Contract:

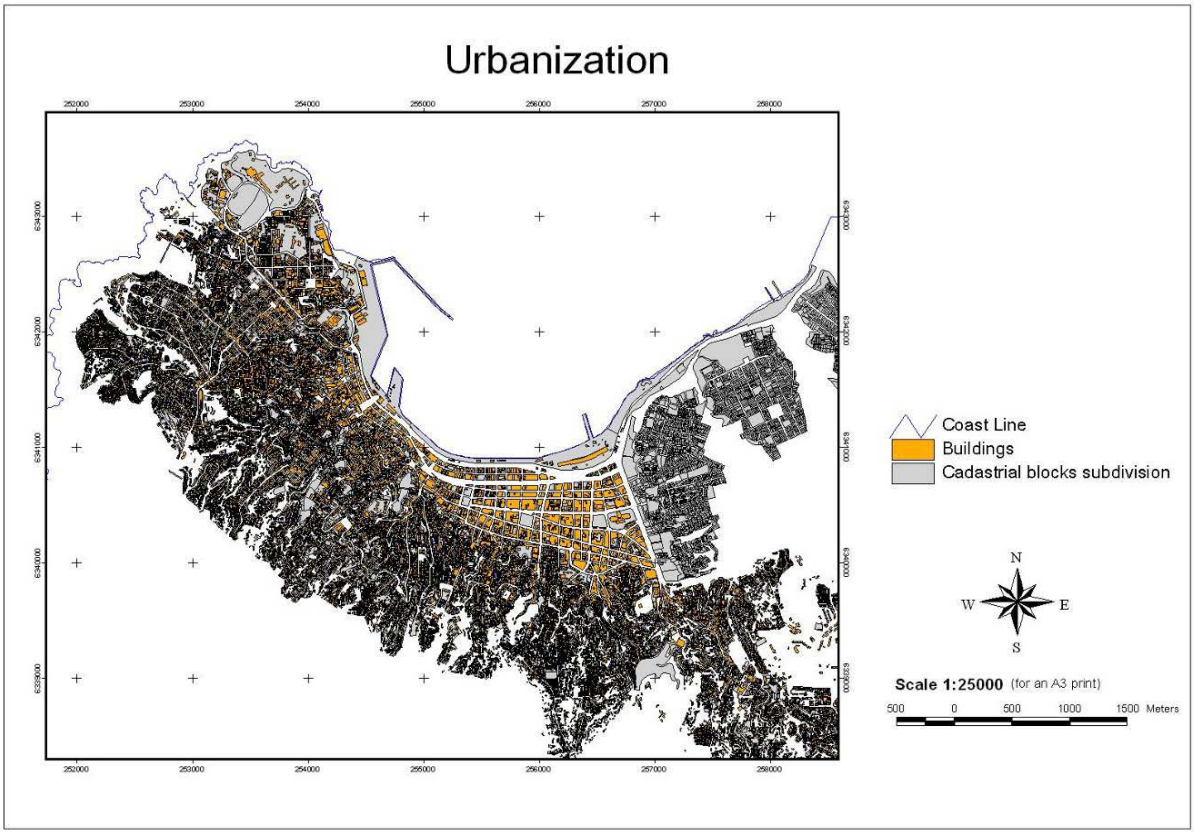
ENEA – Banco Interamericano de Desarrollo (BID)/InterAmerican Development Bank (IDB)

Manejo de Riesgos en Valparaiso, Servicios Técnicos

Acronym: *"MAR VASTO"*

ATN/II-9816-CH

Contract n. **PRM.7.035.00-C**



A GIS DATABASE
FOR THE CITY OF VALPARAISO

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0	**Date**	**30.06.2008**	**Name**	**F. GEREMEI**	**L. BOVIO**	**M. INDIRLI**		
			Signature					
				AUTHORS				

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PREFACE

The activities have been carried out during the last two missions at Valparaíso (May and October-December 2007), and in the following months at the ENEA Departments (Bologna and Roma-Casaccia).

Many Chilean Organizations strongly cooperated to the work of the Italian experts: above all, the Municipality of Valparaíso (mainly the Heritage Office, "Oficína de Gestión Patrimoniál OGP", directed by Arch. Paulina Kaplan Depolo); the Regional Civil Defense ("OREMI"); the SHOA ("Servicio Hidrográfico y Oceanográfico de la Armada de Chile"); Valpomío ("Programa de Recuperación y Desarrollo Urbano de Valparaíso"; the Firemen ("Bomberos") and the Sea Rescue ("Bote Salvavidas") Corps of Valparaíso.

Special thanks to the geographer Mauricio Sebastian Gonzalez Loyola, OGP, for the excellent cooperation to the technical-scientific work, and to Arch. Sotero Apablaza Minchel, an expert functionary of OGP, for the overall supervision given.

Reference documents are the general progress reports **[01-03]** and the specific task reports **[04-09]**.

1. INTRODUCTION

A GIS database is a very helpful tool able to integrate different types of information in an unique platform. Therefore, it is possible to conceive a large scale system (central geo-database), in which alphanumeric, geographic (vector or raster) and narrative (text documents, historical information, etc.) data can be stored, queried and crossed. Various actors (public administrations, professionals, Universities, research centers, etc.) could access and reference this core database and, through operational procedures, implement and/or modify the information. The tool could be also based on WebGIS technology for the dissemination, at various levels, of the stored data.
The organization of the GIS database started in Italy at the beginning of June 2007, after the first mission in Valparaiso (May 2007), and continued for all the project duration, elaborating materials purchased both in Chile and Italy. It has been indispensable to build at ENEA a detailed DEM of the Valparaiso area, by generating ortho-photos (Figs. 1-2) from the very helpful aerial photos **[10]** provided by SHOA (Servicio Hidrografico y Oceanografico de la Armada de Chile).

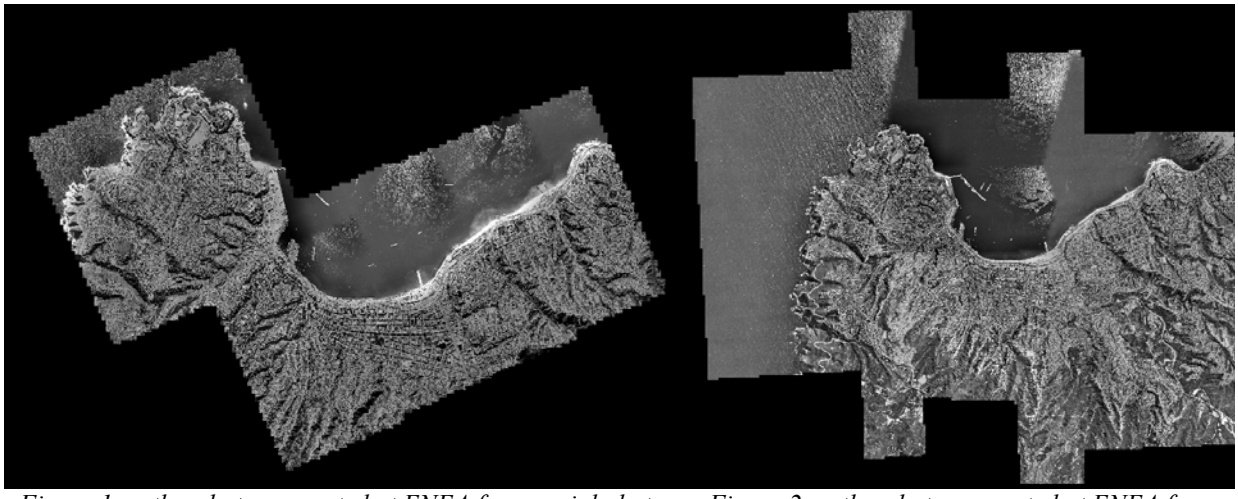


Figure 1: ortho-photo generated at ENEA from aerial photos provided by SHOA (1:15000).

