

A Web GIS for managing post-earthquake emergencies.

Matteo Crozi – Riccardo Galetto – Anna Spalla

DIET – University di Pavia - Italy

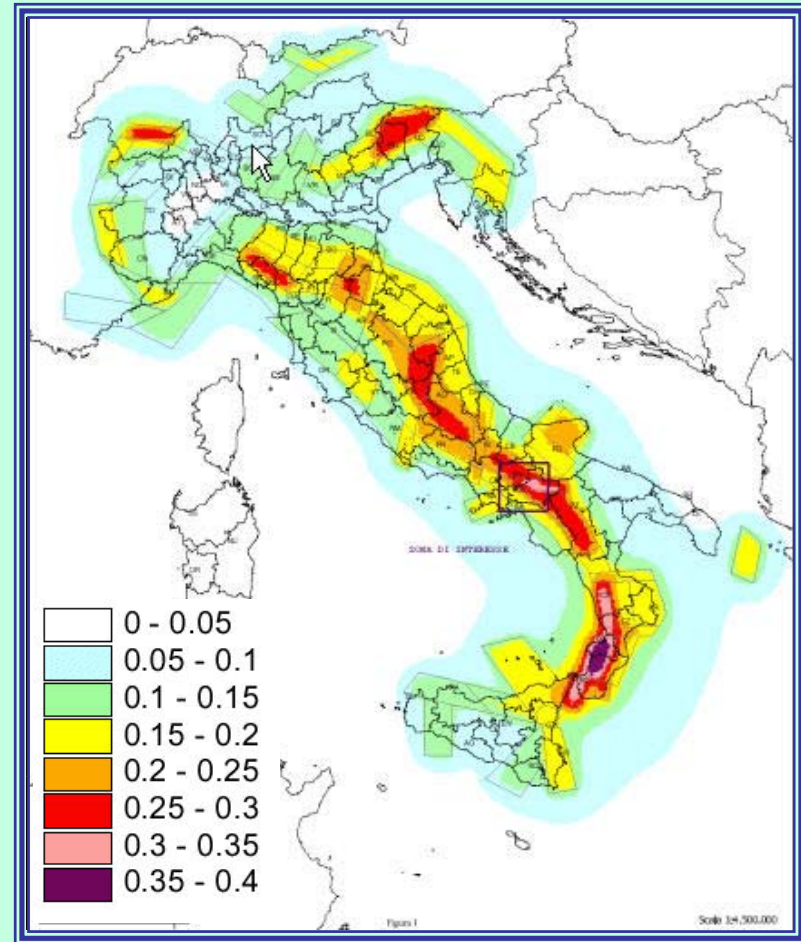


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Map of seismic risk

This map gives the PGA value which can be predicted with 10% probability in the next 50 years



The GNDT (National Group for Earthquake Defence) is a national body which has the mission to coordinate the scientific research in the field of the reduction of seismic risk. The realisation of this Web GIS has been carried out within the frame of the research project sponsored by the GNDT :

*Reduction of the Seismic Vulnerability
of Infrastructural Systems
and Physical Environment*



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The research project, in which eight Universities have participated, takes into consideration the vulnerability of:

- physical environment
- main communication road networks
- bridges
- high voltage electrical lines
- large industrial plants
- earth dams

with the goal to determine:

- the assessment of relevant and specific ground motion
- vulnerability reduction methods
- risk evaluation criteria

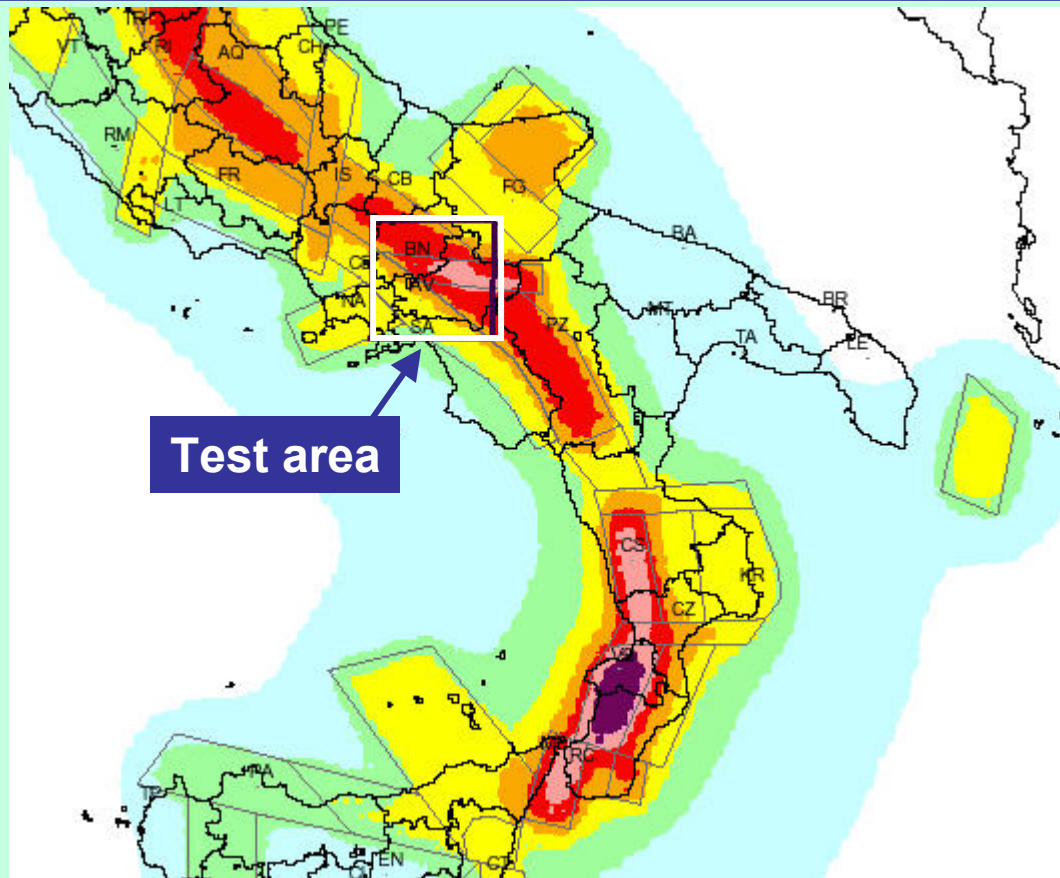


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One of the main tasks of the project has been the realization of a Web GIS able to:

- manage all the data needed for the seismic risk evaluation
- perform simulations of the impact on the infrastructures of hypothetical seismic events
- depict a scenario of the damages to infrastructures as a consequence of a specific seismic event
- give Governmental Bodies the possibility to foresee the best way of managing post- earthquake emergencies.



