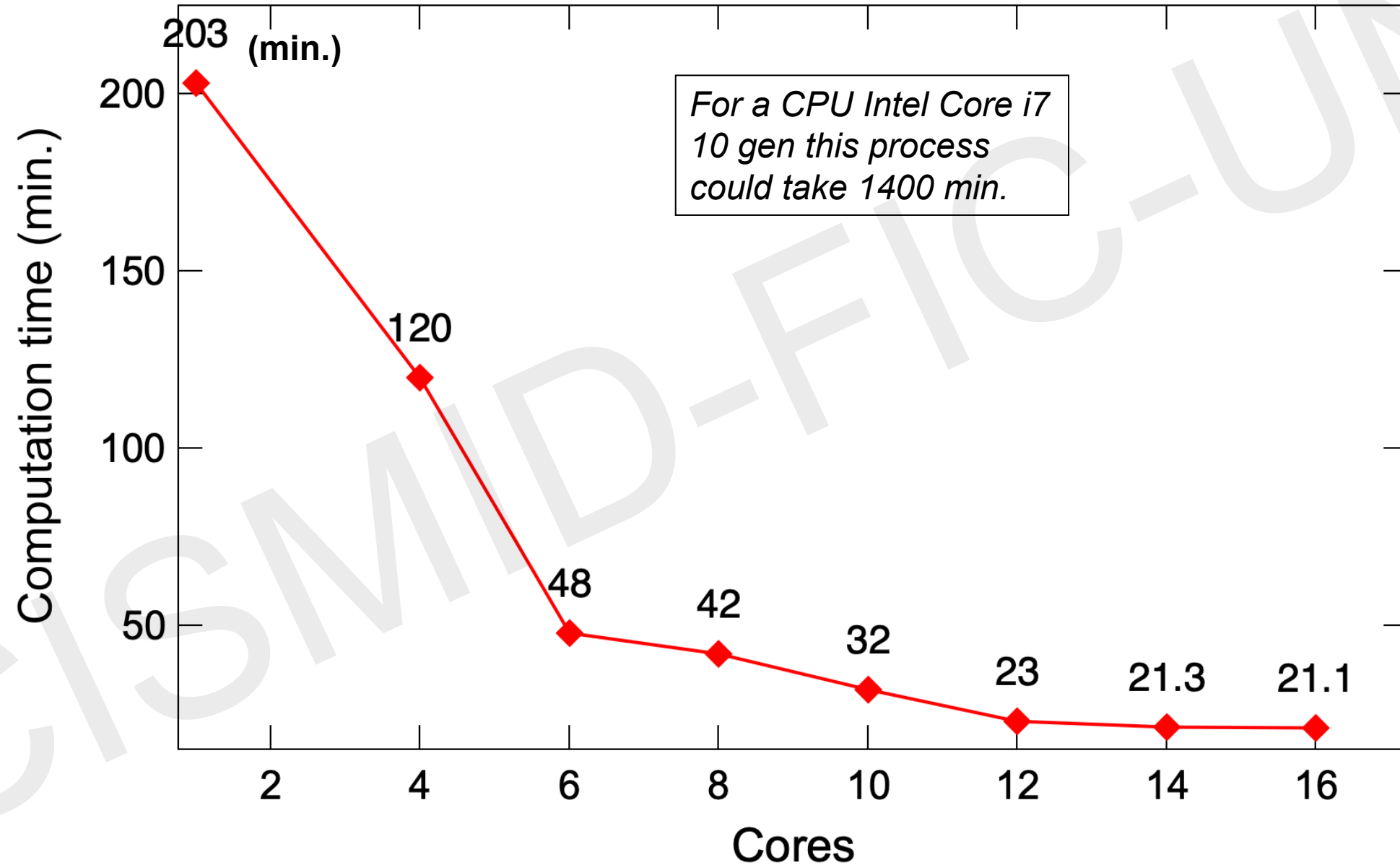
NEC SX-Aurora TSUBASA (Tohoku Univ.)

SX-Aurora TSUBASA



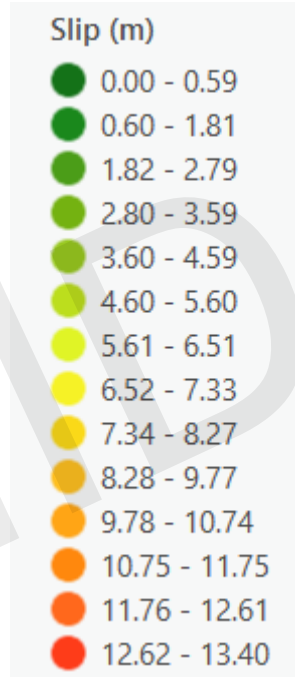
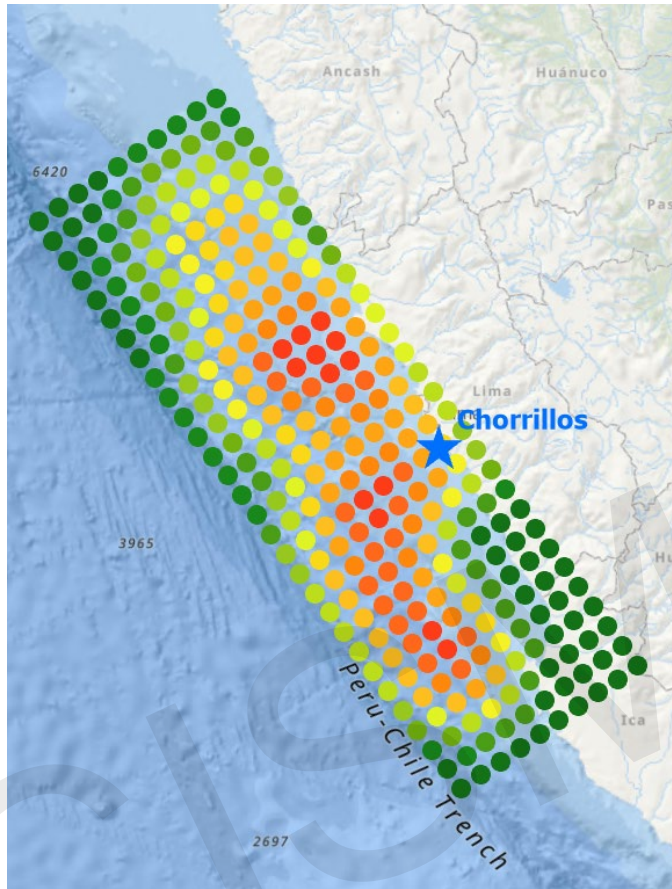
Host	CPU	Xeon Gold 6126 (12C/2.6GHz) × 2
	Memory	96GB DDR4
	Disk	240GBSSD
Vector Engine	CPU	Type10B-P[8Core] × 2 268 GFLOPS/Core 2.15 TFLOPS/Processor 4.3 TFFLOPS/System
	Memory	48 GB/Processor × 2 96 GB/System

Performance of 6-hour Inundation Forecast



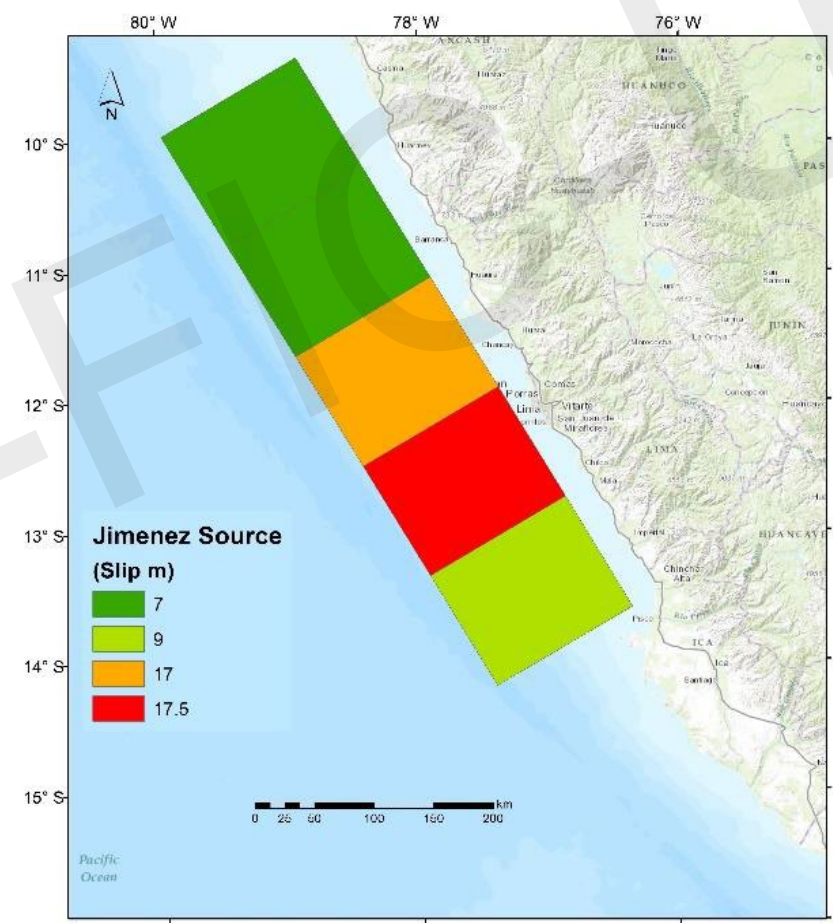
Fuentes Tsunamigénicas

Tsunami source (Mw 8.8): Villegas Lanza et al., (2016)



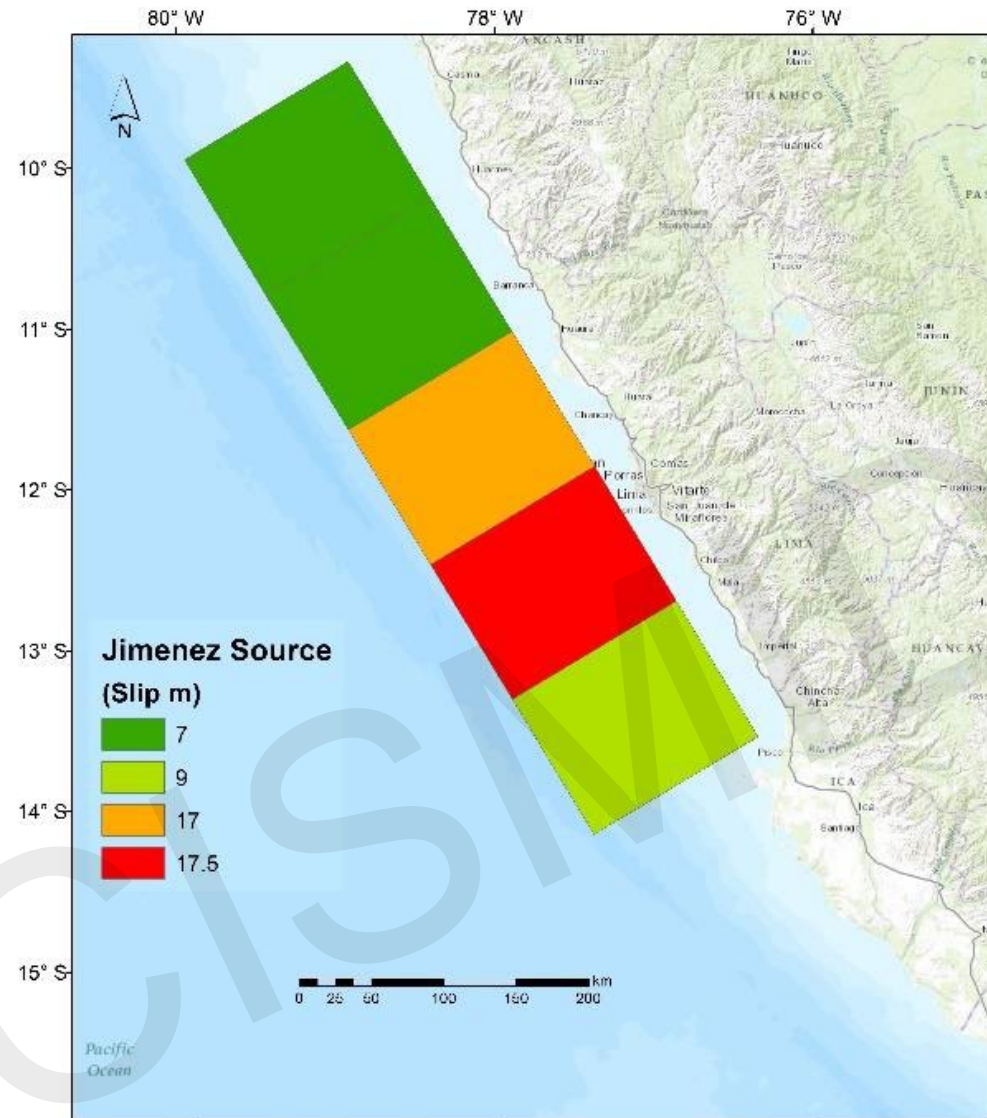
300 subfaults of
20 km x 20 km

Tsunami source (Mw 9.0): C. Jiménez (2015)