Figure 2: ortho-photo generated at ENEA from aerial photos provided by SHOA (1:20000).

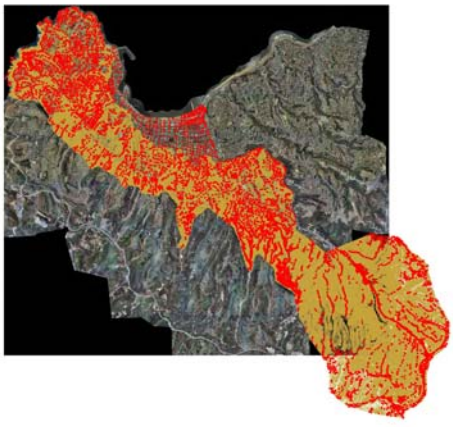


Figure 3: Valparaiso area covered by the DEM (Digital Elevation Model) provided by OGP.

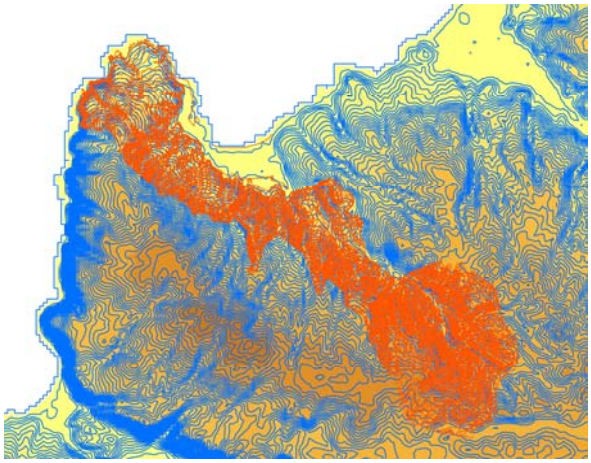


Figure 4: Valparaiso area covered by the DEM (Digital Elevation Model) obtained at ENEA working on radar altimetry data.

In fact, the DEM achieved at Valparaiso from OGP (source: MINVU, Ministerio de Vivienda y Urbanismo) was not complete (Fig. 3), because it covers only a portion of the municipal area, excluding the hills Esperanza, Placeres and Baron (the oriental sector of the city). Before achieving the SHOA materials, other attempts have been carried out, elaborating radar altimetry data coming from NASA Space Shuttle flights **[11]**, as shown by Fig. 4.

The GIS database is an indispensable tool in order to store hazard data (earthquake, tsunami, landslide, fire, see [05-08]) regarding all the Valparaiso area and data (architectonic and urban planning investigation, vulnerability analysis, intervention proposals, etc.[09]) regarding the Cerro Cordillera pilot project.

2. DGPS SURVEY IN THE CITY OF VALPARAISO

Digital cartography provided by OGP (streets, buildings, quoted points, and other information) was often not very accurate and didn't match the above said aerial photo of the Valparaiso region. Therefore, a field survey using DGPS (Differential Global Positioning System) has been considered necessary, in order to check aerial photos and cartography provided by Chilean partners and verify the GIS database from the topographic point of view. The DGPS survey provided a pattern of points (Fig. 5) enabling to remove uncertainties, and clarifying univocally the real geographic position of the GIS final database **[04]**.

Figure 5: DGPS final pattern of points showed by ArcGis.

3. GIS BASIC CARTOGRAPHIC LAYERS

All the following layers are in UTM Coordinate System, time zone 19 South.

3.1 DEM

the DEM cartographic layer (Fig. 6) was carried out at ENEA working, as told before, on the SHOA stereographic aerial photos. It is a 5 meters resolution Dem, build as an ArcGis coverage.

DEM ***file name dem_5mt_a***

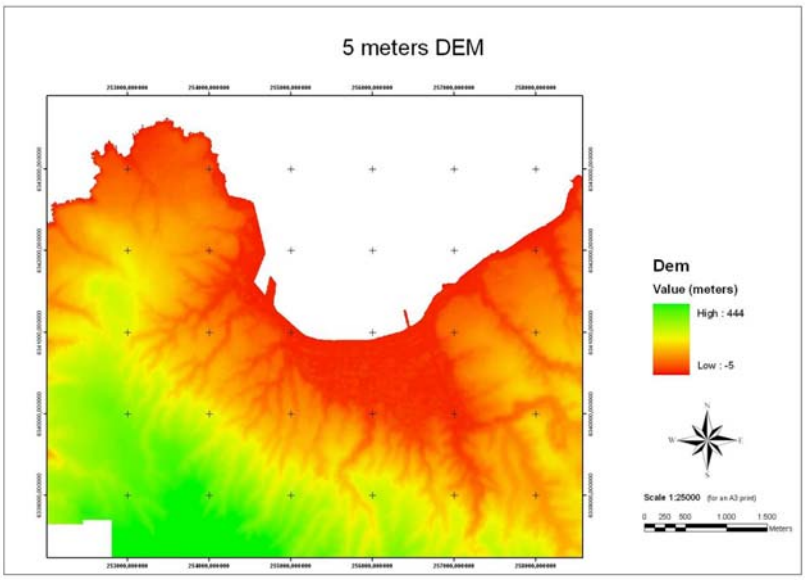


Figure 6: DEM.

3.2 DGPS survey

The results of the said work (see paragraph 2) have been imported as a ESRI Shapefile (Fig. 7).

DGPS survey ***file name Survey.shp***

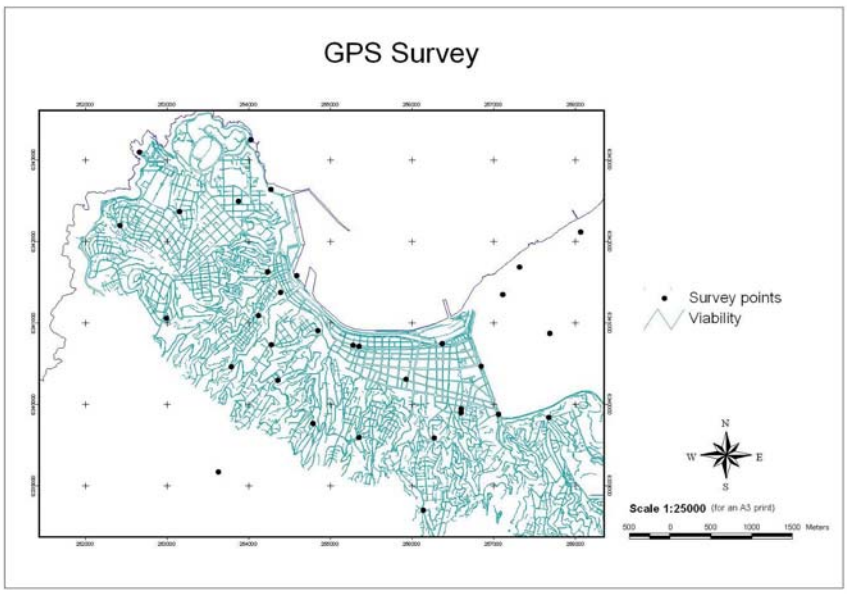


Figure 7: DGPS survey.