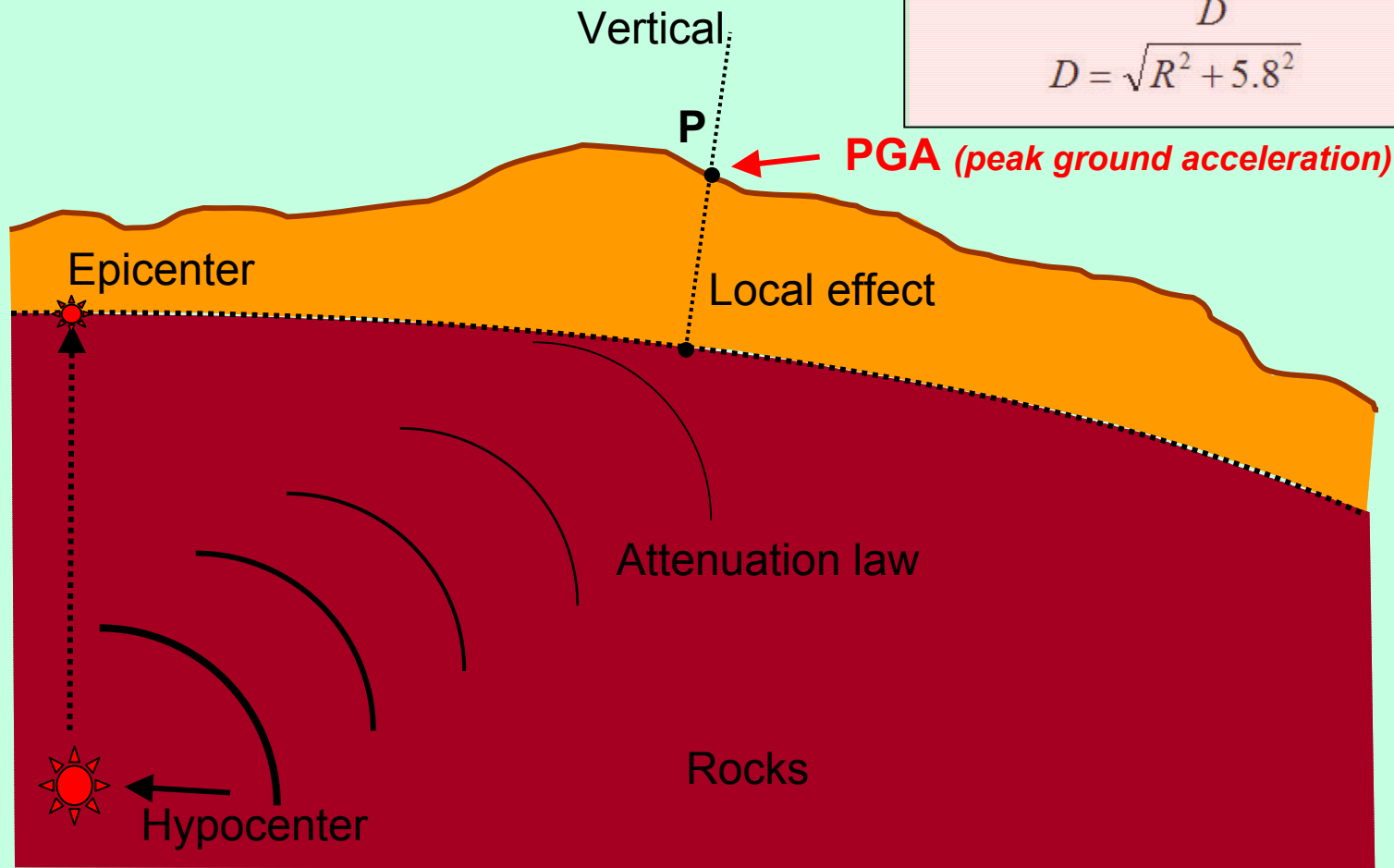
In order to test the results achieved by the research group, a test area was chosen between the towns of Benevento and Avellino.

The characteristics of an earthquake which are taken into consideration in the Web GIS are :

- Magnitude
- Epicenter
- Hypocenter
- Attenuation law
- PGA (peak ground acceleration)

$$PGA = \frac{0.0274 \cdot e^{0.0704M} \cdot e^{-0.39s}}{D}$$

$$D = \sqrt{R^2 + 5.8^2}$$



Two Web GISs have been realized:

- one in the Esri environment
- a second one in proprietary Java based software.

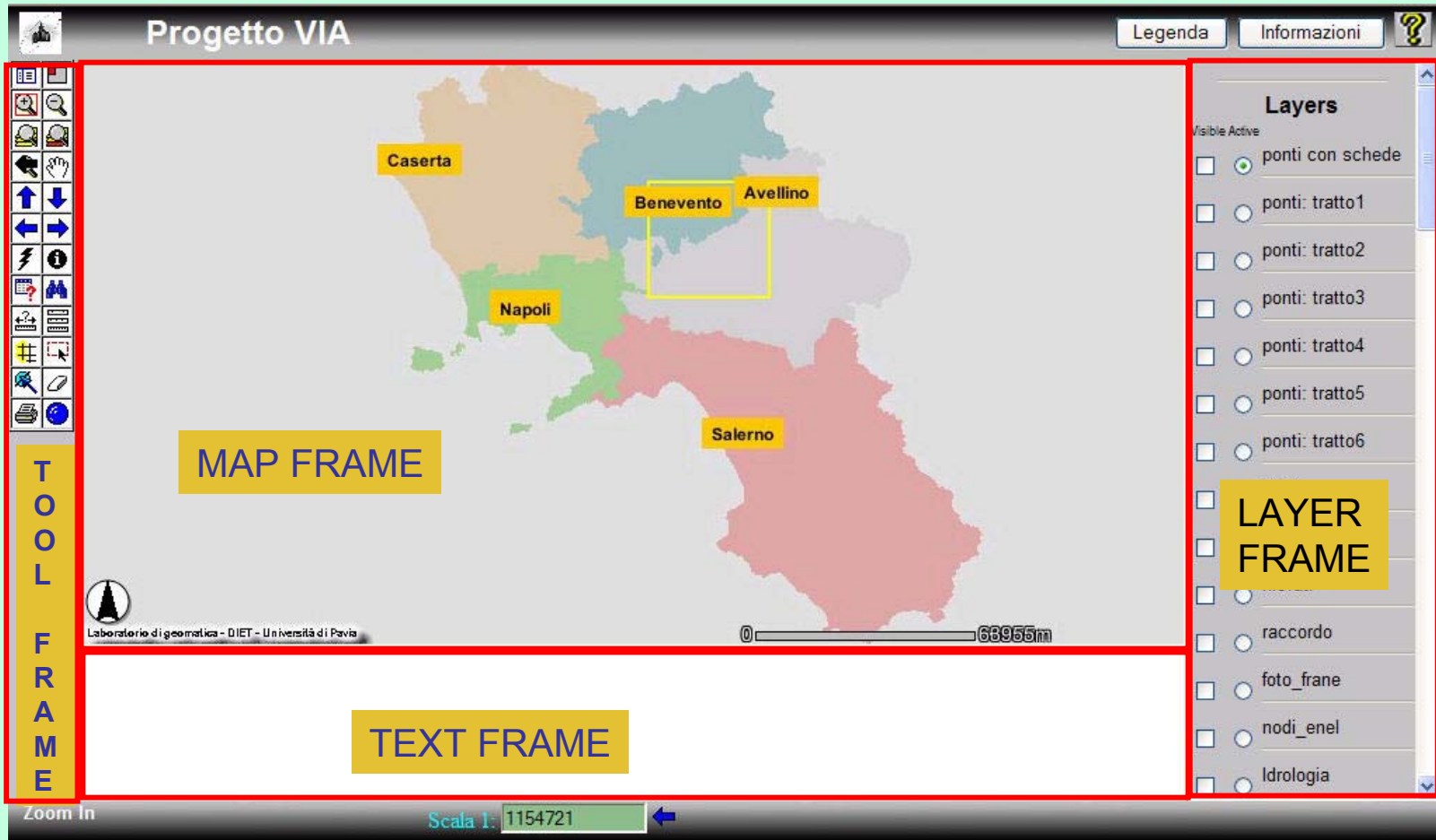
In the first the problem of the simulation of the effects of an earthquake has been approached with a **deterministic** method; in the second with a **probabilistic** method.