5 subfaults of
100 km x 150 km

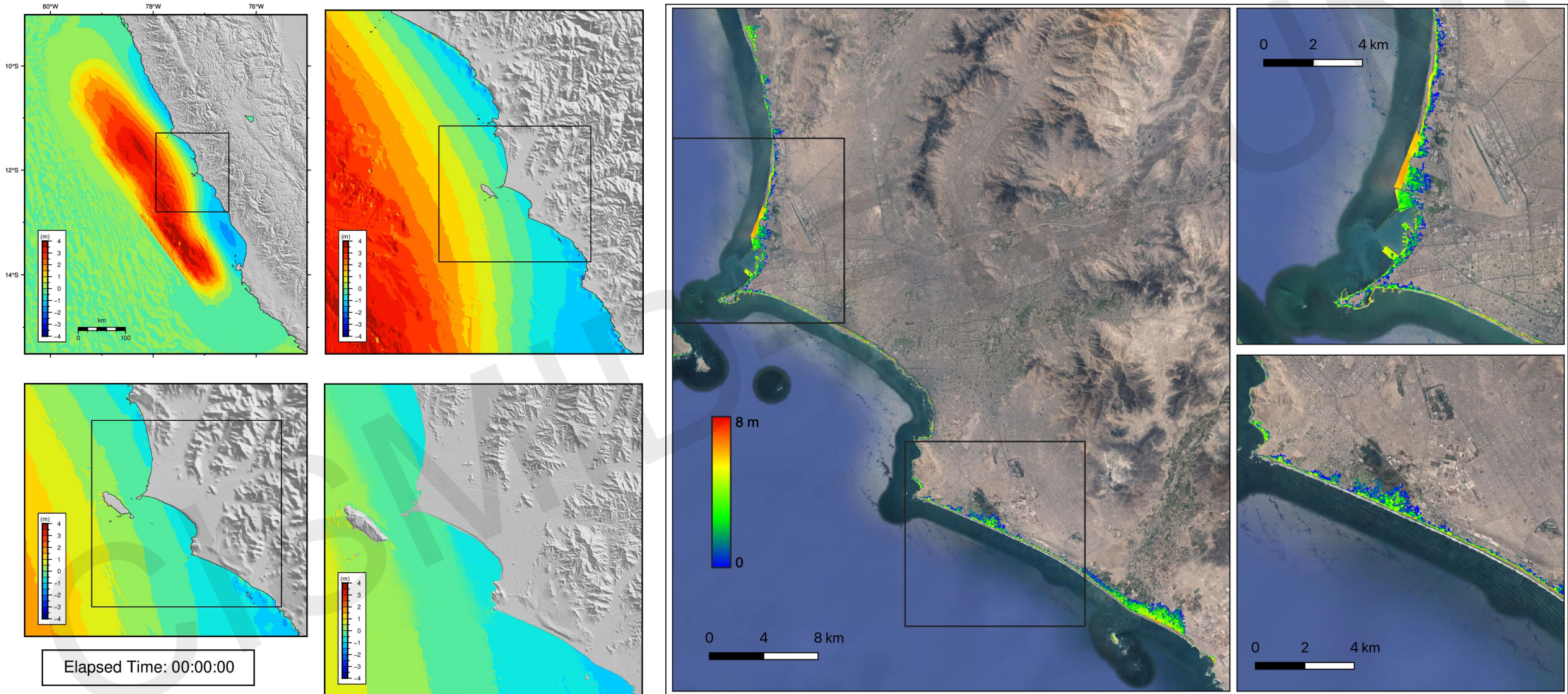
Tsunami source (Mw 9.0): C. Jiménez, (2015)



5 subfaults of
100 km x 150 km



Test Case for 6-hour Inundation Forecast

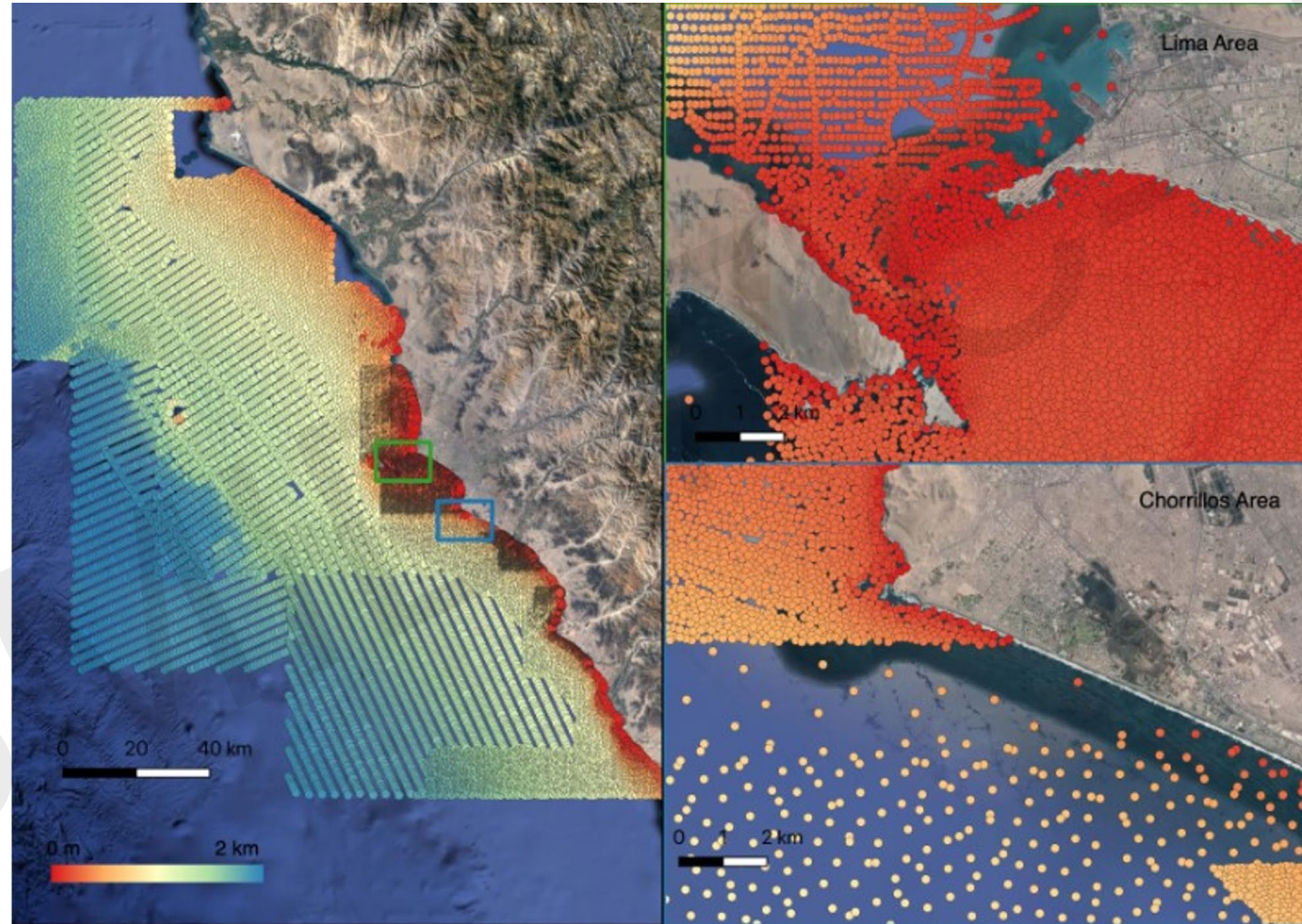


Tsunami source (Mw8.9): Villegas-Lanza et al., (2016), JGR Solid Earth

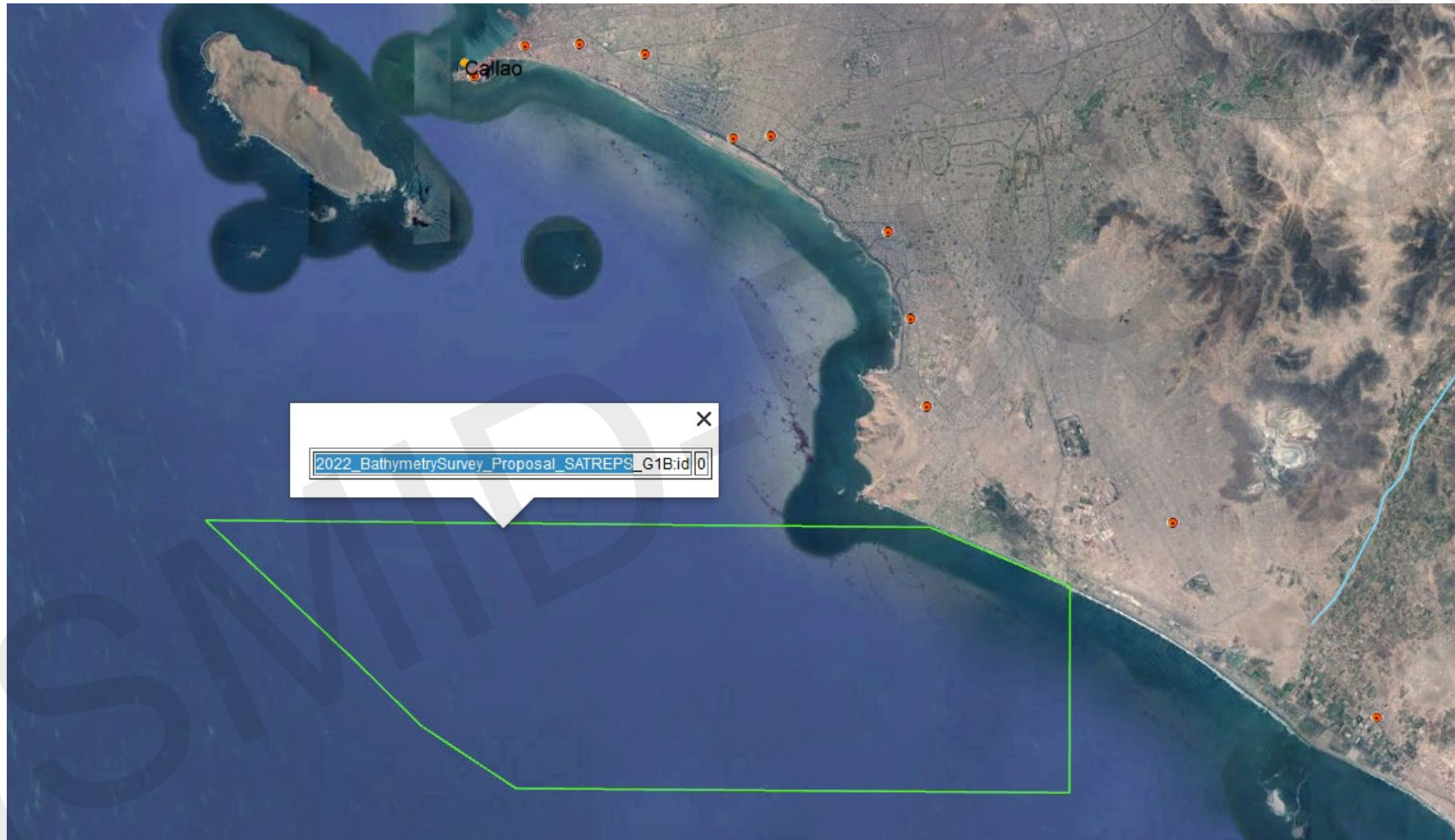
Updating bathymetry and Topography Data

Bathymetry and topography data

- Sources
- Grid size
- Acquisition o generation Schedule (under discussion)



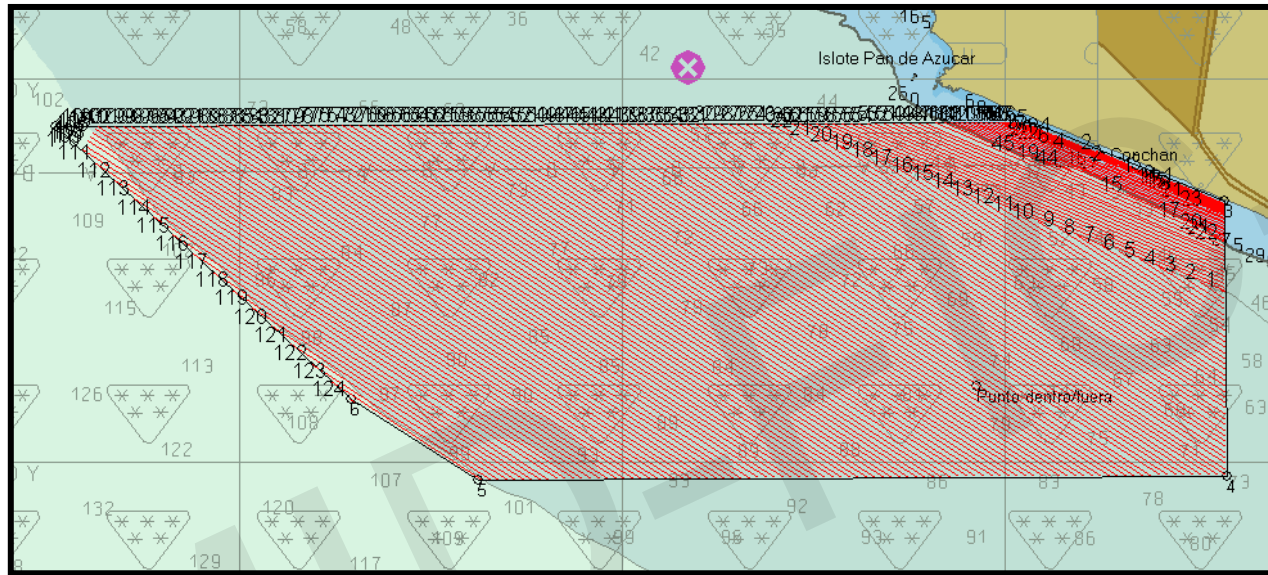
PLANEAMIENTO ACTUALIZADO CARTA HIDRONAV "CHORRILLOS LA CHIRA " SATREPS
DEL ÁREA DEMARCADA (POLIGONO VERDE):



PLANEAMIENTO CARTA HIDRONAV

“CHORRILLOS LA CHIRA”

SATREPS



Sub-Zona	N° Líneas	Long. Promedio (Metros)	Long. Total (Millas)	Tiempo 8 horas a 4 Nudos en Días
A (10 a 20 m.)	23	51,215	27.70	1.00
B (20 a 30 m.)	22	74,032	40.0	1.25
C (30 a 50 m.)	21	166,732	90.1	2.81
D (50 a 100 m.)	124	1'740,503	939.8	29.40
CAIDAS	2	52,000	28.00	1.00
Total en días de Levantamiento				36.0