3.3 Aerial map

Made by MINVU, acquired from OGP, the file was originally only geo-referred, but not ortho-rectified. A simple ortho-rectification, based on the survey points, was carried out at ENEA by using simple algorithms (Fig. 8).

Aerial map ***file name Rectifytotal.tif***

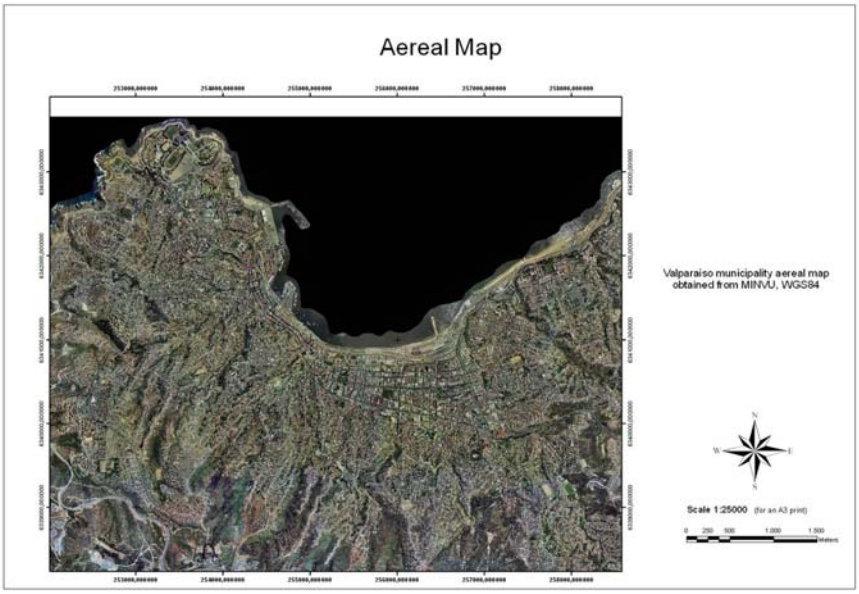


Figure 8: Aerial map.

3.4 Topo-batimetry

the topo-batimetry cartographic layer, showed together with contour lines and height points (Fig. 9), was acquired from SHOA carried out at ENEA working, as told before, on the SHOA; the file format is in S-57 Standard, issued by the International Hydrographic Organization (IHO).

Topo-batimetry ***file name CL5VA015.000***
Contour lines ***file name curvas de nivel.shp***
Height points ***file name cotas.shp***

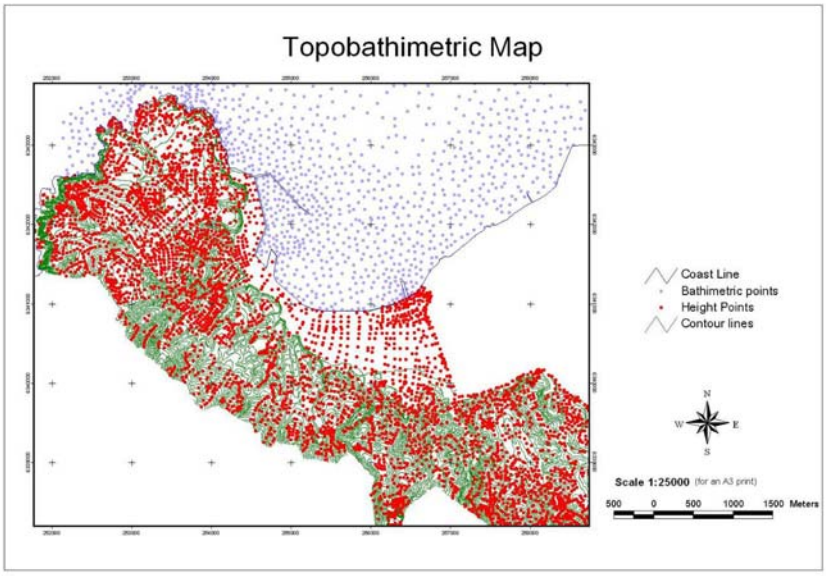


Figure 9: Topo-batimetry.

Moreover, thanks to the information provided by Arch. Sotero Apablaza Minchel (OGP), the submarine area of the Valparaiso Bay is outspread by naval underwater heritage (Fig. 10, see also http://www.archeonavale.org).

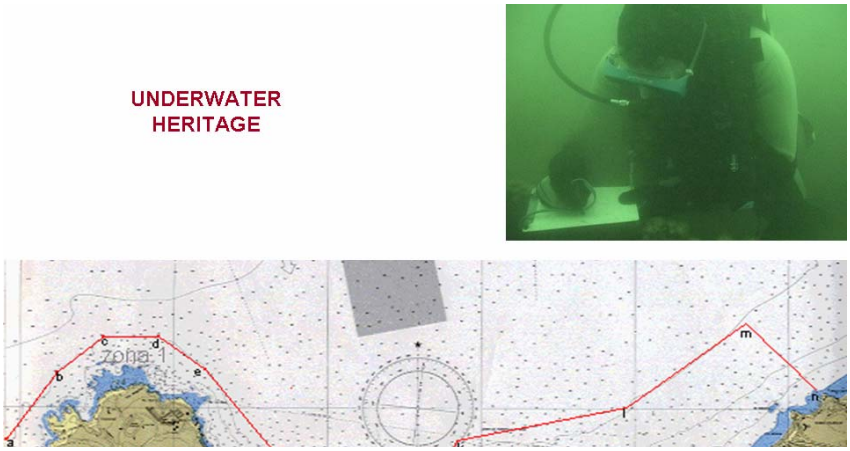


Figure 10: Underwater heritage.

3.5 Other urban layers

All these layers (Figs. 11-13) are ESRI Shapefiles (made by MINVU and acquired from OGP). Exept the cadastral Block Subdivision Layer, they don't cover all the Valparaiso.

Green areas	***file name areas verdes.shp***
Woodlands	***file name arbolada.shp***
Trees	***file name arbol.shp)***
Palms	***file name palmera.shp***
Shrubs	***file name matorral.shp***
Escarps	***file name escarpe.shp***

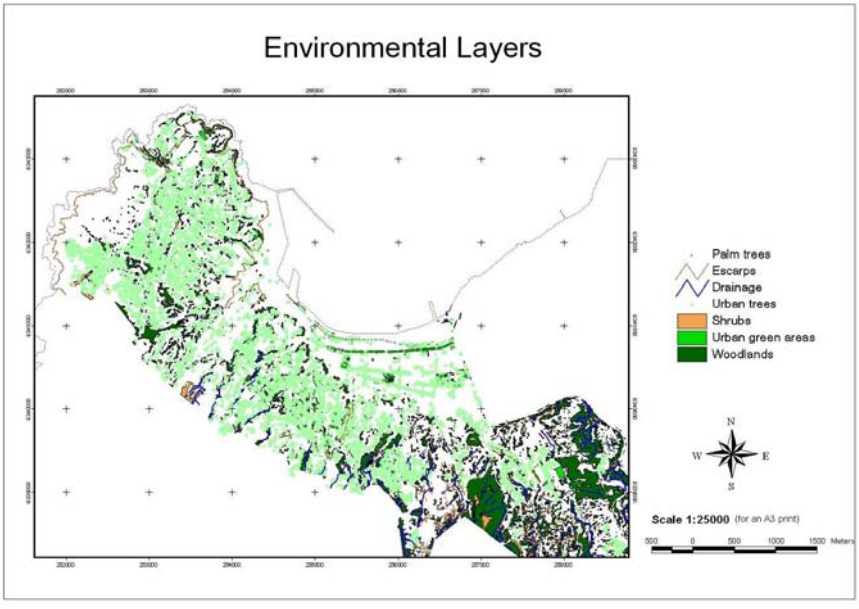


Figure 11: Environmental layers.