Characteristics of the Web GIS ESRI software based:

Map Server: ESRI ArcIMS

Web server: IIS (Internet Information Server)

Servlet: Servletxect



User Interface Layout

In the Web GIS two kinds of data are stored:

- environment description data
- Infrastructure data



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quadro Carta 1: dissesti Autorità di Bacino is now the Active Layer (12)

Zoom In Scala 1: 12423

Technical map

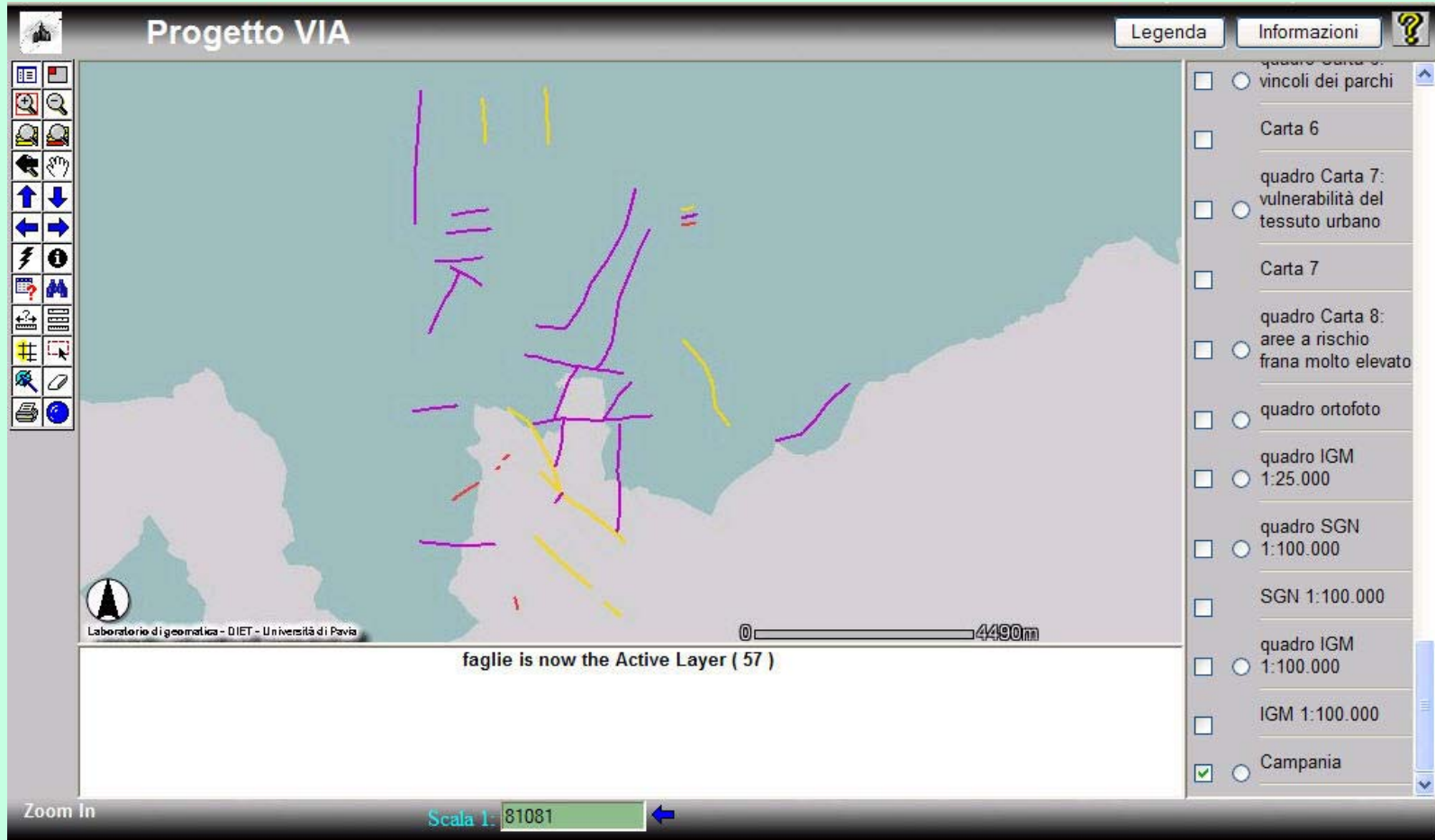
Progetto VIA Legenda Informazioni

quadro Carta 1: dissesti Autorità di Bacino is now the Active Layer (12)

Zoom In Scala 1: 15777

- DTM 10m
- DTM 40 m
- carta delle pendenze
- carta dell'orientamento
- carta dell'illuminazione
- quadro Carta 1: dissesti Autorità di Bacino
- Carta 1
- quadro Carta 2: dissesti fenomeni franosi
- Carta 2
- quadro Carta 3: carta geologica
- Carta 3

Landslides map



Faults map

Progetto VIA Legenda Informazioni 



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Carta Geologica
 Hyperlink to <http://geo-survey.unipv.it/vialink/Legenda/b3.htm>

Zoom In Scala 1: 38605 

Layers
 Visible Active

- ponti con schede
- ponti: tratto1
- ponti: tratto2
- ponti: tratto3
- ponti: tratto4
- ponti: tratto5
- ponti: tratto6
- città
- muri
- rilevati
- raccordo
- foto_frane
- nodi_enel
- Idrologia

Geological Map



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Layers

Visible Active

- ponti con schede
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- ponti: tratto2
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- ponti: tratto5
- ponti: tratto6
- città
- muri
- rilevati
- raccordo
- foto_frane
- nodi_enel
- Idrologia

0 296m

ponti con schede is now the Active Layer (32)

Zoom In Scala 1: 5354 ←

Ortophoto

Progetto VIA

Legenda Informazioni ?

FS

Carta Geologica

Carta Litotecnica

DTM 10m

DTM 40 m

carta delle pendenze

carta dell'orientamento

carta dell'illuminazione

quadro Carta 1: dissesti Autorità di Bacino

quadro Carta 2: dissesti fenomeni franosi

quadro Carta 3: carta geolitologica

Carta 3

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0 4788m

ponti con schede is now the Active Layer (32)

Hyperlink Scala 1: 86366

Digital Terrain Model



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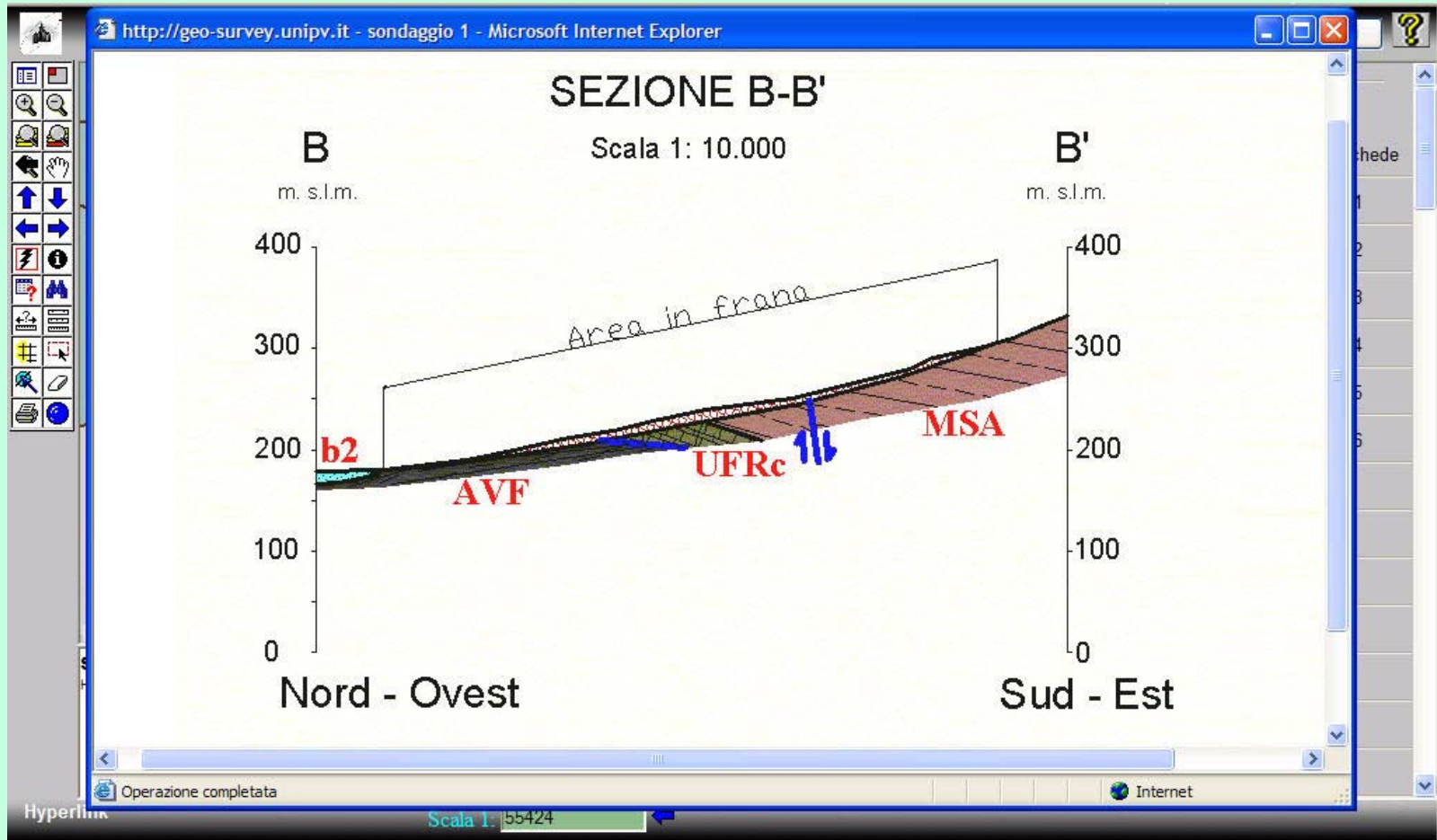
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sezioni
Hyperlink to <http://geo-survey.unipv.it/vislink/sezioni/BB.htm>