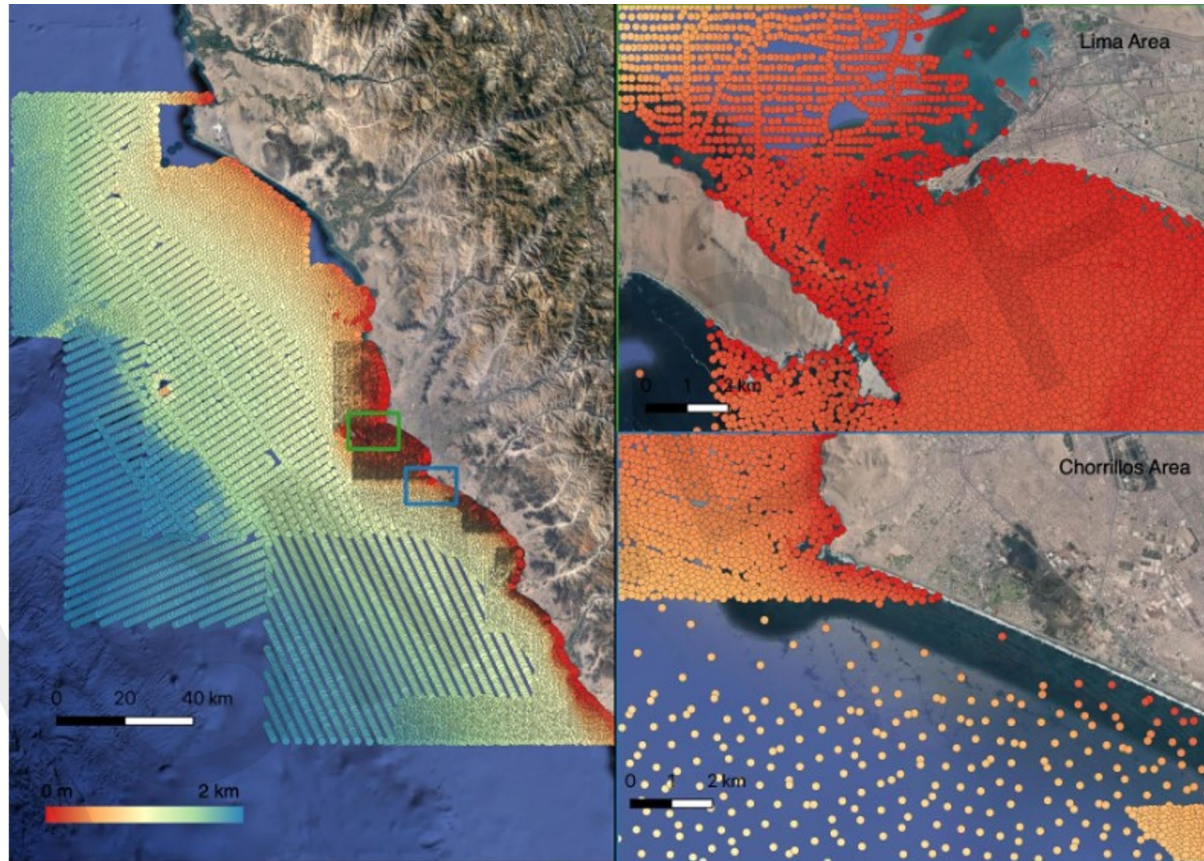
Actualización de datos batimétricos y topográficos

Reuniones de Coordinación con DHN



Bathymetry and topography data

- Sources
- Grid size
- Acquisition o generation Schedule (under discussion)



Actualización de la topografía y exposición

Flight plan 3

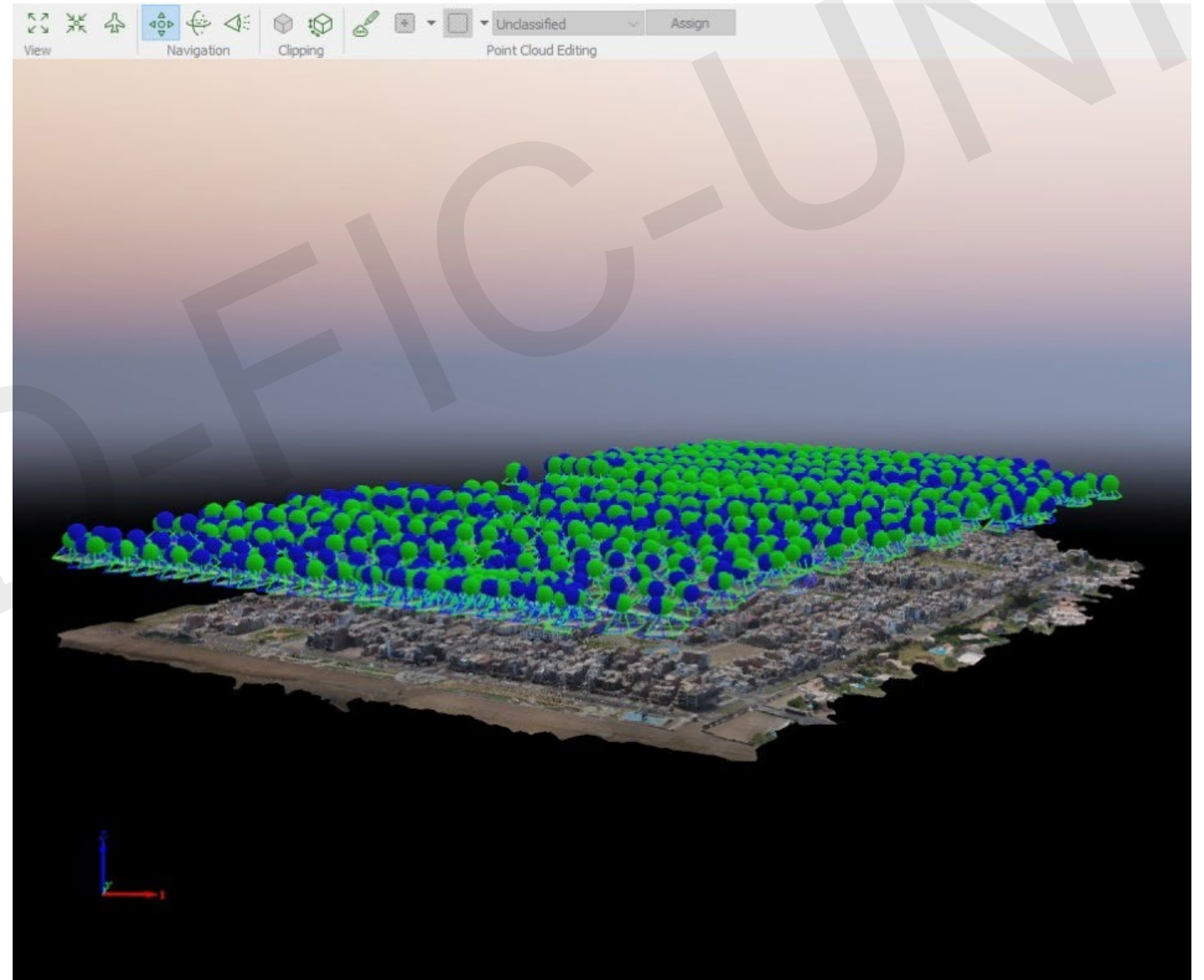
Area: 25.67 hect
Distance: 7.95 km
Path Speed: 10.6 m/s
Duration: 14m 15s
Batteries: 1
Images: 227
Points: 272
Storage: 1.19 GB

Flight plan 2

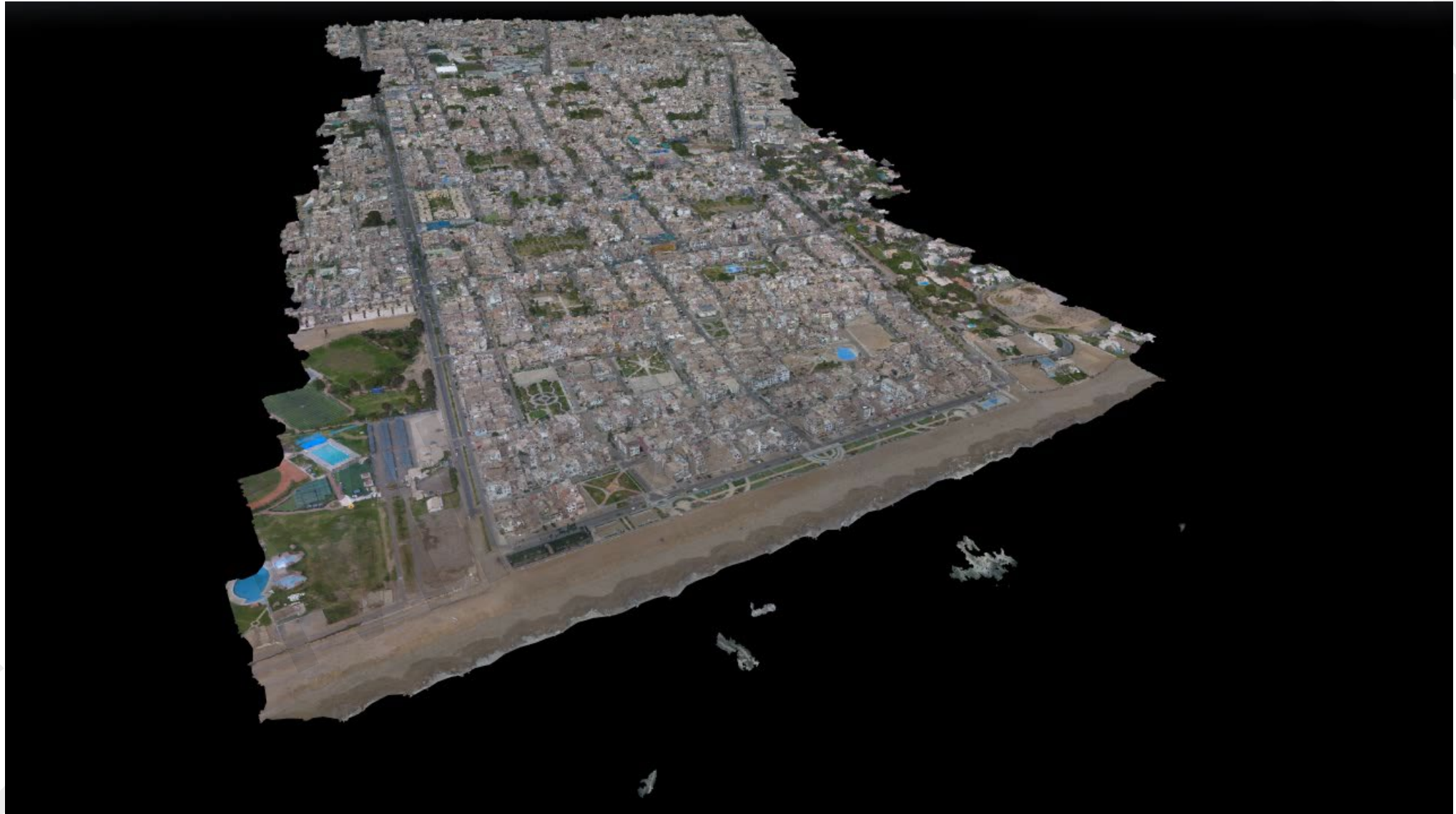
Area: 19.27 hect
Distance: 6.00 km
Path Speed: 10.6 m/s
Duration: 11m 10s
Batteries: 1
Images: 170
Points: 204
Storage: 0.89 GB

Flight plan 1

Area: 15.13 hect
Distance: 4.74 km
Path Speed: 10.6 m/s
Duration: 9m 11s
Batteries: 1
Images: 125
Points: 150
Storage: 0.66 GB

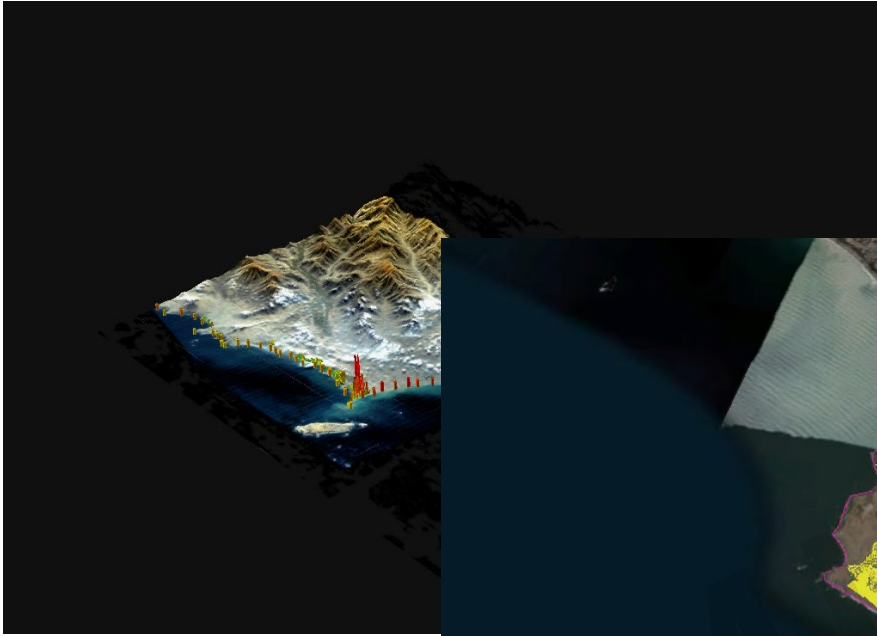


Actualización de la Topografía y Datos de Exposición



3D Digital Model of Chorrillos Coastal Area

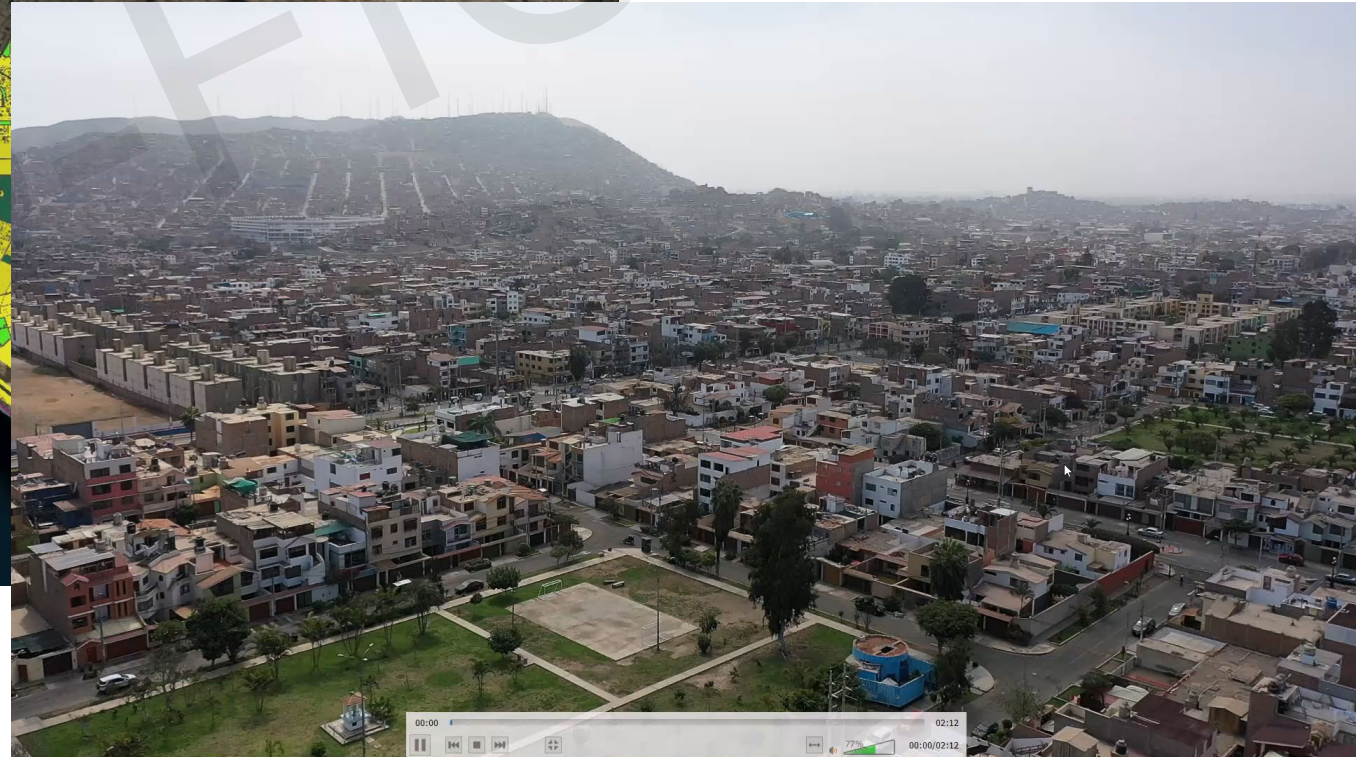
Datos de Exposición (Población y Edificaciones)