Buildings ***file name construccion.shp***
Cadastral Blocks subdivision ***file name datos roldecobro.shp***
Scales ***file name escalas.shp***

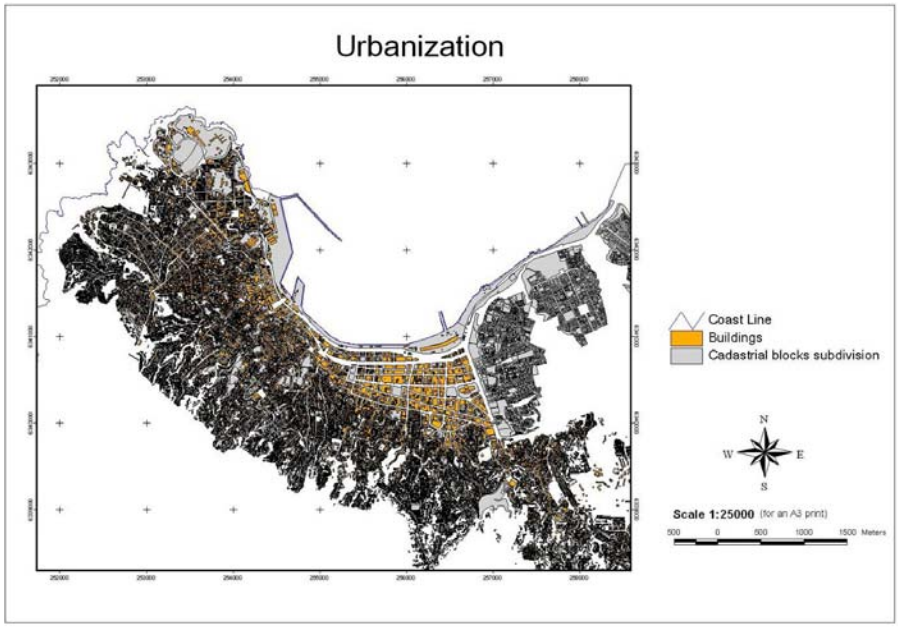


Figure 12: urban layers.

Coast line ***file name linea de costa.shp***
Viability ***file name vialidad.shp***
Railways ***file name ferrocaril.shp***

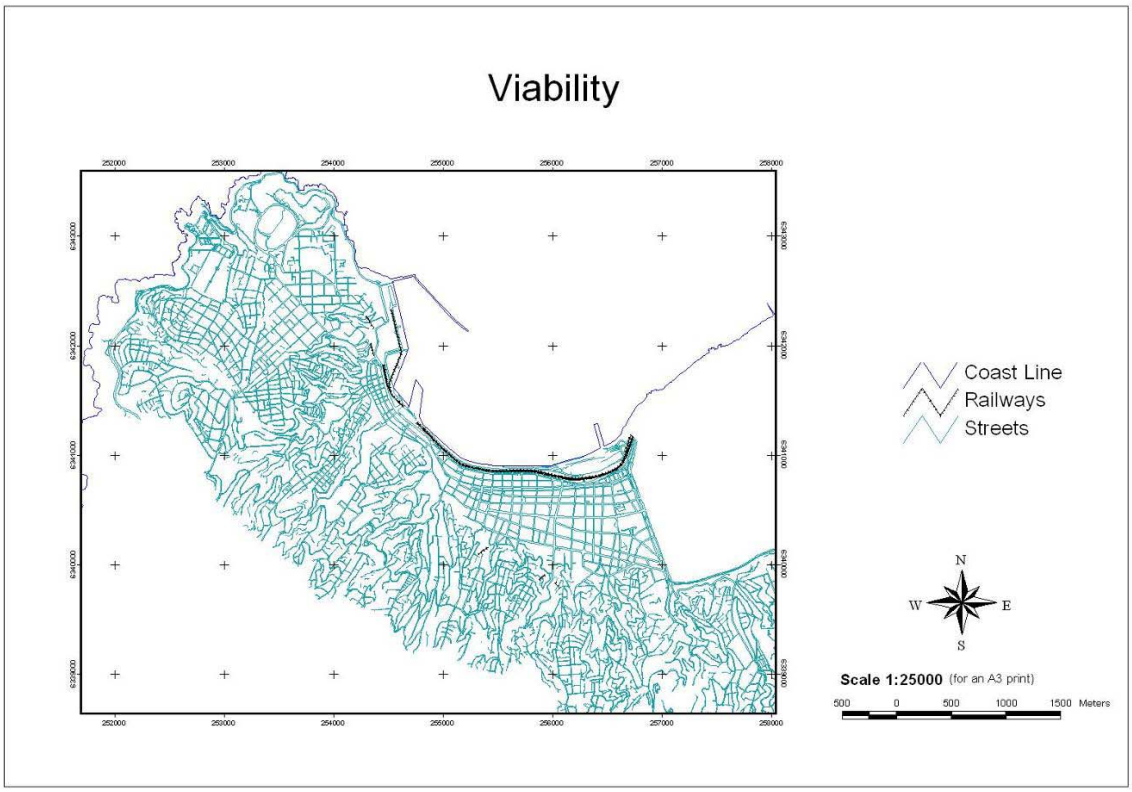


Figure 13: viability layers.

3.6 Historical maps layers

Most of the historical maps have been extracted from **[12]** and then geo-referenced in the GIS database. A couple of examples are reported by Fig. 14. Additional historic information on Valparaiso can be found at http//valparaisoantiguo.tk, managed by Lautaro Triviño.

Valparaiso historical map Year 1895 ***file name Valparaiso108-1895.tif***
Valparaiso historical map Year 1928 ***file name Valparaiso121-1928.tif***