Zoom In Scala 1: 26641

Landslide map



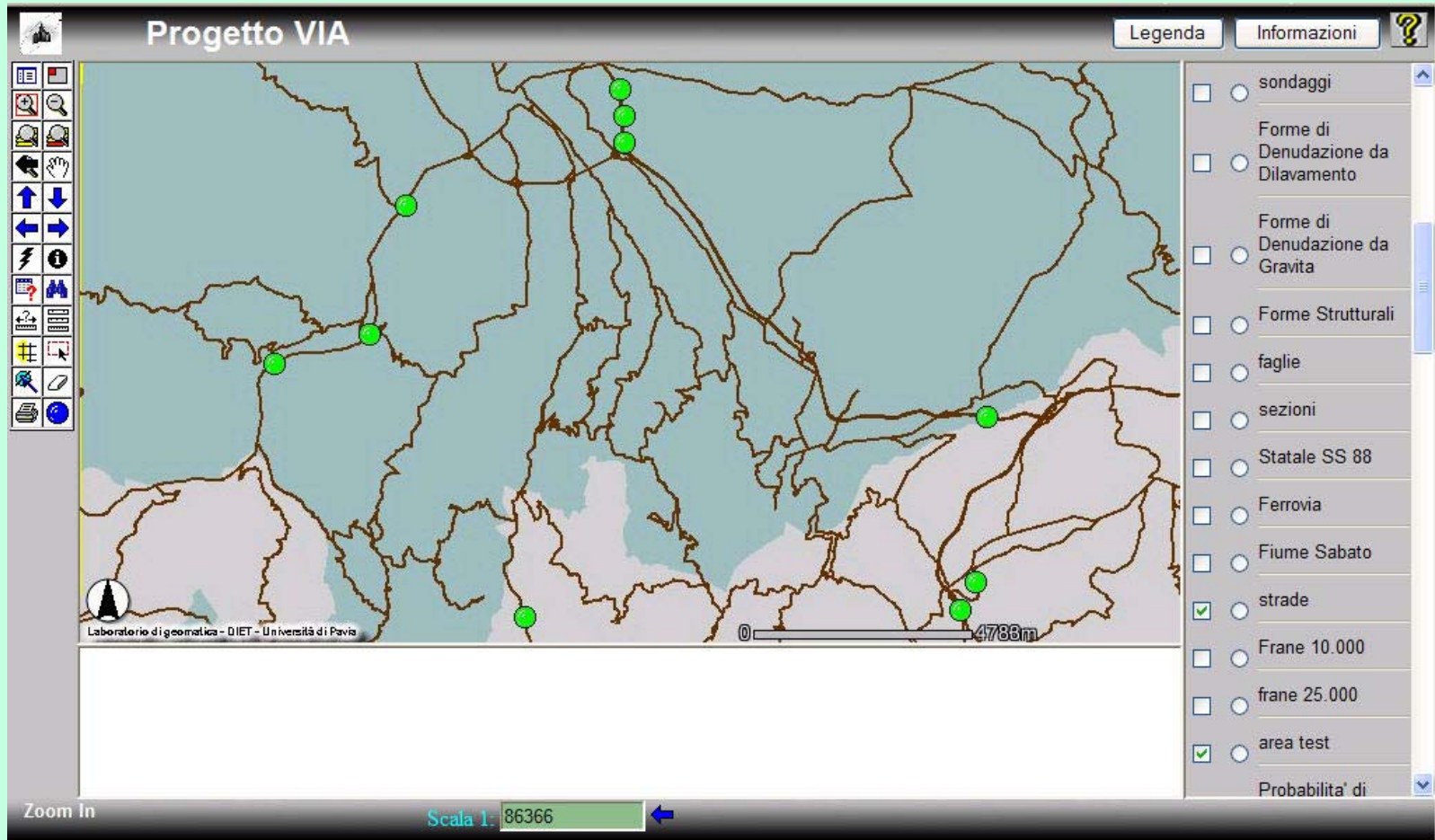
Landslide section

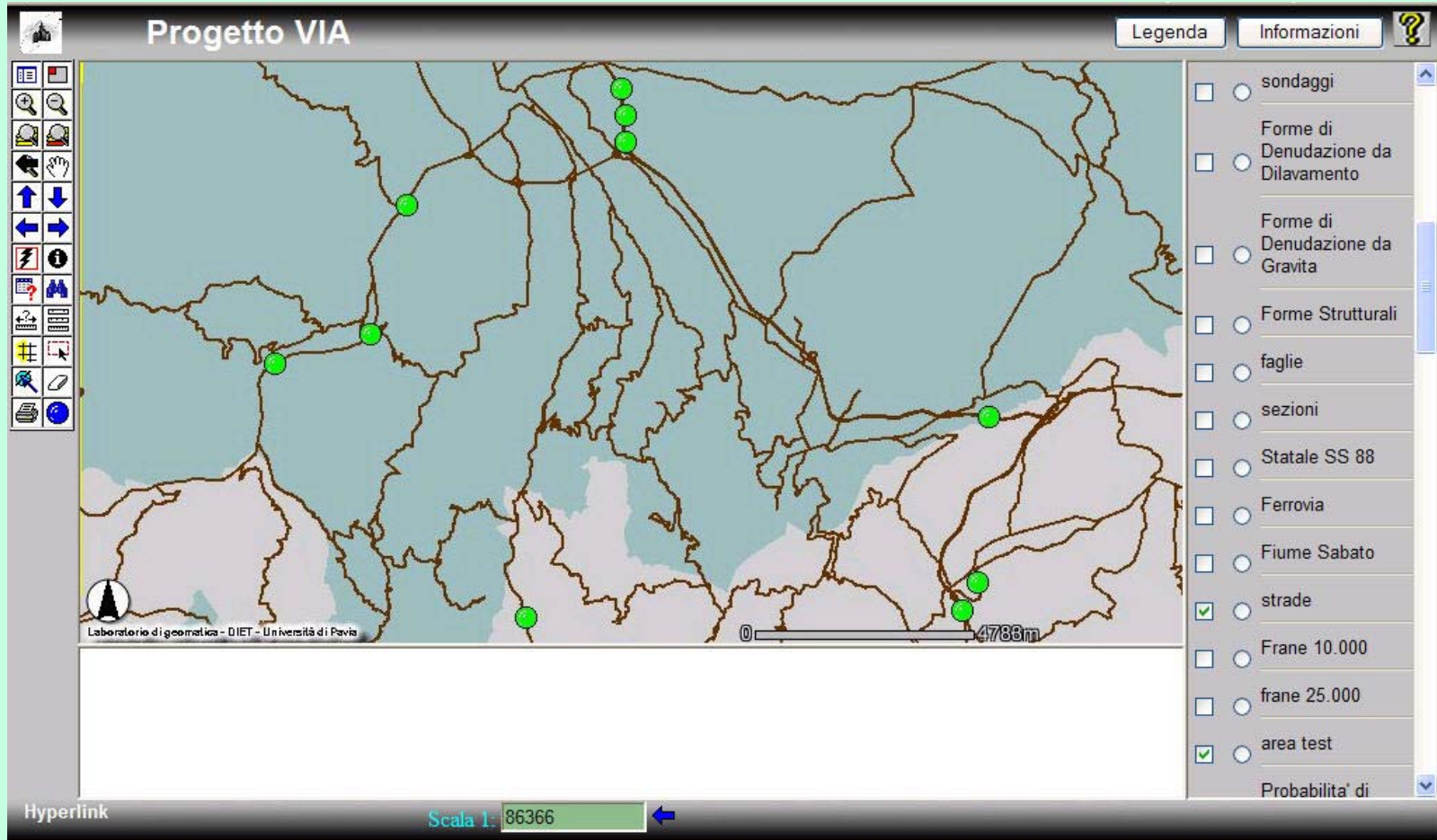
Data concerning infrastructures

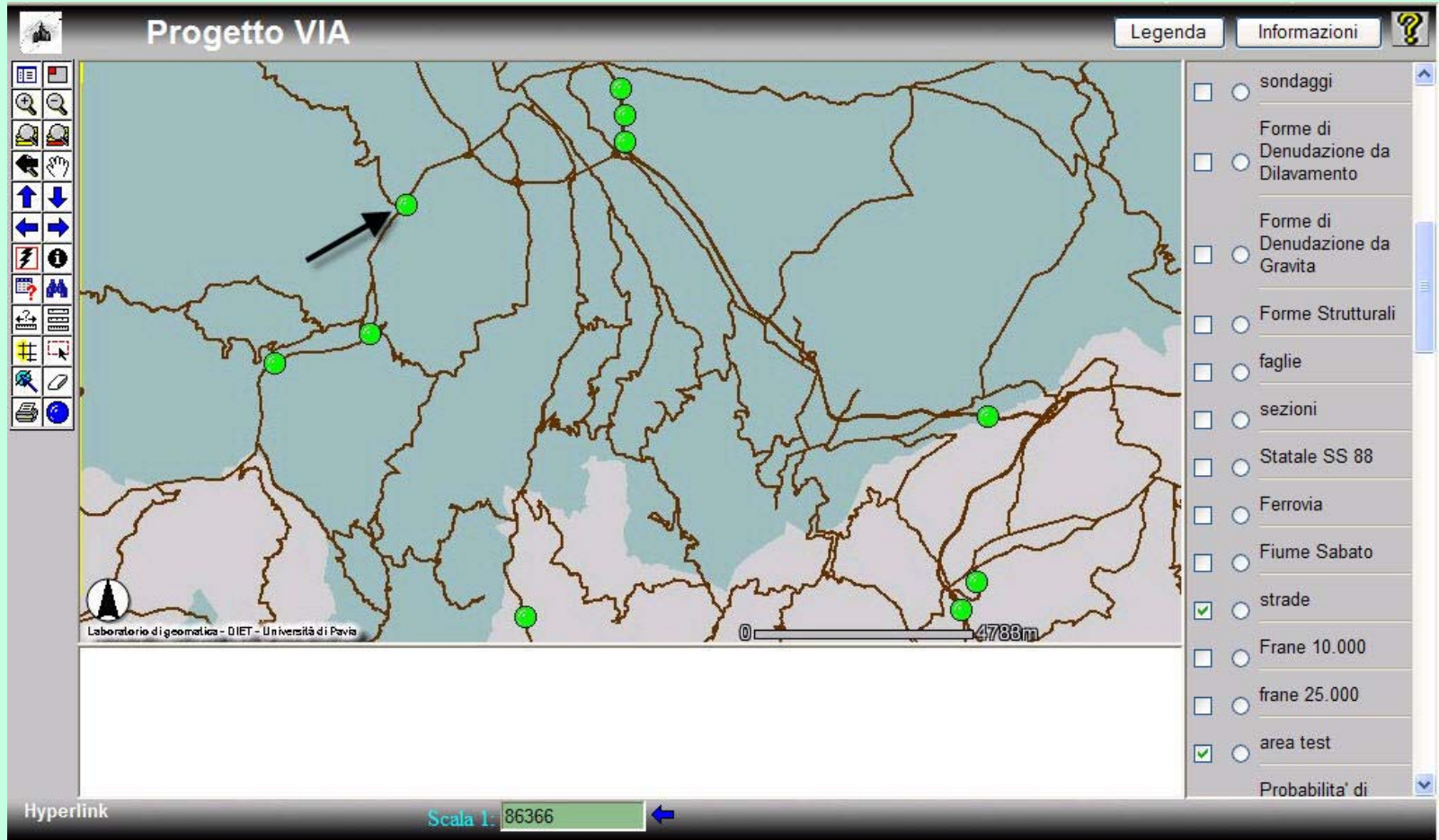


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http://geo-survey.unipv.it - tratt...

Internet

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ponti con schede
 Hyperlink to http://geo-survey.unipv.it/vialink/ProgVIA_Ponti/tratto3_c03.htm

Hyperlink Scala 1: 86366

0 4788m

- Idrologia
- sondaggi
- Forme di Denudazione da Dilavamento
- Forme di Denudazione da Gravita
- Forme Strutturali
- faglie
- sezioni
- Statale SS 88
- Ferrovia
- Fiume Sabato
- strade
- Frane 10.000
- frane 25.000
- area test

Progetto VIA Legenda Informazioni

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- Forme di Denudazione da Dilavamento
- Forme di Denudazione da Gravita
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- frane 25.000
- area test
- Probabilita' di

http://geo-survey.unipv.it - tratto 3 ponte c03 - Microsoft Internet Explorer