Block aggregated
cadastral information



Lot cadastral information

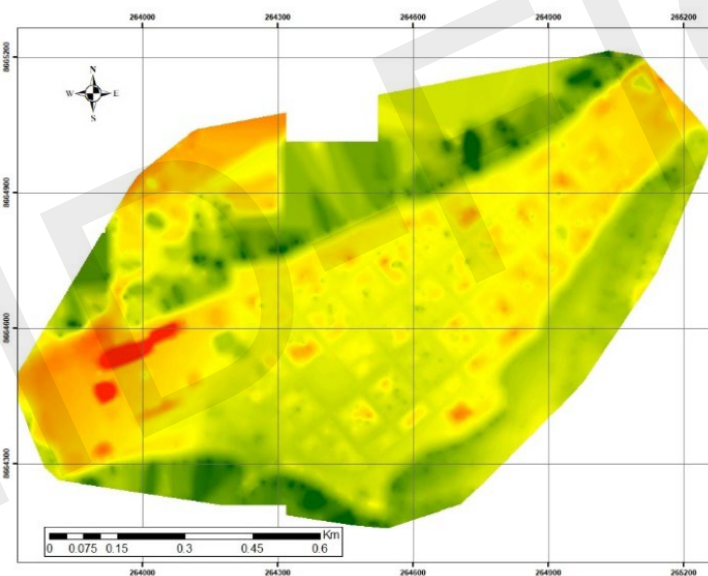


Extracción del Número de Pisos de Edificaciones

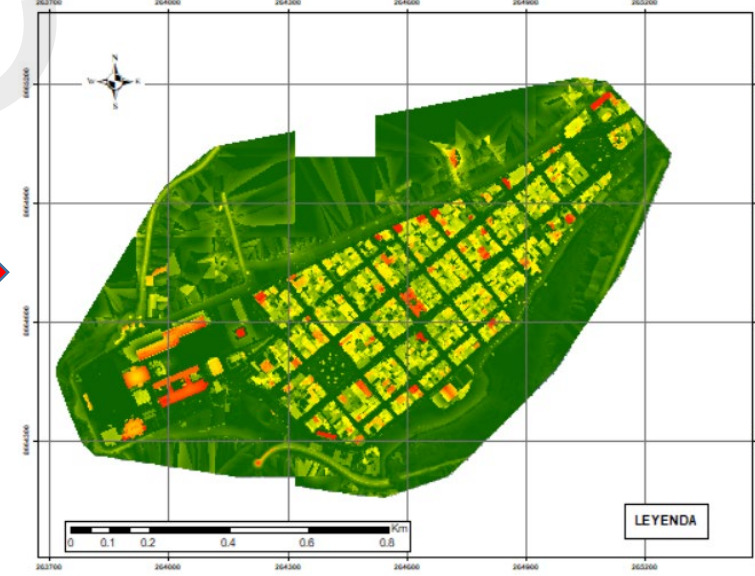
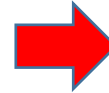
Identificación de Edificaciones Altas
Consideradas como posibles lugares de
evacuación vertical



DIGITAL SURFACE MODEL (DSM)

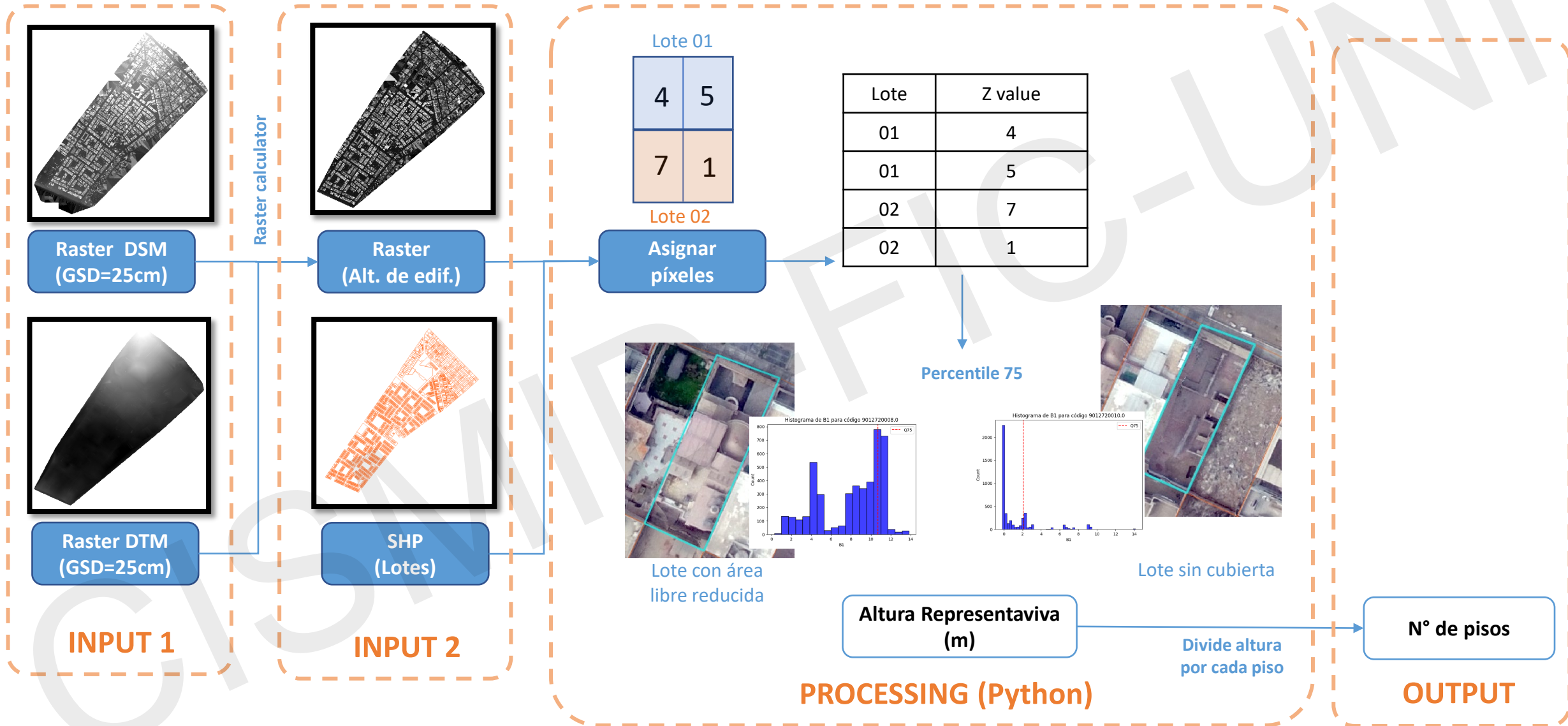


DIGITAL TERRAIN MODEL (DTM)

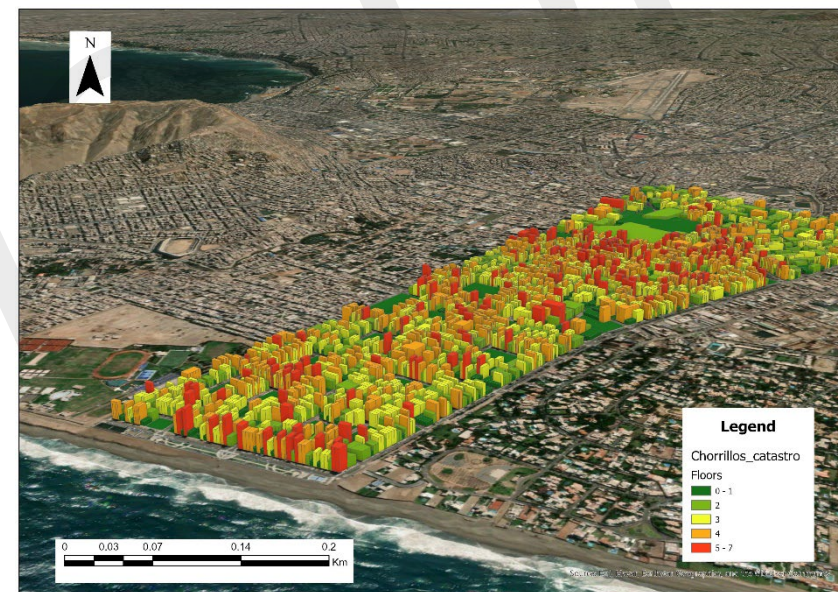
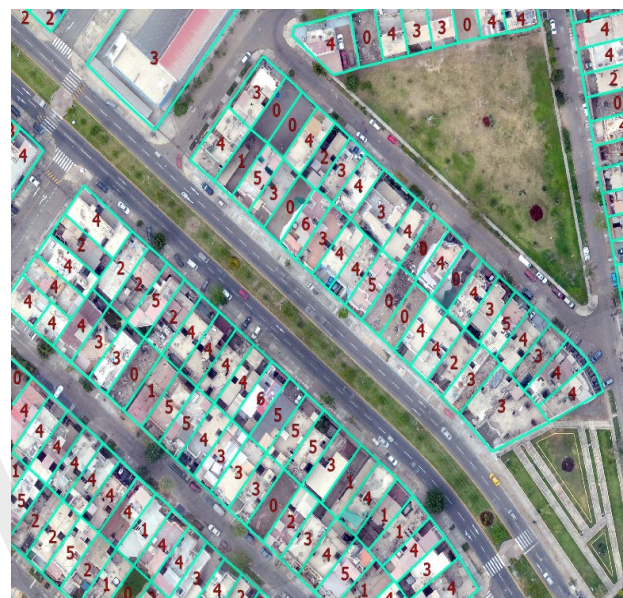
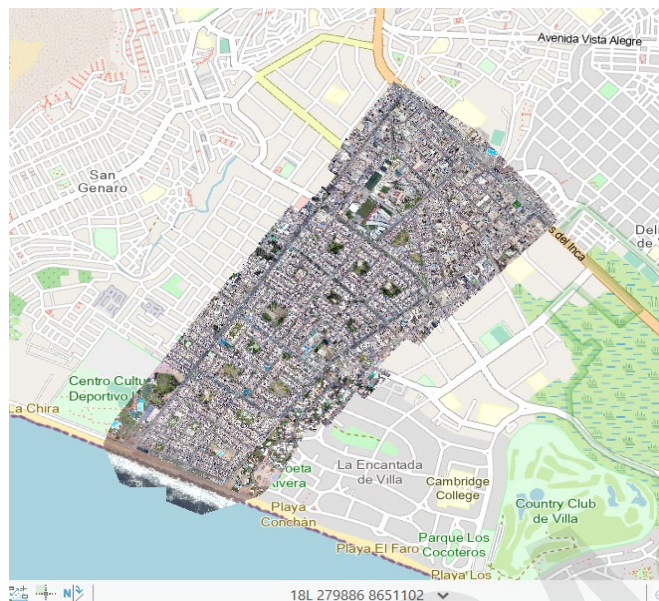


DIFERENCIA DSM - DTM

Flujo de Trabajo para la Determinación del Número de Pisos de Edificaciones



Flujo de Trabajo para la Determinación del Número de Pisos de Edificaciones Aplicación para el Distrito de Chorrillos (1400 lotes)