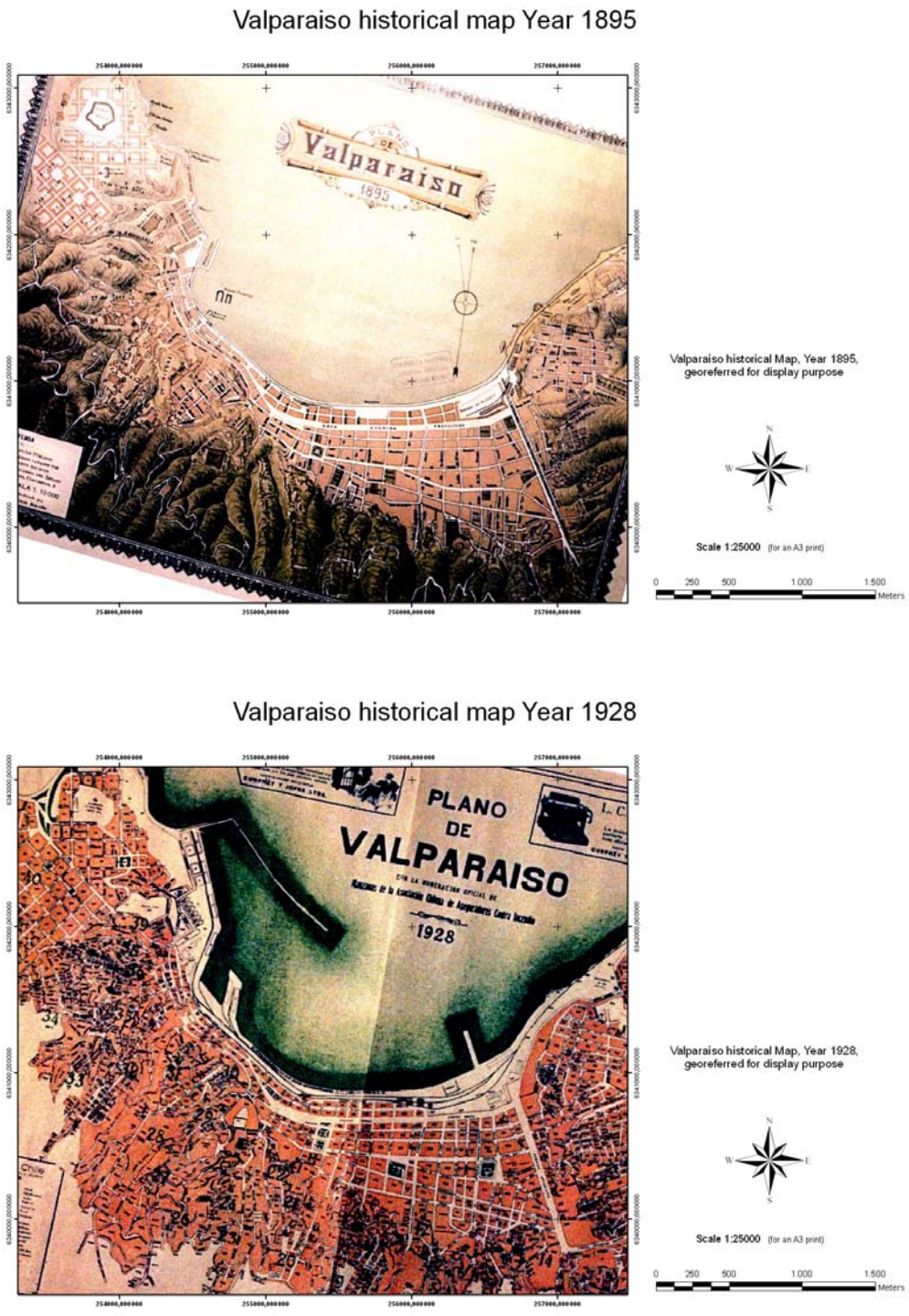


Figure 14:examples of geo-referenced historical maps.

4. HAZARD LAYERS

4.1 Fire Hazard

The implementation of a GIS database allows to detect the most fire hazard prone areas **[06]**. The main information organized in the geo-database are:
- street accessibility;
- hill slope exposure (aspect);
- vegetation covering;
- urban covering.

All the specific layers used for fire hazard evaluation are showed by Table 1.

MACRO VALUES			
VEGETAL			
thematic item		**description**	**layer grid**
area verde	*green area*	location polygons	averd_1
matorral	*bush*	bush areas polygons	mato_1
arboleda	*grove*	grove location polygons	arb_1
FISICAL			
thematic item		**description**	**layer grid**
DEM	*DEM*	Digital Elevation Model	valpo_1
URBAN			
thematic item		**description**	**layer grid**
vialidad	*streets*	street classification	vial_1
casco urbano	ownership and blocks location	elements detailing ownership and blocks location in Valparaiso	pred_1 manz_1

Table 1: Specific layers used for fire hazard evaluation.

ARCVIEW 3.2 software and its module MODEL BUILDER, a weighted overlay procedure, permitted a spatial analysis of the above said variables, assigning them a weighted factor and representing them in percentage. The result of the work is shown by Fig. 15.

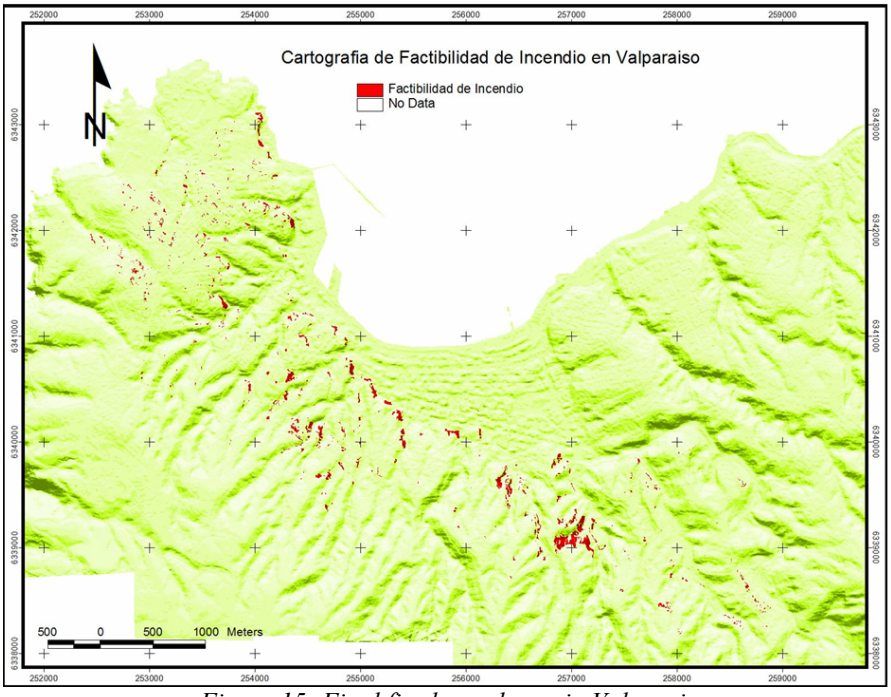


Figure 15: Final fire hazard map in Valparaiso.

4.2 Landslide hazard

The work carried out to evaluate landslide susceptibility in the Valparaiso area **[05]** has been organized in GIS geo-database. The main information is (Figs 15-16):
- a landslide inventory implemented with information coming from historic and archive analyses;
- susceptibility maps for mud-debris flow and fall events.