RILIEVO PONTE n.8						
DENOMINAZIONE PONTE						
DENOMINAZIONE TRATTA STRADALE	SS 7 - APPIA					
COMUNE	Benevento					
ANNO O PERIODO DI COSTRUZIONE						
CATEGORIA SOVRACCARICHI	DM L.L.P.P. 04/05/80			ASSEGNATI		
	I	II	III	PERMANEN.KN		ACCIDENT.KN
TIPOLOGIA SPALLE	<input type="checkbox"/>	RIGIDE		<input type="checkbox"/>	FLESSIBILI	
TIPOLOGIA PILE	<input type="checkbox"/>	MONOFUSTO		<input type="checkbox"/>	TELAIO	
	<input type="checkbox"/>	CONTINUO		<input type="checkbox"/>	A TRAVI SOSTATICHE	

Operazione completata Internet

Hyperlink
Scala 1: 86366



Progetto VIA Legenda Informazioni

http://geo-survey.unipv.it - Tratto 1 ponte a02 - Microsoft Internet Explorer

The drawing shows a cross-section of a bridge with four spans. The spans are labeled with dimensions: 2,4, 2,3, 2,3, and 2,4. The bridge has a central pier with a width of 0,6 and a height of 0,2. The bridge deck has a thickness of 0,2. The drawing is displayed in a browser window with a toolbar on the left and a legend on the right.