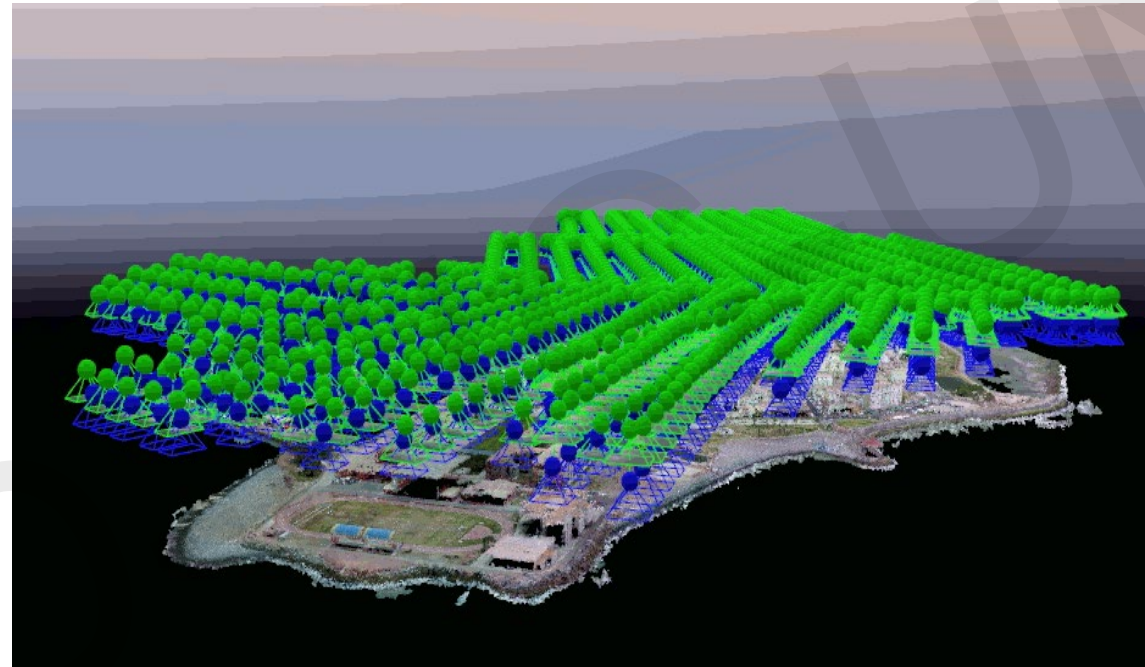
Inspección en La Punta, Callao



Plan de vuelo – La Punta Callao

Características Técnicas del Plan de Vuelo

	CARACTERÍSTICA	VALOR
1	Área cubierta	104 ha.
2	Velocidad de vuelo promedio	9 m/s
3	Total de vuelos programados	5
4	Tiempo promedio cada vuelo	15 min
5	Total de imágenes	1262
6	Altura de vuelo programada	90 m
7	Resolución mínima obtenida	4.0 cm/pixel
8	Tiempo de procesamiento	4 horas



Adquisición de imágenes de drone georreferenciadas

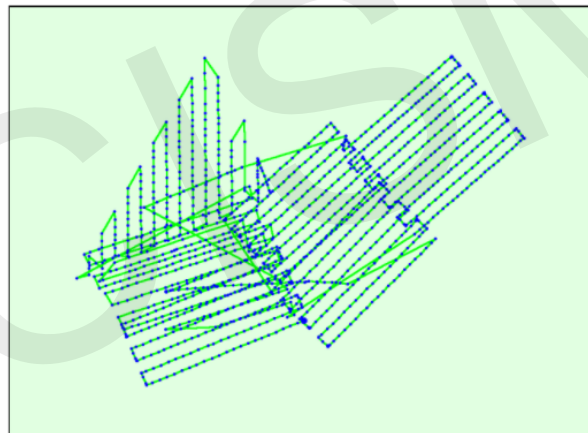


Diagrama de las líneas de los planes de vuelo



Cuadrícóptero

Simulación de Inundación Sismo 8.8 Mw La Punta - Callao



Simulación de Evacuación: La Punta - Callao



Comparación de Profundidades de Inundación Según Fuente Tsunamigénica



Fuente Tsunamigénica: J.C. Villegas - 8.8 Mw (2016)