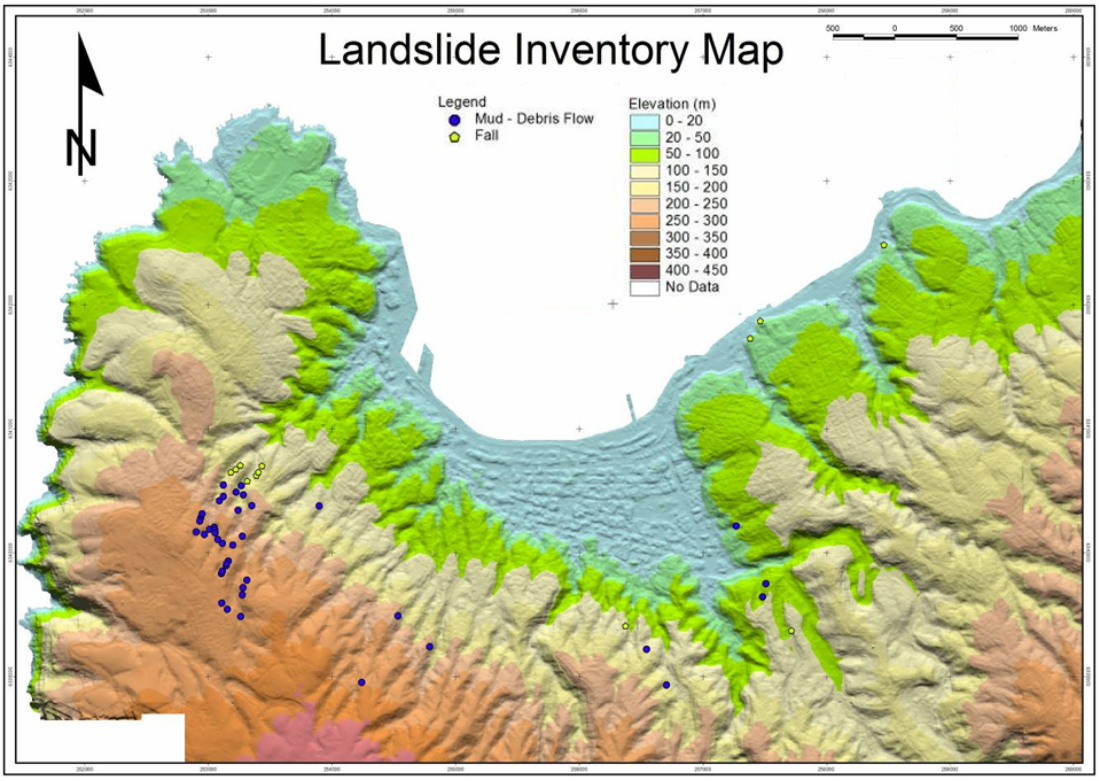
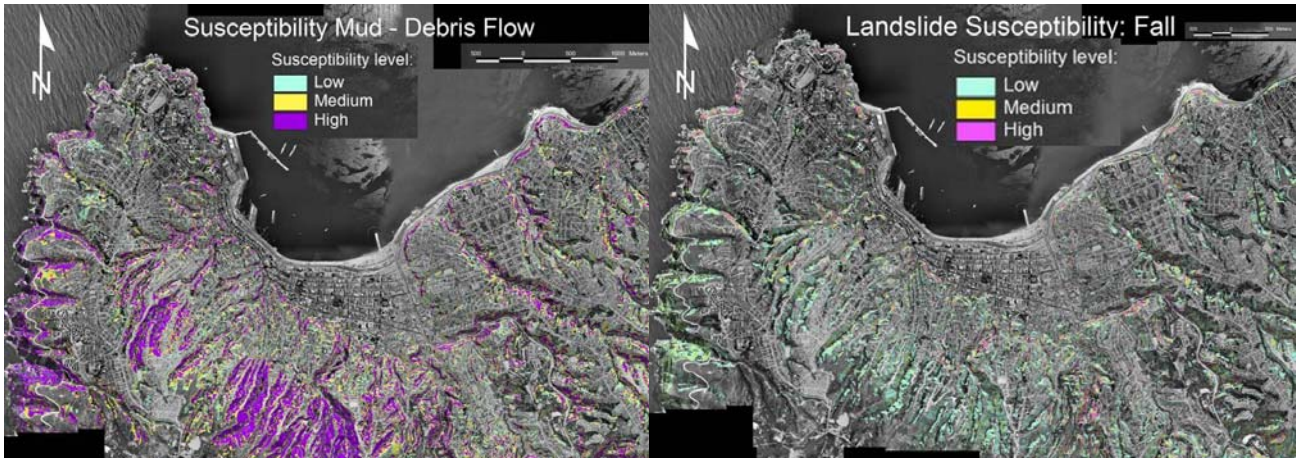


Figure 16: landslide inventory in the pilot area of the Cerro Cordillera and other events taken from the historic analysis



mud-debris flow events *fall events*

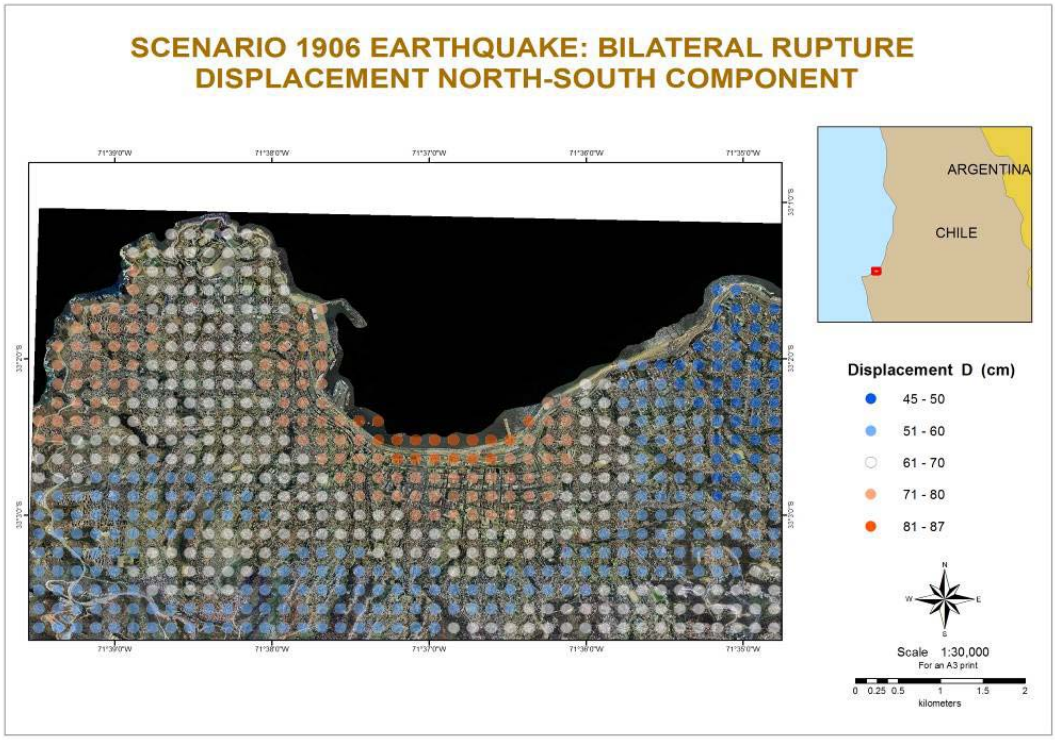
Figure 17: susceptibility maps.

4.3 Earthquake hazard

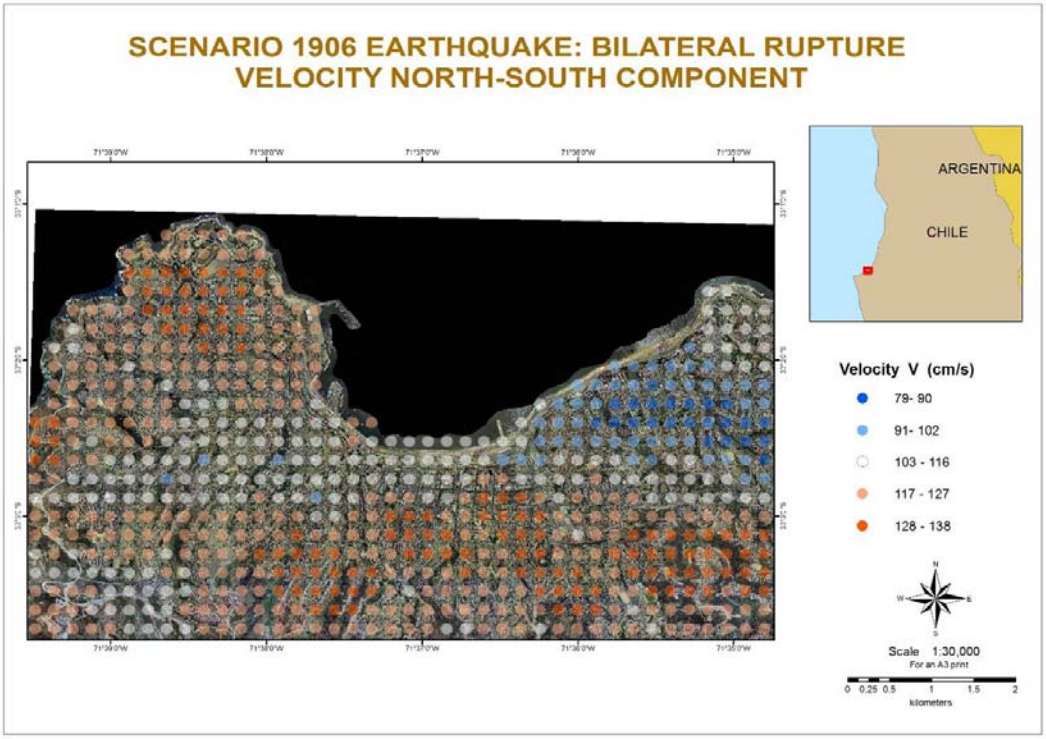
The work has been carried out in order to evaluate several earthquake scenarios (1906 earthquake, 1985 earthquake, Mw 7.5 earthquake and Mw 8.5 earthquake **[07]**) in the Valparaiso area, producing, as final output, 96 maps; for any earthquake scenario (bilateral and unilateral rupture, north-south and east-west horizontal components) displacement, velocity, acceleration and relative period (see Table 2) have been mapped, as shown in three examples reported by Fig. 18.
All the maps have been stored in separate files.