Legenda

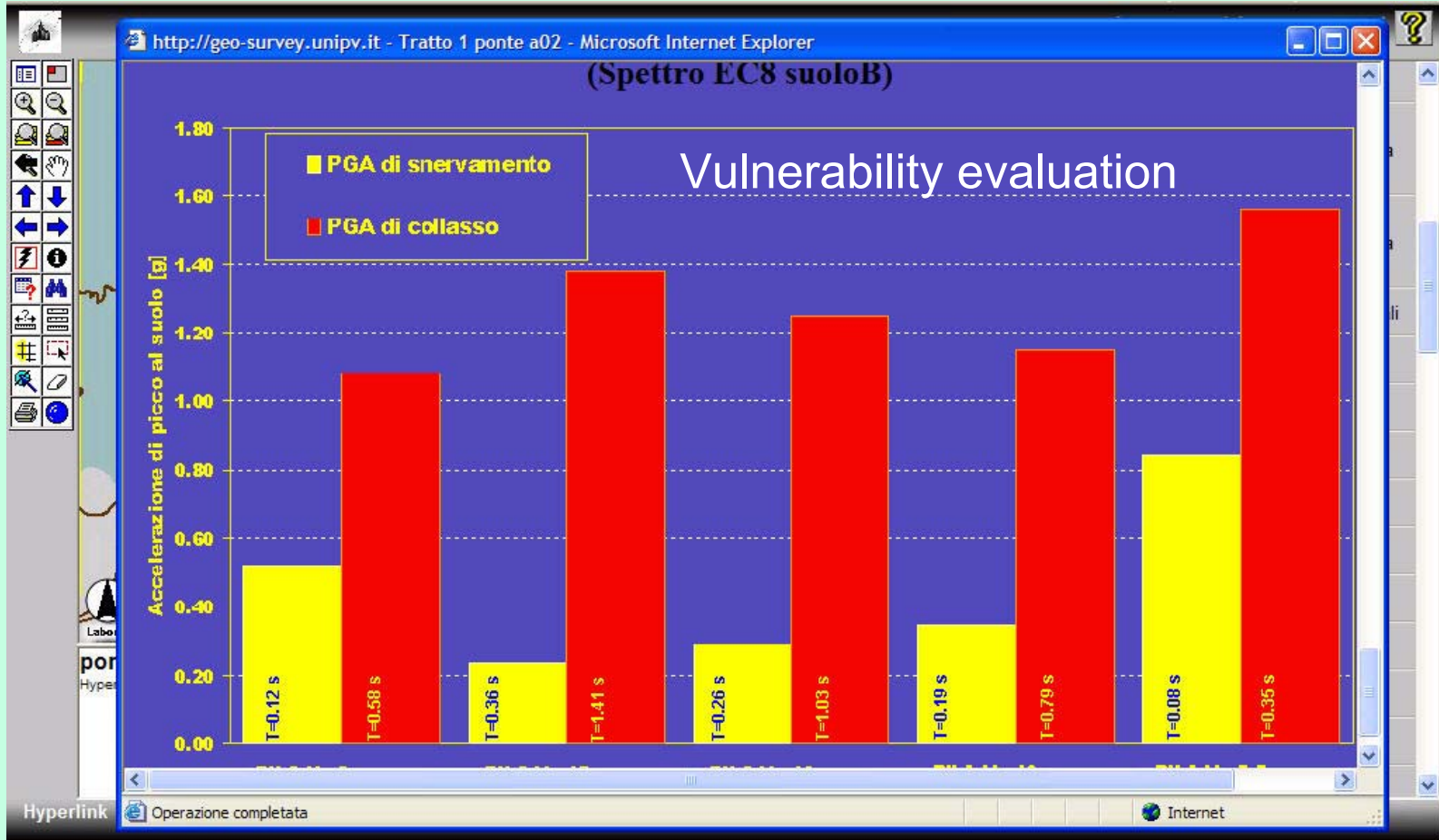
- sondaggi
- Forme di Denudazione da Dilavamento
- Forme di Denudazione da Gravita
- Forme Strutturali
- faglie
- sezioni
- Statale SS 88
- Ferrovia
- Fiume Sabato
- strade
- Frane 10.000
- frane 25.000
- area test
- Probabilita' di