Fuente Tsunamigénica: C. 2015 Jiménez, 9.0 Mw

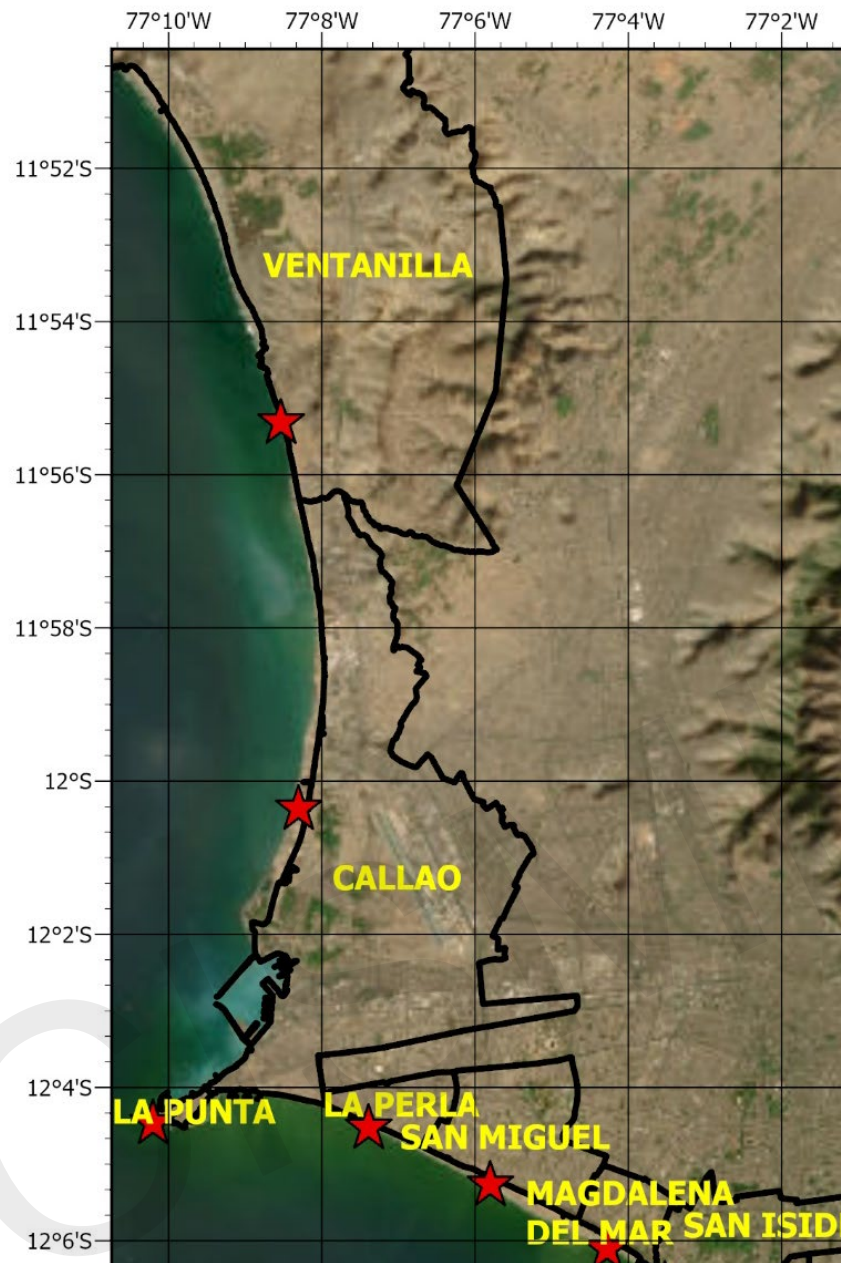


Gráfico de Mareogramas sintéticos a los largo de la Costa de Lima

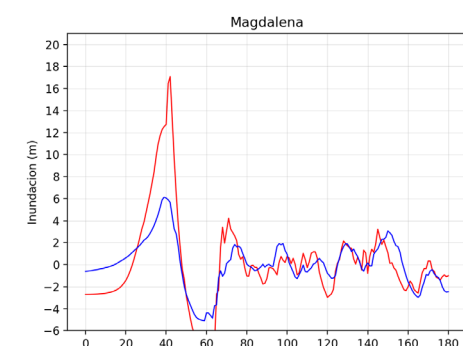
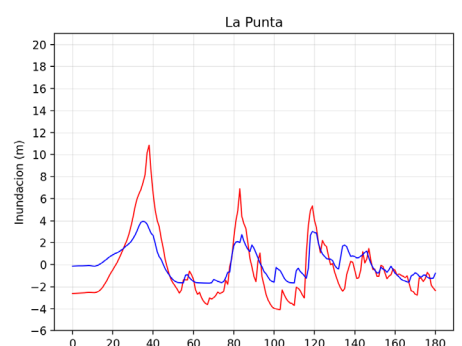
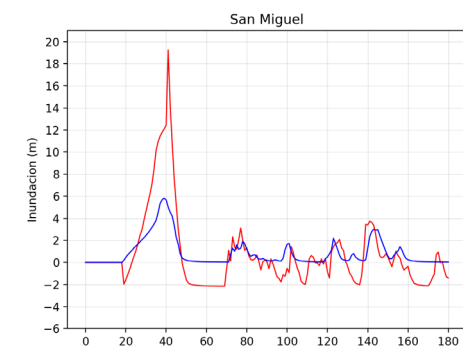
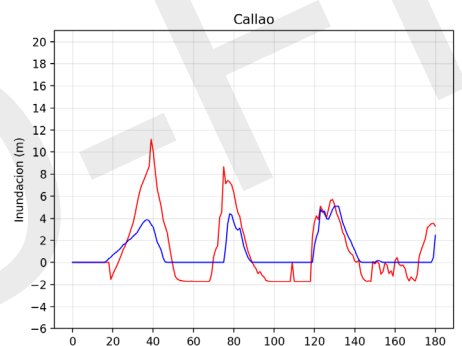
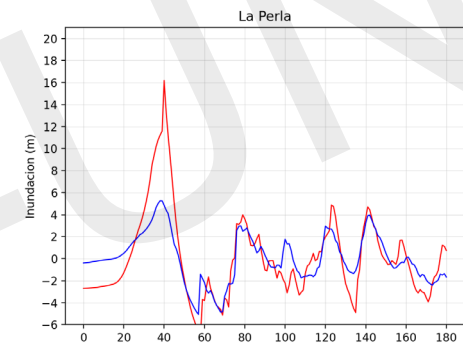
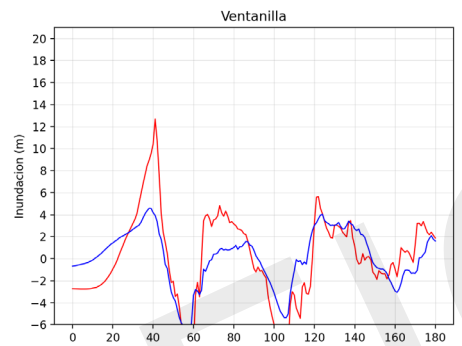
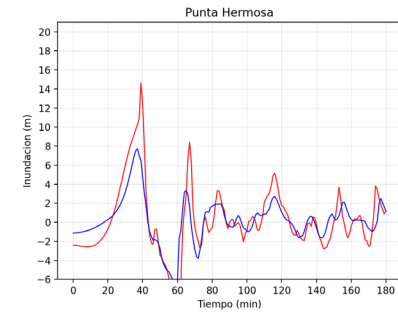
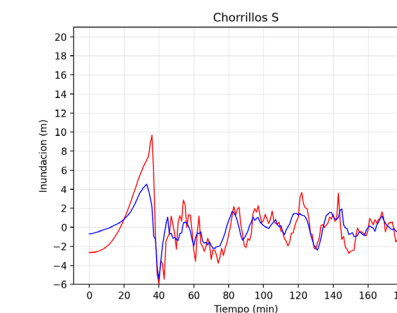
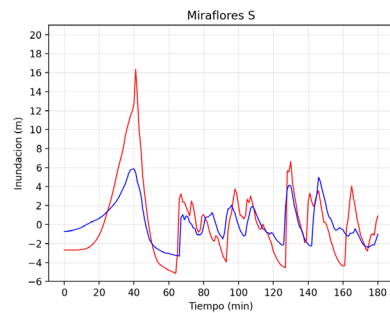
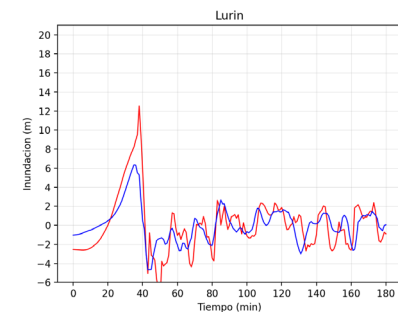
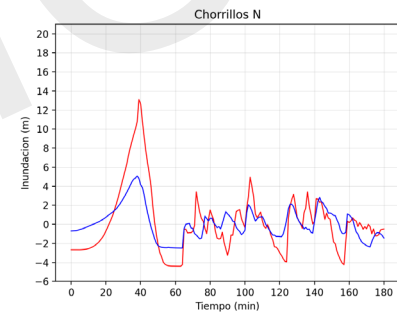
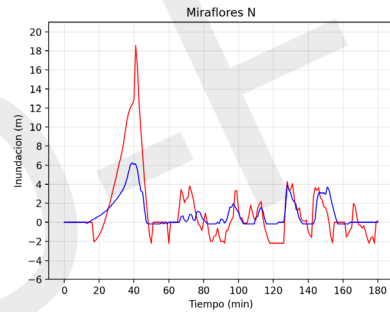
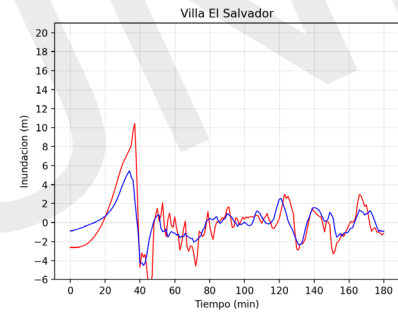
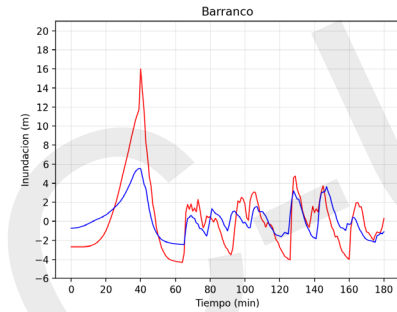
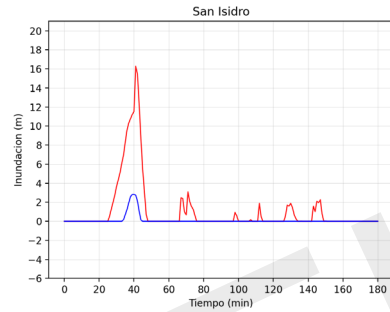
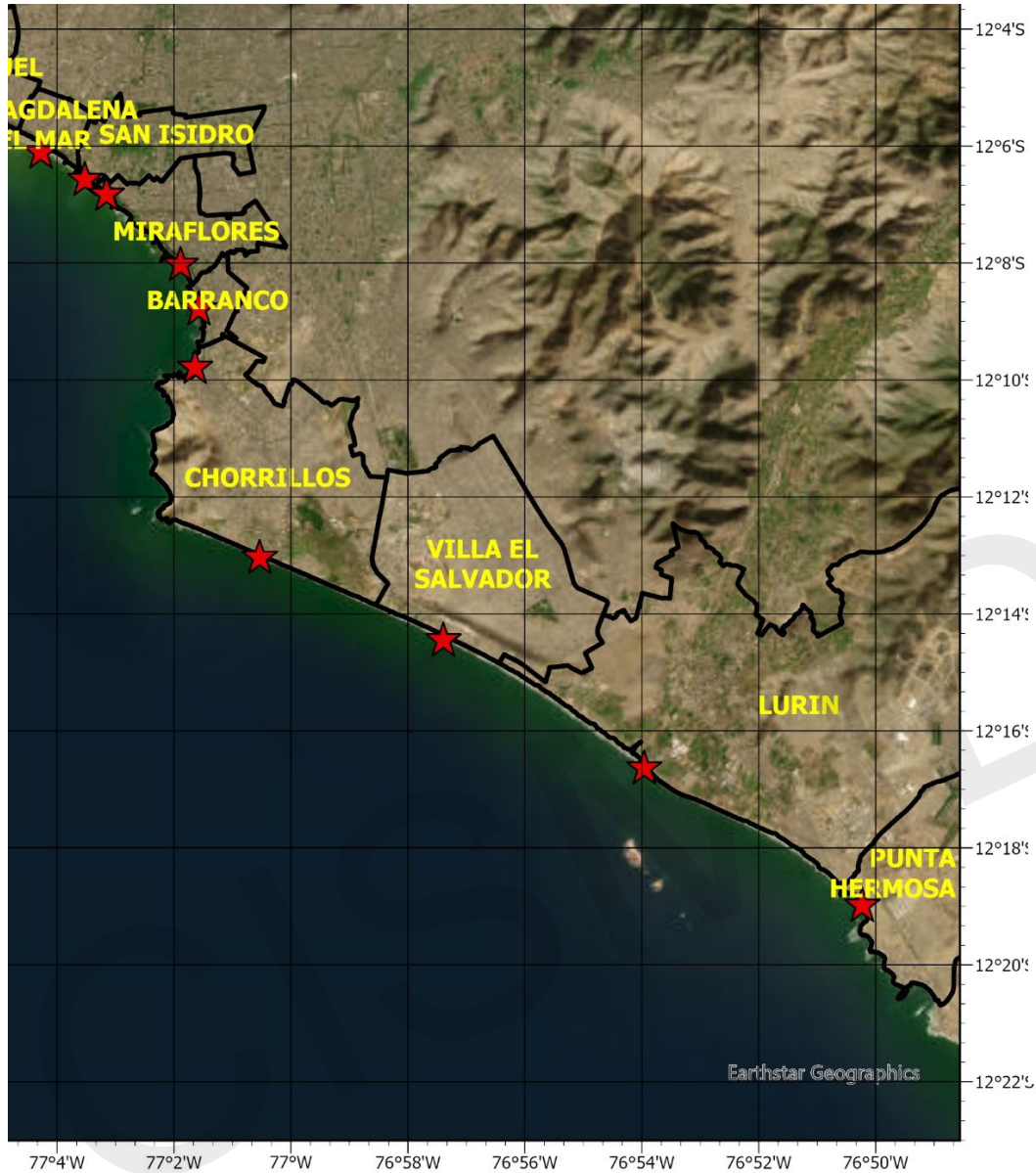
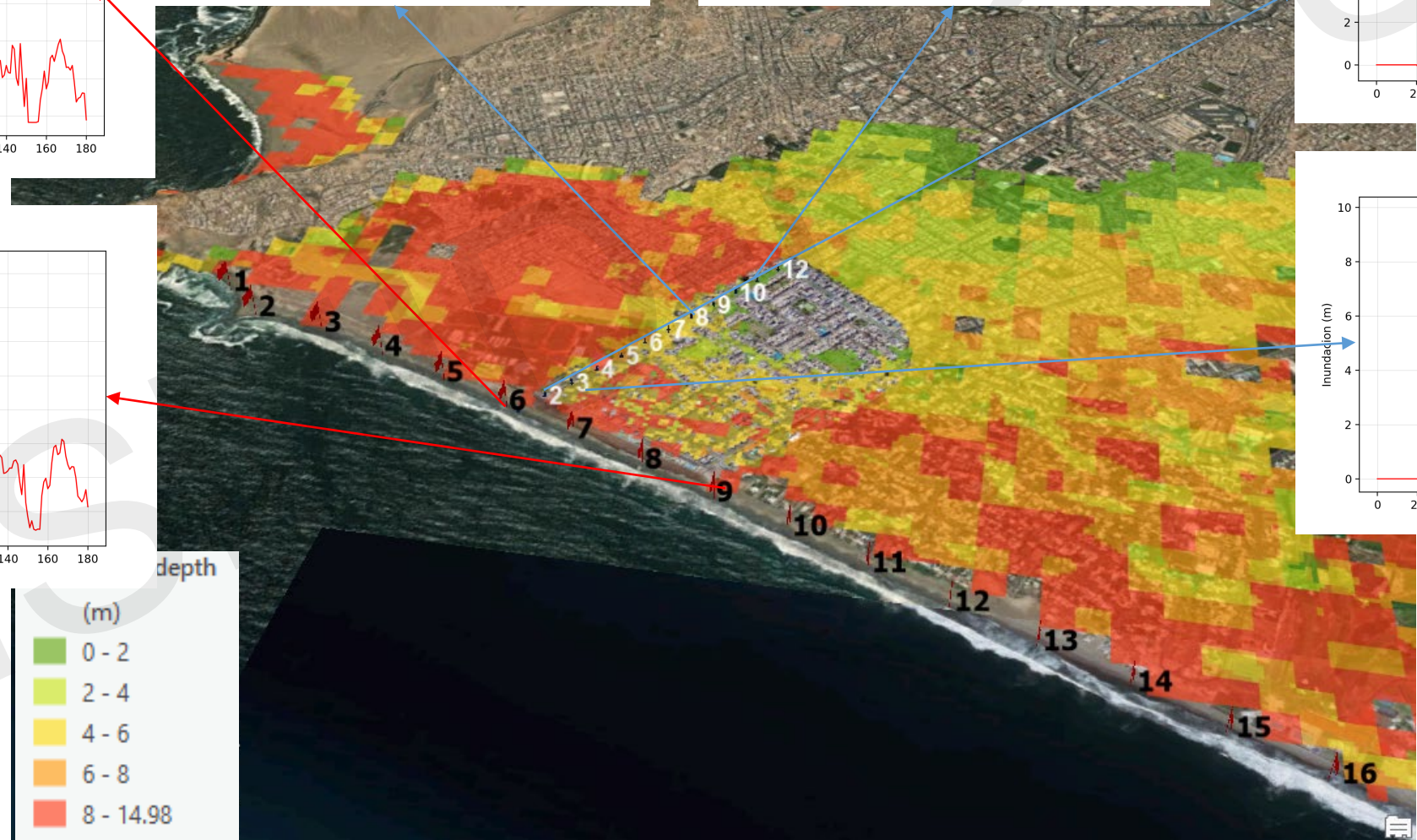
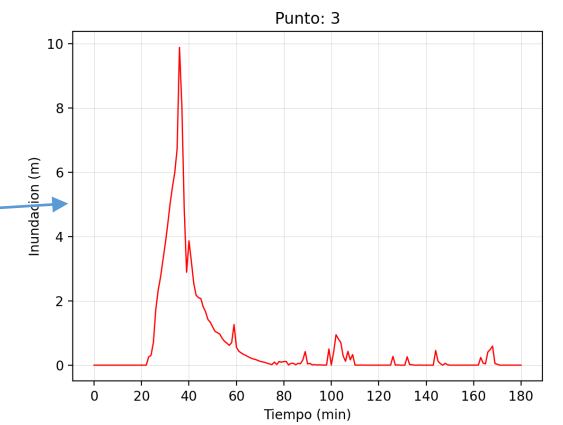
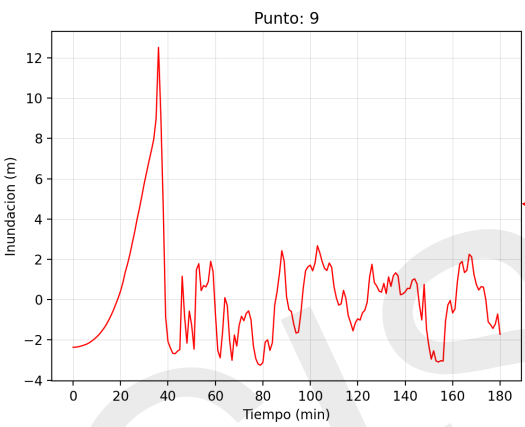
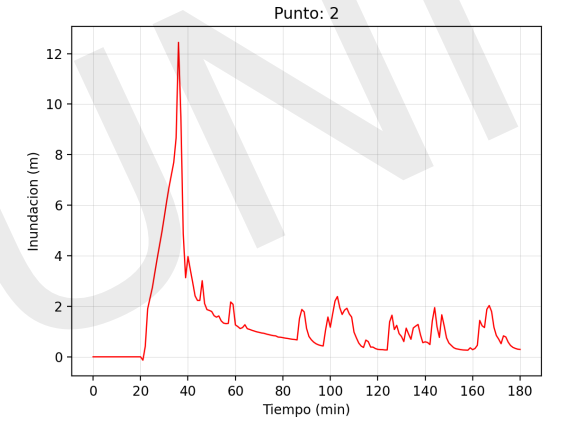
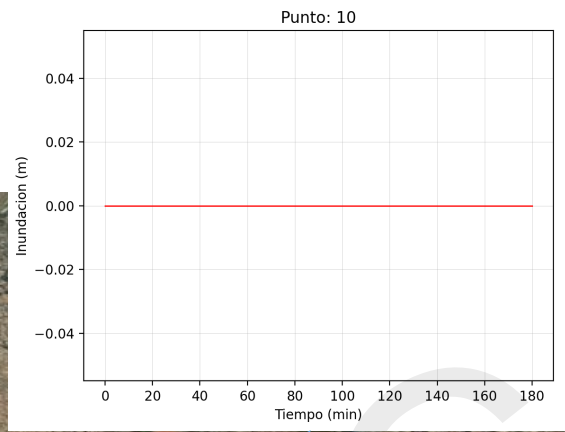
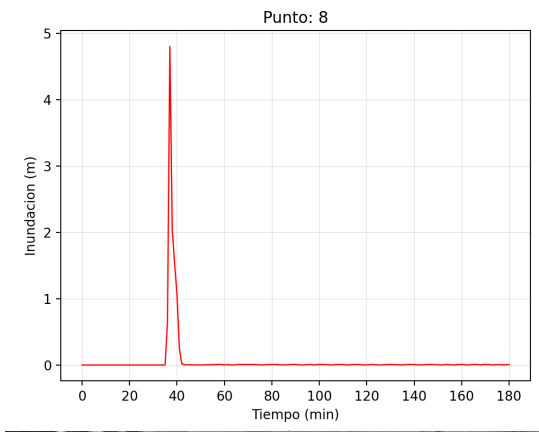
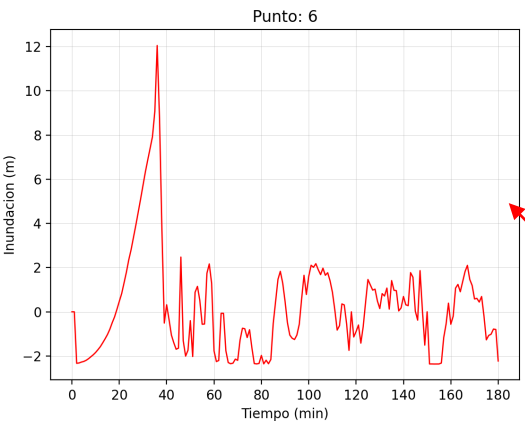