Table 2: maps produced for the 4 earthquake scenarios considered in the Valparaiso area.

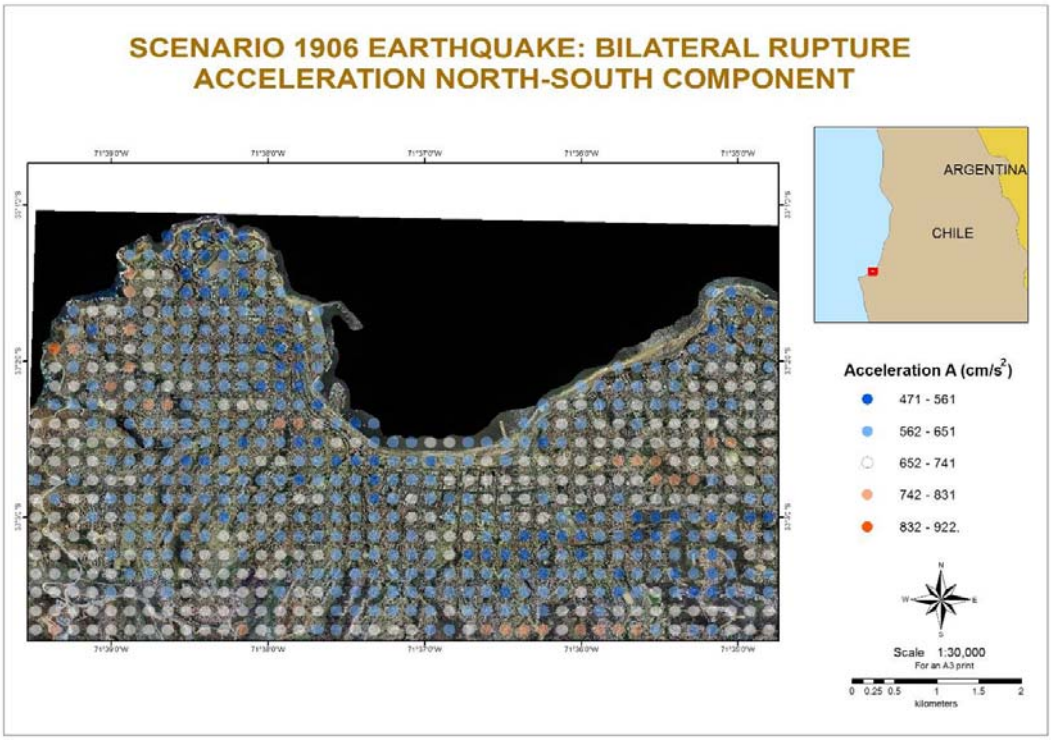
				1906 earthquake		1985 earthquake		Mw 7.5 earthquake		Mw 8.5 earthquake	
				A	**B**	**C**	**D**	**E**	**F**	**G**	**H**
variable number	variable		variable component	bilateral rupture	unilateral rupture	bilateral rupture	unilateral rupture	bilateral rupture	unilateral rupture	bilateral rupture	unilateral rupture
1	*Displacement D [cm]*	f0	NS	MAP A1	MAP B1	MAP C1	MAP D1	MAP E1	MAP F1	MAP G1	MAP H1
2			EW	MAP A2	MAP B2	MAP C2	MAP D2	MAP E2	MAP F2	MAP G2	MAP H2
3	*Velocity V [cm/s]*	f1	NS	MAP A3	MAP B3	MAP C3	MAP D3	MAP E3	MAP F3	MAP G3	MAP H3
4			EW	MAP A4	MAP B4	MAP C4	MAP D4	MAP E4	MAP F4	MAP G4	MAP H4
5	*Acceleration A [cm/s^2]*	f2	NS	MAP A5	MAP B5	MAP C5	MAP D5	MAP E5	MAP F5	MAP G5	MAP H5
6			EW	MAP A6	MAP B6	MAP C6	MAP D6	MAP E6	MAP F6	MAP G6	MAP H6
7	*Period P_D*	T0	NS	MAP A7	MAP B7	MAP C7	MAP D7	MAP E7	MAP F7	MAP G7	MAP H7
8			EW	MAP A8	MAP B8	MAP C8	MAP D8	MAP E8	MAP F8	MAP G8	MAP H8
9	*Period P_V*	T1	NS	MAP A9	MAP B9	MAP C9	MAP D9	MAP E9	MAP F9	MAP G9	MAP H9
10			EW	MAP A10	MAP B10	MAP C10	MAP D10	MAP E10	MAP F10	MAP G10	MAP H10
11	*Period P_A*	T2	NS	MAP A11	MAP B11	MAP C11	MAP D11	MAP E11	MAP F11	MAP G11	MAP H11
12			EW	MAP A12	MAP B12	MAP C12	MAP D12	MAP E12	MAP F12	MAP G12	MAP H12



DISPLACEMENT
north-south component
1906 earthquake map: bilateral rupture
Figure 18a: Examples of earthquake hazard maps.



VELOCITY
north-south component
1906 earthquake map: bilateral rupture
Figure 18b: Examples of earthquake hazard maps.



ACCELERATION
north-south component
1906 earthquake map: bilateral rupture
Figure 18c: Examples of earthquake hazard maps.

4.4 Tsunami hazard

The work has been carried out in order to evaluate several tsunami scenarios (mainly those connected to the 1906 and 1985 earthquakes, **[07]**). Inundations happened several times in the past (Fig. 19). Information has been provided by SHOA (**[13]** and Fig 20), on the basis of which further simulations have been implemented **[08]**.

Figure 19. An old picture showing an inundation in Valparaiso.