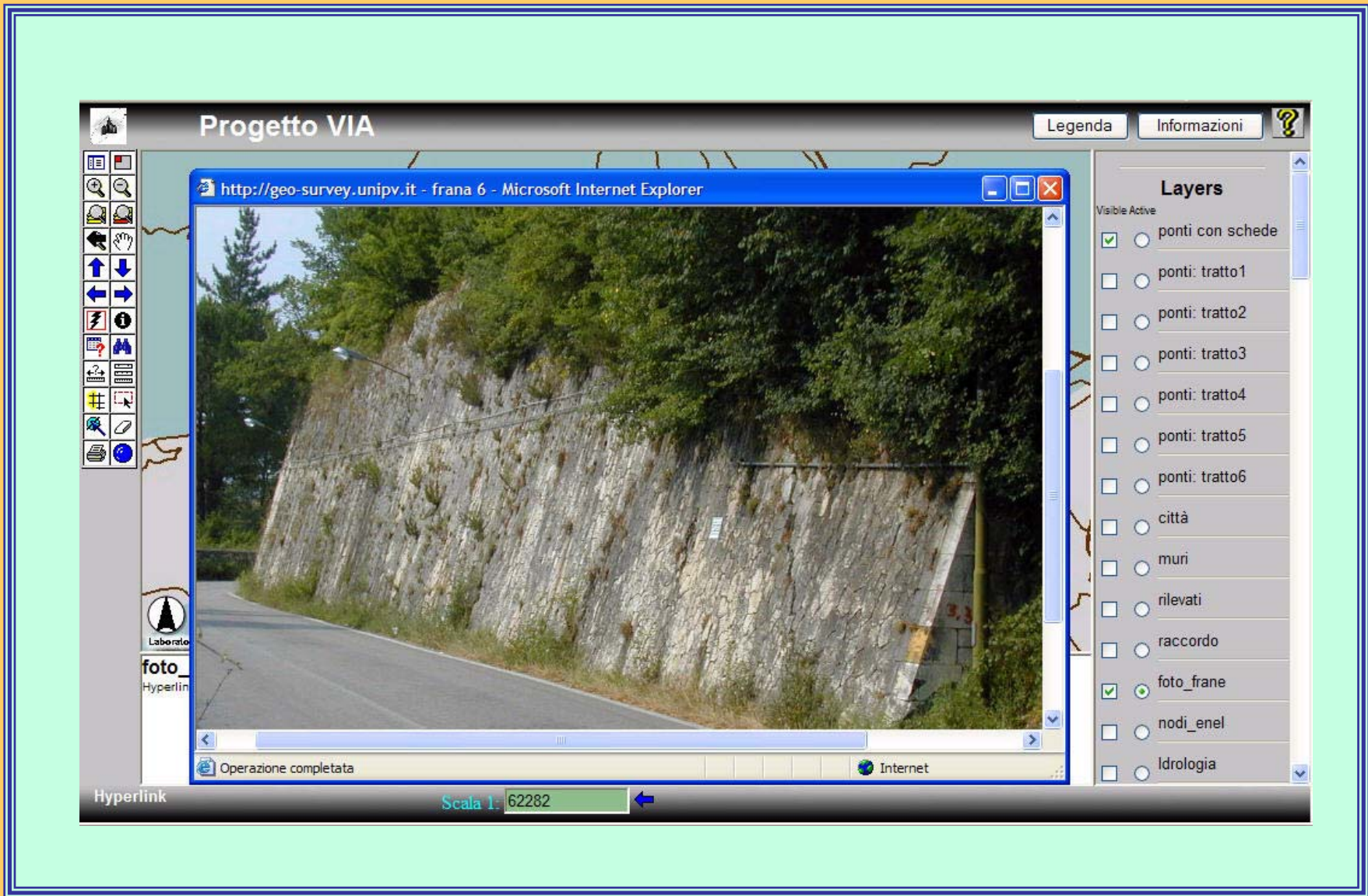
Hyperlink Scala 1: 86366

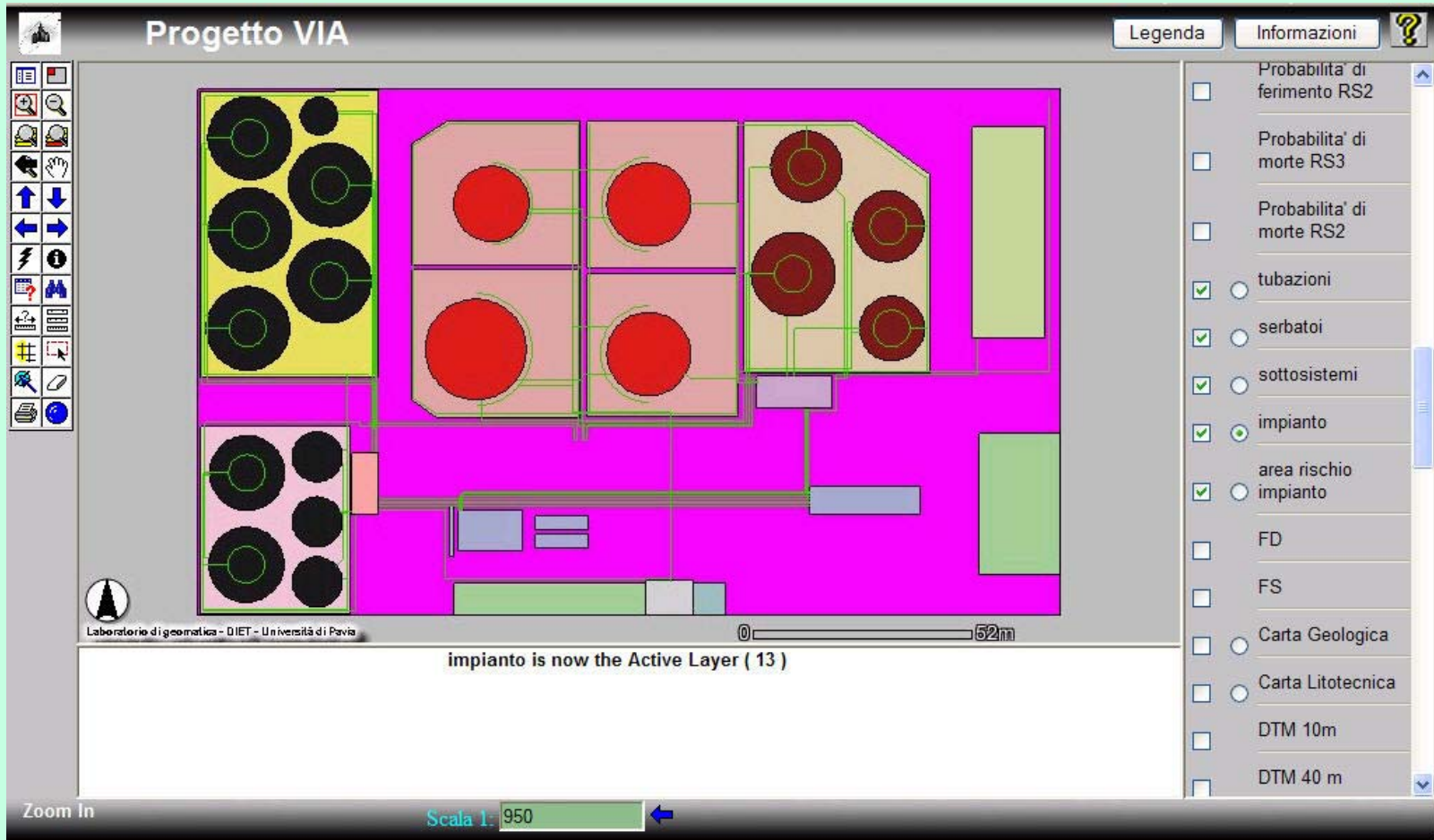


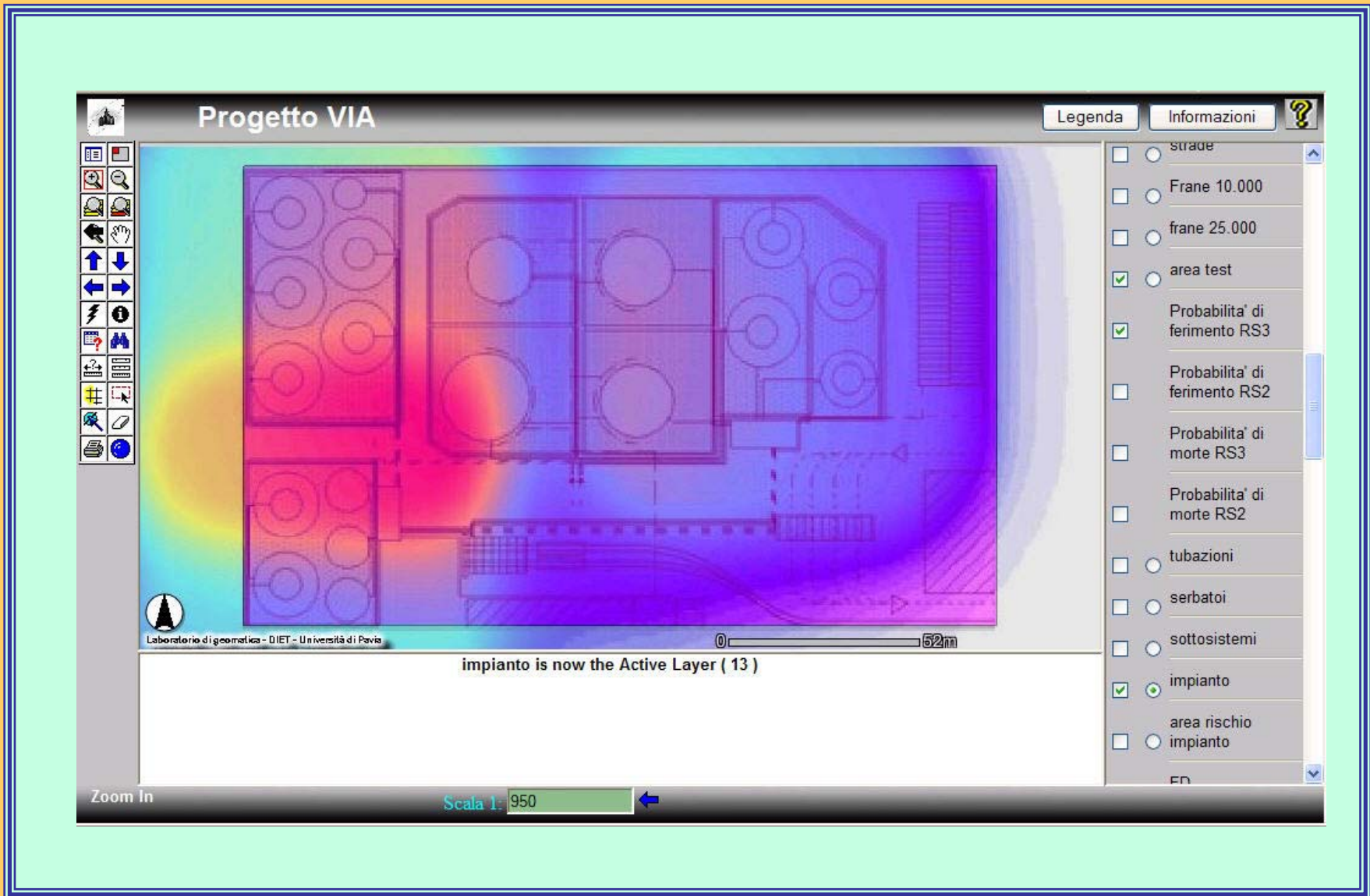
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In the **deterministic approach** the problem of giving support for managing a post-earthquake emergency has been approached in the following way:

when the magnitude and the coordinates of the hypocenter of an earthquake are entered in the Web GIS, a devoted application allows the generation, in real time, of a series of maps and tabulations relating to the foreseen damages of the existing infrastructures in the area of interest on the basis of their previously computed vulnerability.

Special emphasis has been given to the problem of evaluating the effects of a seismic event on bridges and on the potential landslides, to foresee the situation of the road network.

The effects of the simulated seismic event on the infrastructures are determined in relation to their vulnerability.

The data concerning the vulnerability of the infrastructures (bridges, dams, industrial plants), stored in the GIS database, is derived from the studies performed by the researchers of the Universities participating in the project.



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The earthquake simulation module of the Web GIS



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Forme di Denudazione da Gravita
 Forme Strutturali
 faglie
 sezioni
 Statale SS 88
 Ferrovia
 Fiume Sabato
 strade
 Frane 10.000
 frane 25.000
 area test
 Probabilita' di ferimento RS3
 Probabilita' di ferimento RS2

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 ponti con schede is now the Active Layer (32)
 Zoom In Scala 1: 86366



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città
 muri
 rilevati
 raccordo
 foto_frane
 nodi_enel
 Idrologia
 sondaggi
 Forme di Denudazione da Dilavamento
 Forme di Denudazione da Gravita
 Forme Strutturali
 faglie
 sezioni
 Statale SS 88

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 0 4788m
 ponti con schede is now the Active Layer (32)
 Zoom In Scala 1: 86366

Progetto VIA Legenda Informazioni ?