Gráfico de Mareogramas sintéticos a los largo de la Costa de Lima

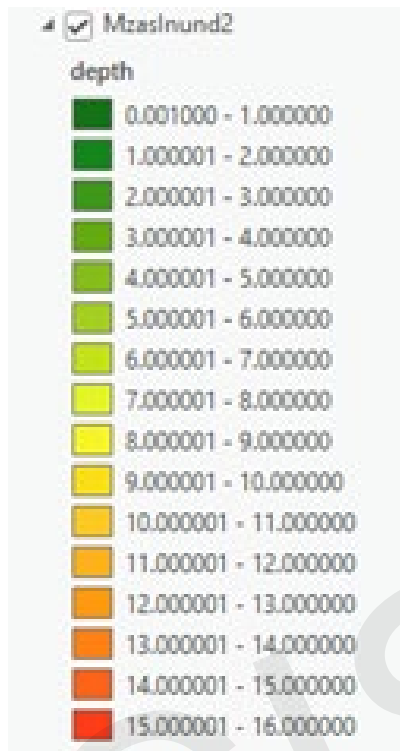


Synthetic Tide Gauges



- depth (m)
- 0 - 2
 - 2 - 4
 - 4 - 6
 - 6 - 8
 - 8 - 14.98

Profundidad de Inundación



Profundidad de Inundación

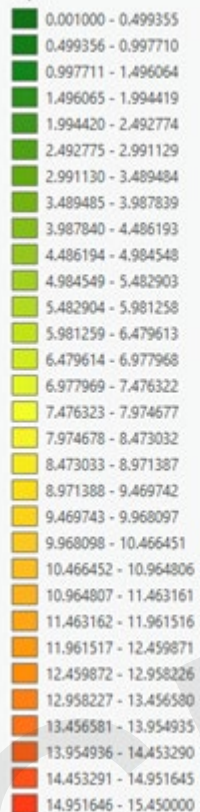


Población calculada con los datos censales de 2017

Población Afectada

4 Mzaslnund_buffer (Pop. Total)

depth



Población calculada con los datos censales de 2017

Población Afectada



Población calculada con los datos censales de 2017

Población Afectada



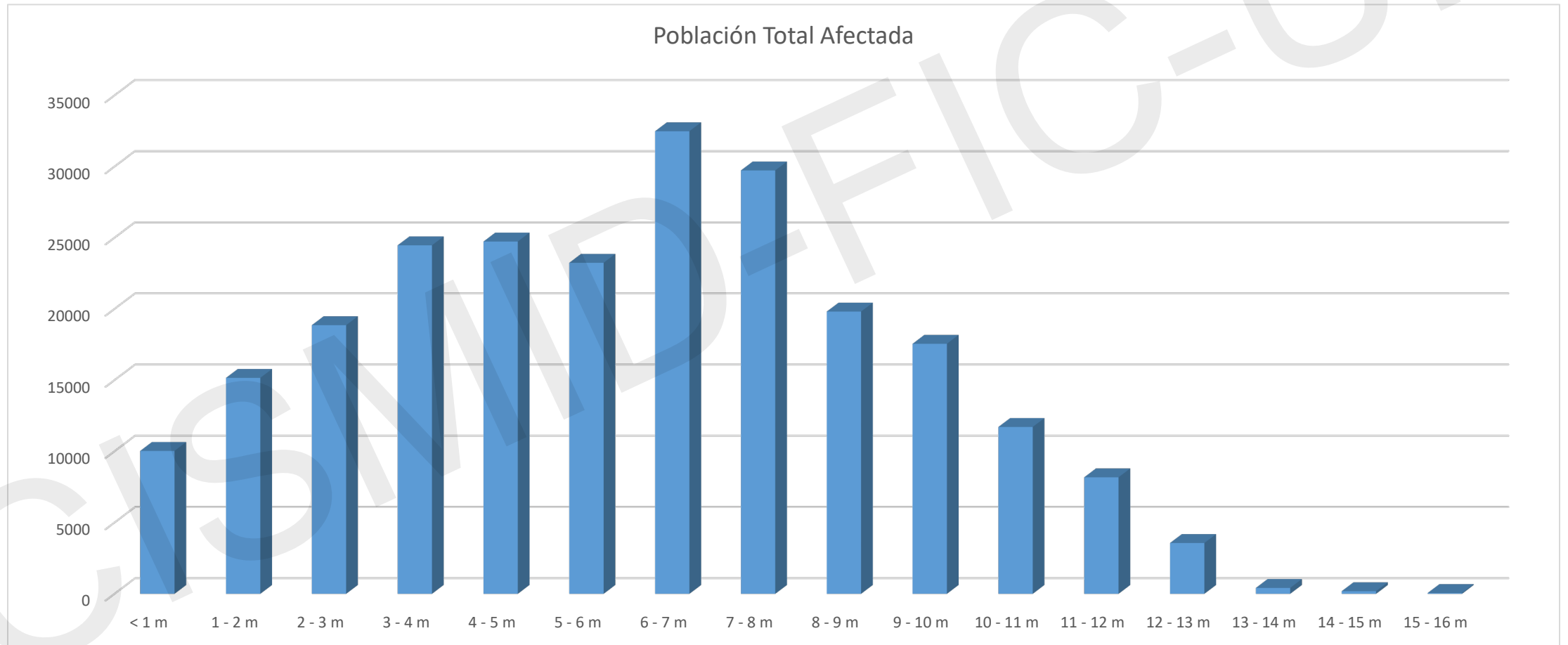
Población calculada con los datos censales de 2017

Población Afectada (Censo 2017)

Nivel de Inundación	Profundidad	Cantidad de manzanas	Población Total Afectada	Población menor a 14 años	Población de 15 a 29 años	Población de 30 a 44 años	Población de 45 a 64 años	Población mayor a 65 años
A	< 1 m	90	10028	2445	2282	1698	1261	2342
B	1 - 2 m	115	15157	3574	3485	2514	2198	3386
C	2 - 3 m	153	18860	4795	4251	3063	2547	4204
D	3 - 4 m	186	24470	6447	5631	3779	2916	5697
E	4 - 5 m	195	24735	6205	5316	4274	3370	5570
F	5 - 6 m	174	23243	6282	4891	3818	3094	5158
G	6 - 7 m	227	32485	7693	6978	5367	4813	7634
H	7 - 8 m	226	29731	7167	6348	4912	4239	7065
I	8 - 9 m	143	19815	4589	4101	3470	3111	4544
J	9 - 10 m	146	17552	4177	3632	2997	2656	4090
K	10 - 11 m	103	11709	2884	2425	1926	1791	2683
L	11 - 12 m	44	8177	2049	1779	1291	1071	1987
M	12 - 13 m	24	3567	915	805	527	402	918
N	13 - 14 m	4	416	98	72	76	85	85
O	14 - 15 m	1	187	35	57	25	10	60
P	15 - 16 m	1	58	11	10	17	7	13

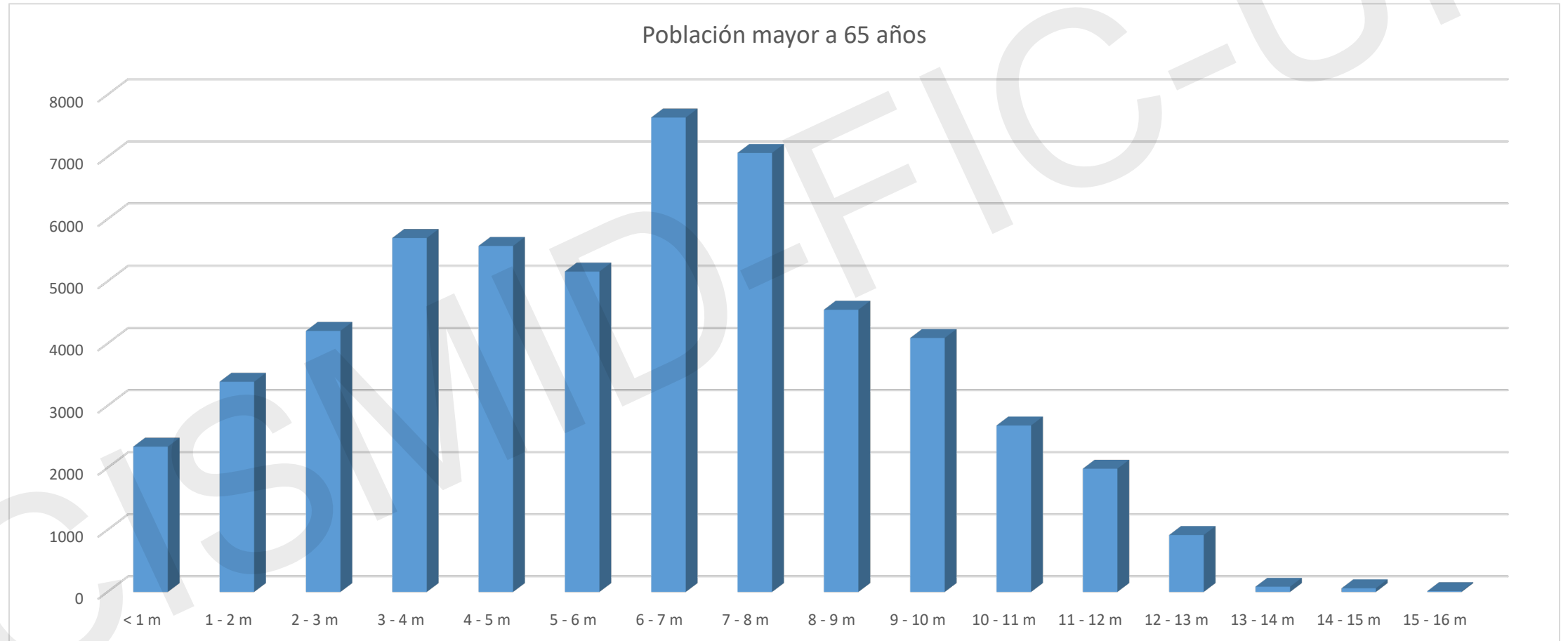
Población calculada con los datos censales de 2017

Población Total Afectada en la Costa de Lima por un Tsunami (Censo 2017)



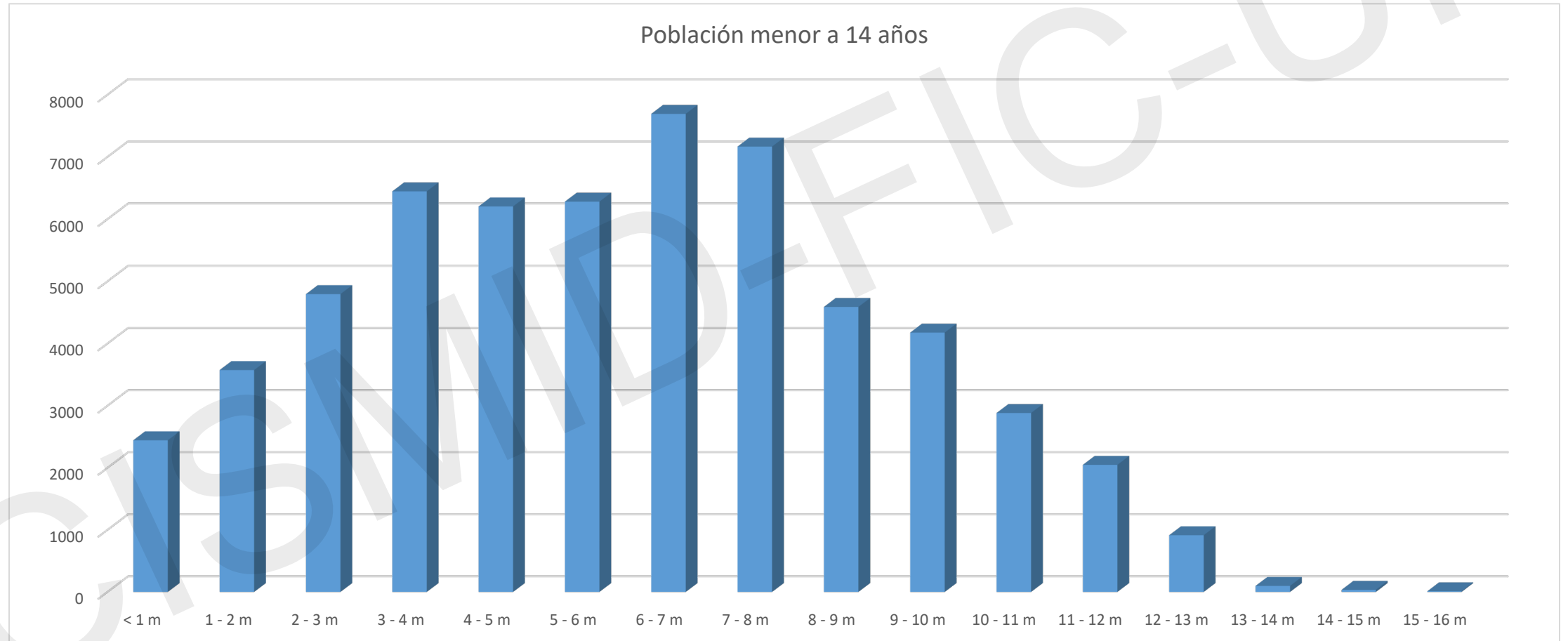
Población calculada con los datos censales de 2017