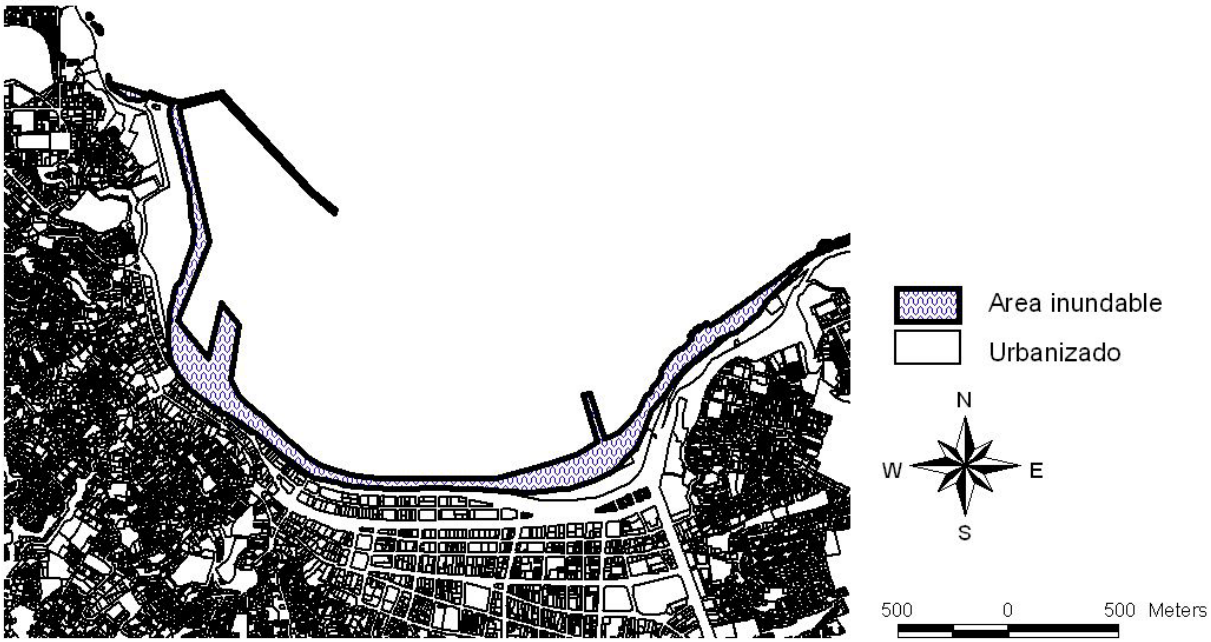


Figure 20: Tsunami inundation map for the 1906 seismic event (elaboration from SHOA).

5. ARCHITECTONIC, STRUCTURAL AND URBAN PLANNING ANALYSIS IN THE CERRO CORDILLERA PILOT SECTOR

The work is widely described in **[09]**. An example of the basic shapefiles is shown by Fig. 21.

Cerro Cordillera

Buildings area	***file name buildings_area_final.shp***
Front_elevation	***file name front_elevation.shp***
Streets	***file name street.shp***
Open_space	***file name open_space.shp***

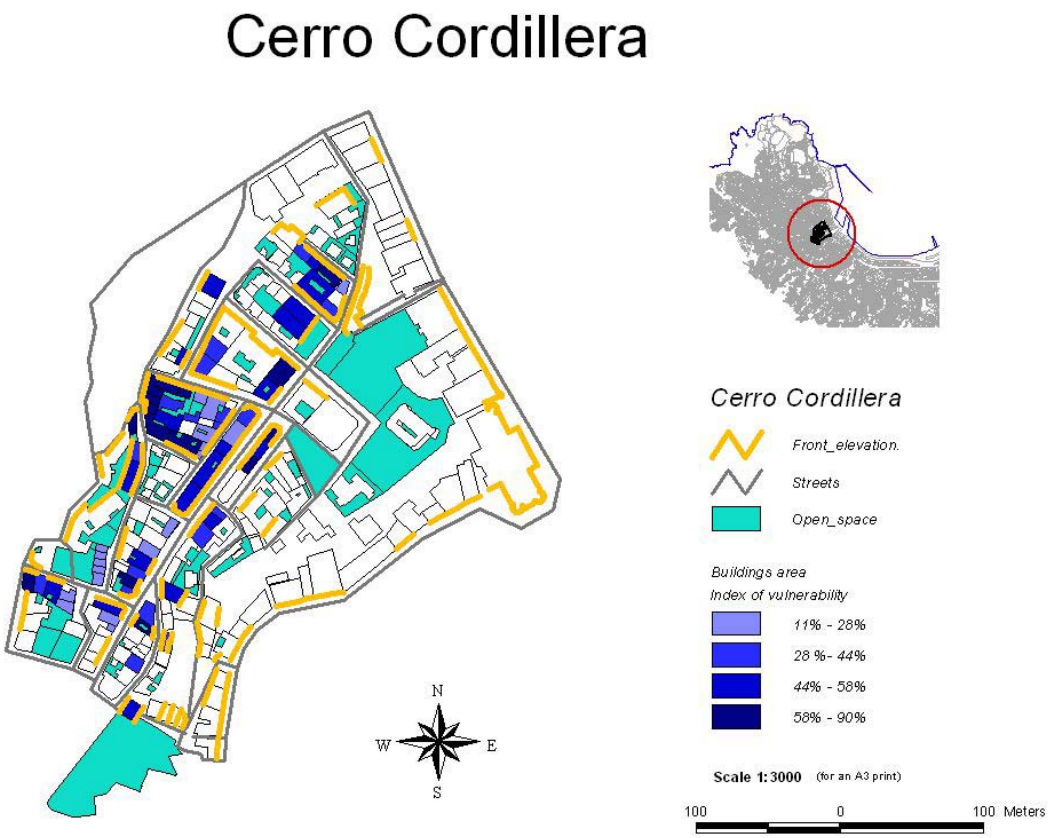


Figure 21: Example of a shapefile used for the analyses carried out in the Cerro Cordillera pilot area.

6. CONCLUSIONS

The work carried out in the framework of the "MAR VASTO" project allowed to develop a GIS database platform, organizing a huge amount of data of general interest, but also information targeted on specific hazards.

In addition, the activities performed in the framework of the Cerro Cordillera pilot project **[09]** can be considered a robust step ahead**,** having focused, even if for a limited area, architectonic and urban planning analyses, structural evaluation of structural vulnerability and definition of some intervention proposals.

It is hopeful that the core results obtained in this specific study would be considered as a basis for the development of future projects, in cooperation with Local Authorities, enhancing the database and enlarging the followed procedure to the whole Valparaiso area.

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[02] "MAR VASTO" Project, General Progress Report n. 2, 28.01.2008.
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[04] "MAR VASTO" Project, DGPS survey in the City of Valparaiso, 15.06.2008.
[05] "MAR VASTO" Project, Geomorphologic hazard in the City of Valparaiso, 15.06.2008
[06] "MAR VASTO" Project, Fire hazard in the City of Valparaiso, 15.06.2008
[07] "MAR VASTO" Project, Seismic hazard in the City of Valparaiso, 30.06.2008.
[08] "MAR VASTO" Project, Tsunami hazard in the City of Valparaiso, 30.06.2008.
[09] "MAR VASTO" Project, Cerro Cordillera pilot project (Valparaiso), 30.06.2008.
[10] Aerial photos provided by SHOA (Servicio Hidrografico y Oceanografico de la Armada de Chile) of the Valparaiso urban area:
scale 1:15000, black and white, 2004;
scale 1:20000, black and white, 1994.
[11] Radar altimetry data coming from NASA Space Shuttle flights have been purchased from: http://srtm.csi.cgiar.org/; ftp://e0srp01u.ecs.nasa.gov/srtm/version2/.
[12] Nelson L. Vasquez; Ricardo S. Iglesias, Mauricio A. Molina;
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[13] Servicio Hidrografico y Oceanografico Armada de Chile.
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