Población Mayor a 65 años Afectada en la Costa de Lima por un Tsunami



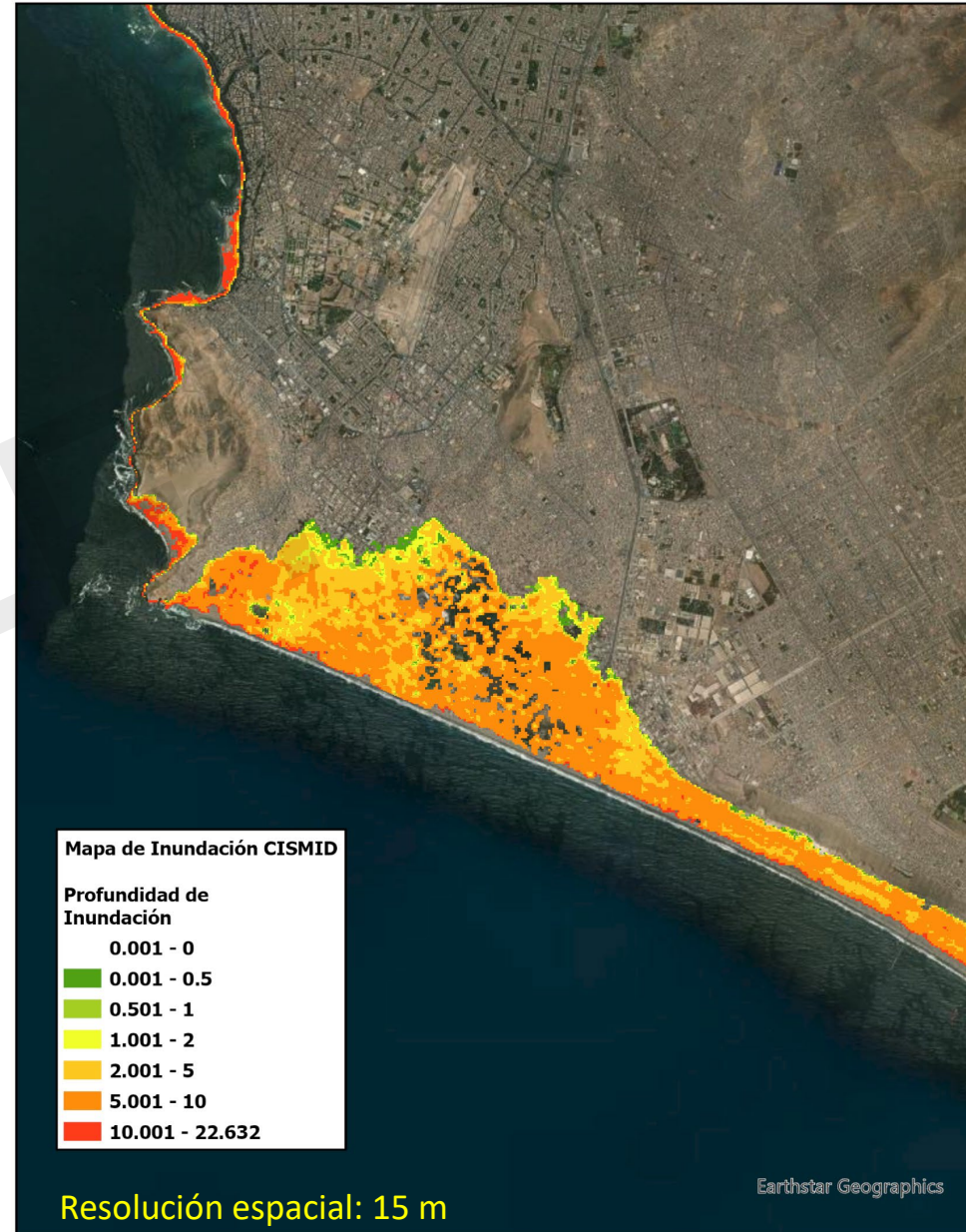
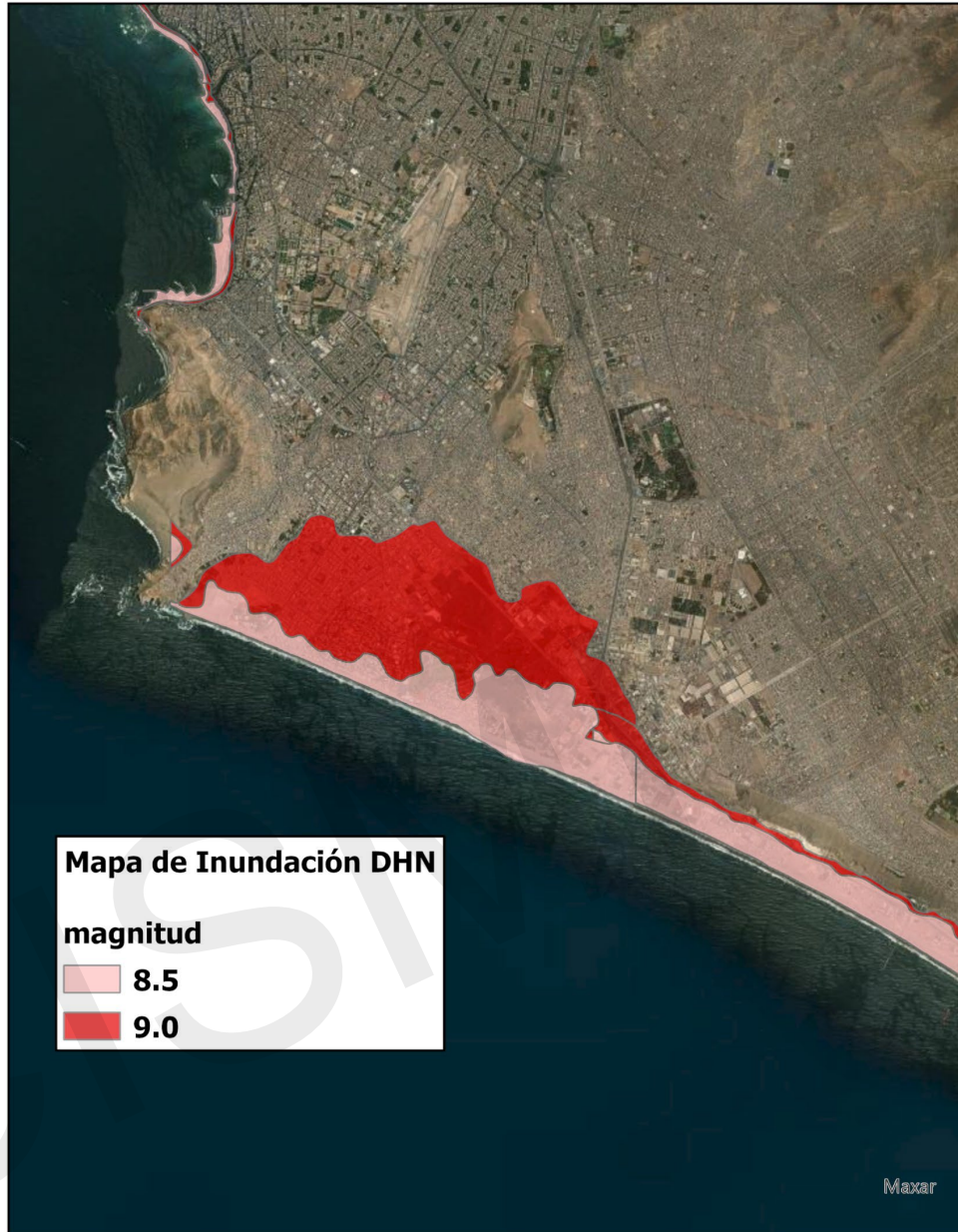
Población calculada con los datos censales de 2017

Población Menor a 14 años Afectada en la Costa de Lima por un Tsunami

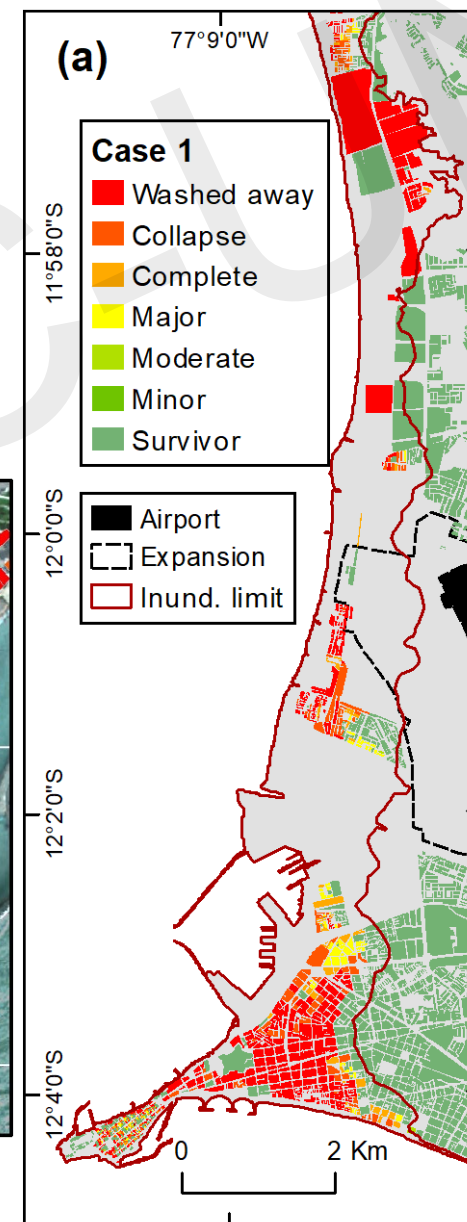
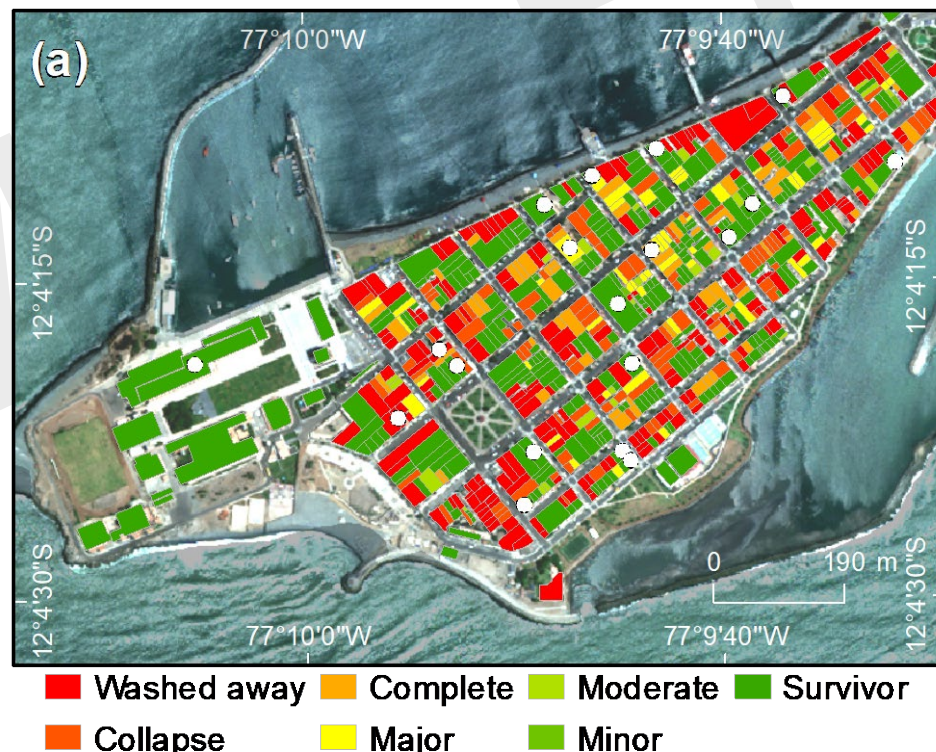
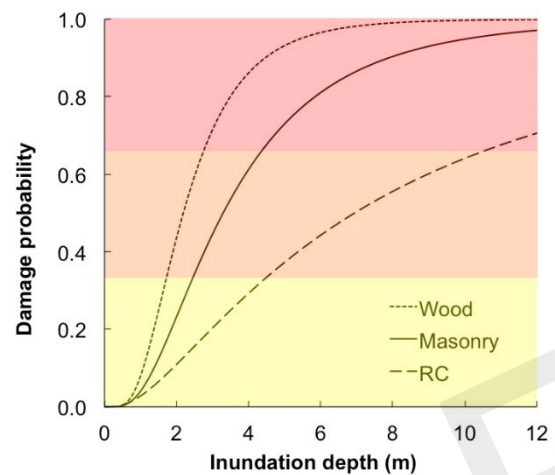
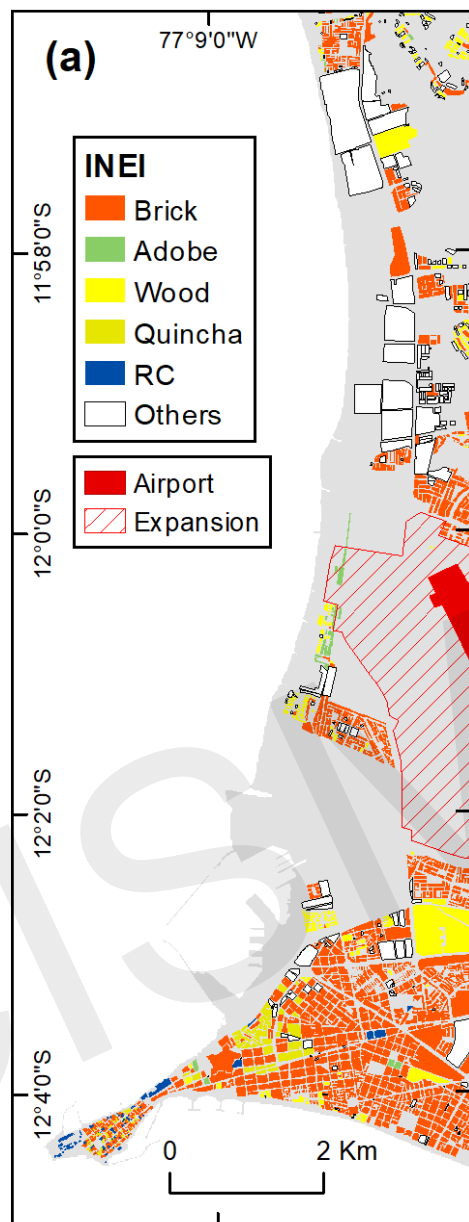


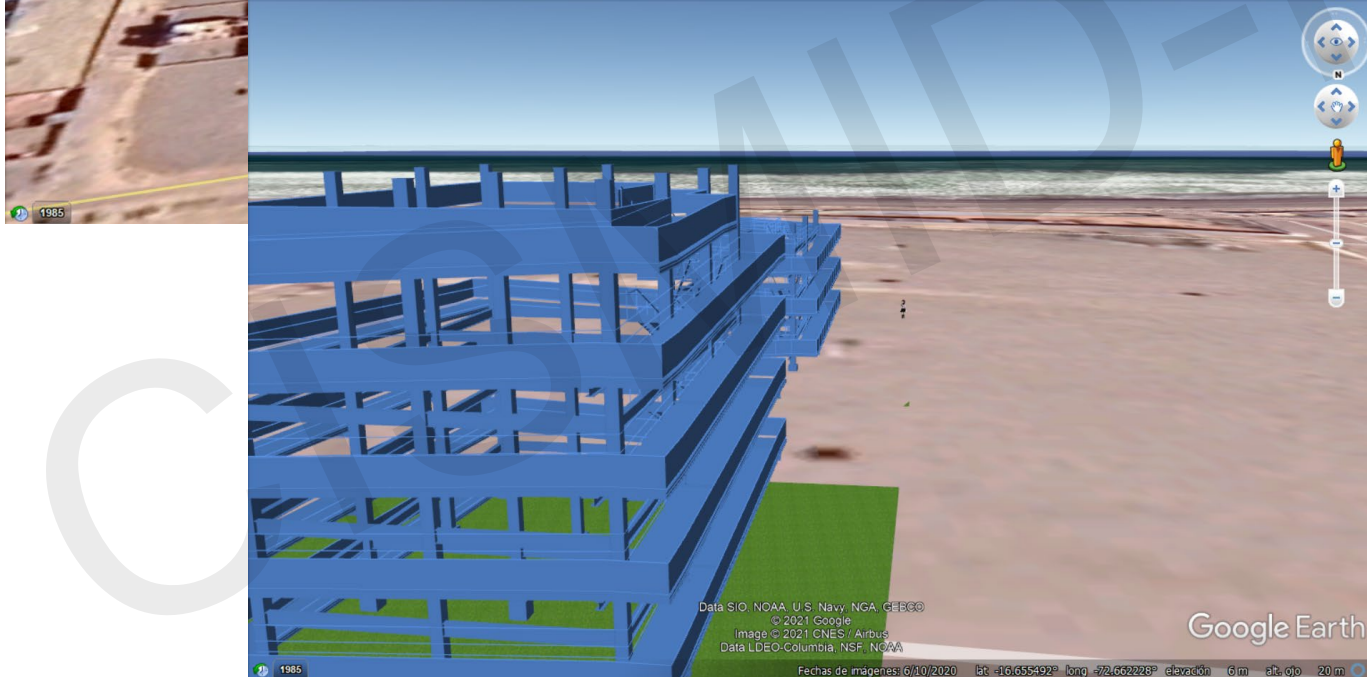
Población calculada con los datos censales de 2017

Propuesta de Nuevos Mapas de Inundación Considerando la Profundidad de Inundación por Tsunami



Proyecto SATREPS: Evaluación del Daño por Tsunami





Propuesta de Estructura de Evacuación Vertical



Fujiwara Industry Tsunami Evacuation Tower (Japan)