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coordinate Avvia Simulazione

Nord [m] Magnitudo

Est [m] Profondità [m]

Simulazione terremoti Scala 1: 86366

Progetto VIA Legenda Informazioni

città
 muri
 rilevati
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 Forme di Denudazione da Gravita
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 Nord [m] Magnitudo
 Est [m] Profondità [m]

Simulazione terremoti Scala 1:

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Progetto VIA Legenda Informazioni ?

città
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Simulazione terremoti Scala 1:

Progetto VIA Legenda Informazioni ?

città
 muri
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 Statale SS 88

coordinate Avvia Simulazione
 Nord [m] Magnitudo
 Est [m] Profondità [m]

Simulazione terremoti Scala 1: ←

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Progetto VIA Legenda Informazioni ?

http://geo-survey.unipv.it - Simulazione terremoti - Microsoft Internet Explorer

File Modifica Visualizza Preferiti Strumenti ?

Indietro Cerca Preferiti SnagIt

Caratteristiche Sisma			
Coordinate Ipocentro			Magnitudo
Nord [m]	Est [m]	Profondità [m]	
4544497	2508232	500	7

Risultati della simulazione										
Nome	ID	Tipo	Coord N [m]	Coord E [m]	Distanza Ipocentro [km]	S	PGA snervamento	PGA collasso	PGA simulato	Stato
CASILLO BENVENUTO (VENTICANO)	a11	viadotto	2511598	4546345	3.872	0	0.14	0.41	0.543	Crollato
SAN NICOLA	a04	viadotto	2503720	4552318	9.043	0	0.36	1.1	0.352	Agibile
SAMBUCHI	a03	viadotto	2503720	4552877	9.531	0	0.32	1.08	0.339	Parzialmente agibile
CASINO RUSSO	a02	viadotto	2503610	4553460	10.097	0	0.23	1.08	0.325	Parzialmente agibile
fl7	fl7	Ponte	2501559	4541993	7.145	0	0	0	0.411	Transitabile
c07	c07	ponte	2496092	4547488	12.513	0	0	0	0.274	Transitabile
c05	c05	ponte	2498170	4548131	10.71	0	0	0	0.311	Transitabile
c03	c03	ponte	2498962	4550946	11.304	0	0	0	0.298	Transitabile

Simulazione terremoti Scala 1: 86366 Statale SS 88

Characteristics of the Web GIS Java software based:

Web GIS Software :

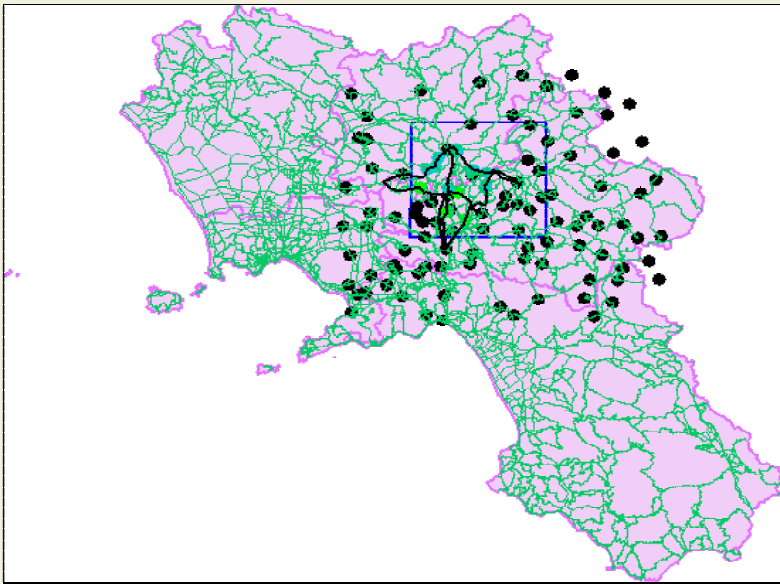
- Web server: Apache
- Servlet: Tomcat
- Map Server: Geovisio (ASI Mantova)

In the **probabilistic approach** the problem of giving support for managing a post-earthquake emergency has been approached in the following way:

given a road network involved in a seismic event, to compute the minimum and maximum value of the probability that two points of the road network are connected.








Progetto VIA - Microsoft Internet Explorer

Indirizzo <http://localhost/via/> Vai



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 e-mail: diet@unipv.it

search legend

-  campania_shape
-  ponti_schede
-  ponti_prob
-  tratto1
-  tratto2
-  tratto3
-  tratto4

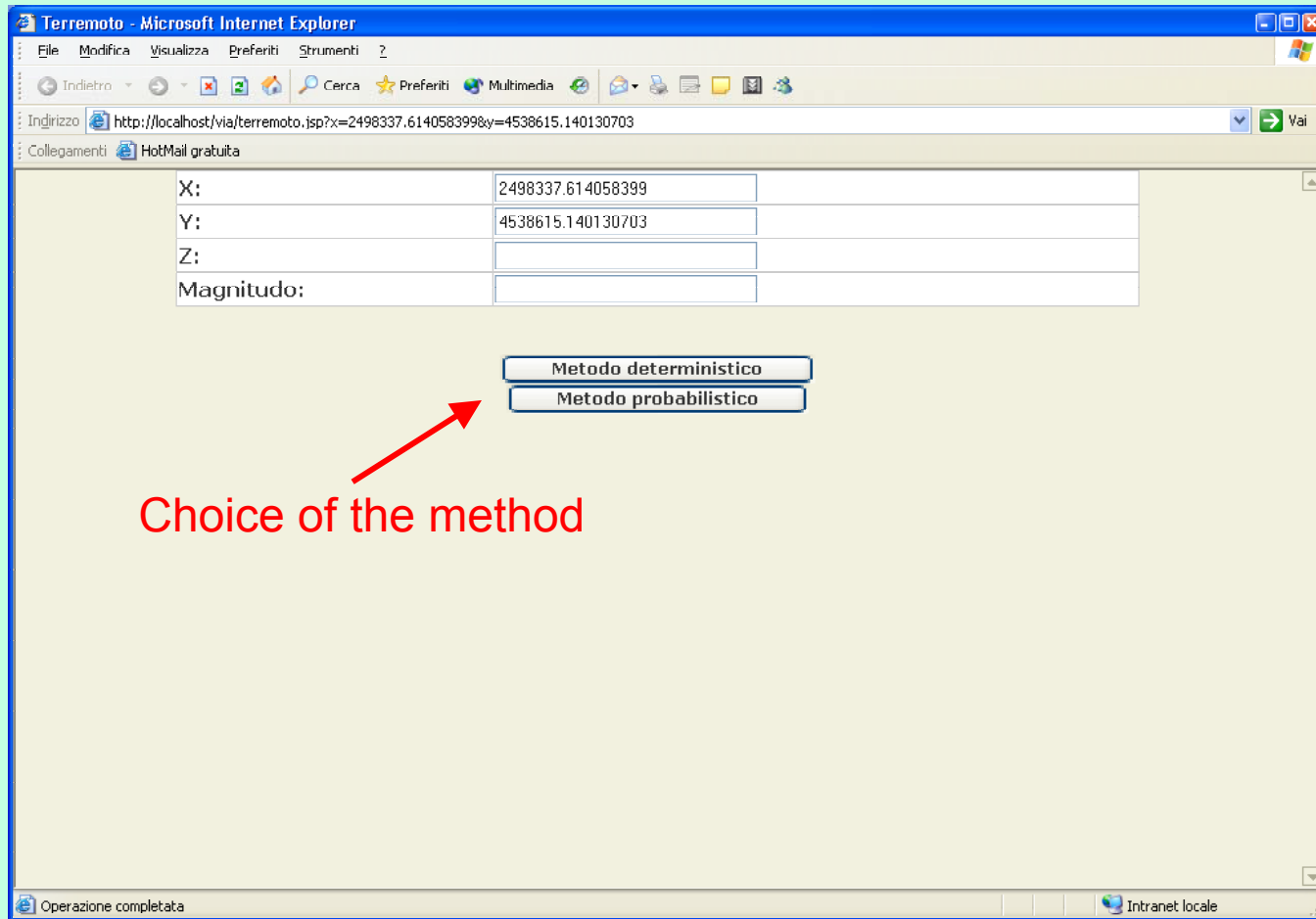
ponti_prob

ponti_prob.dbf

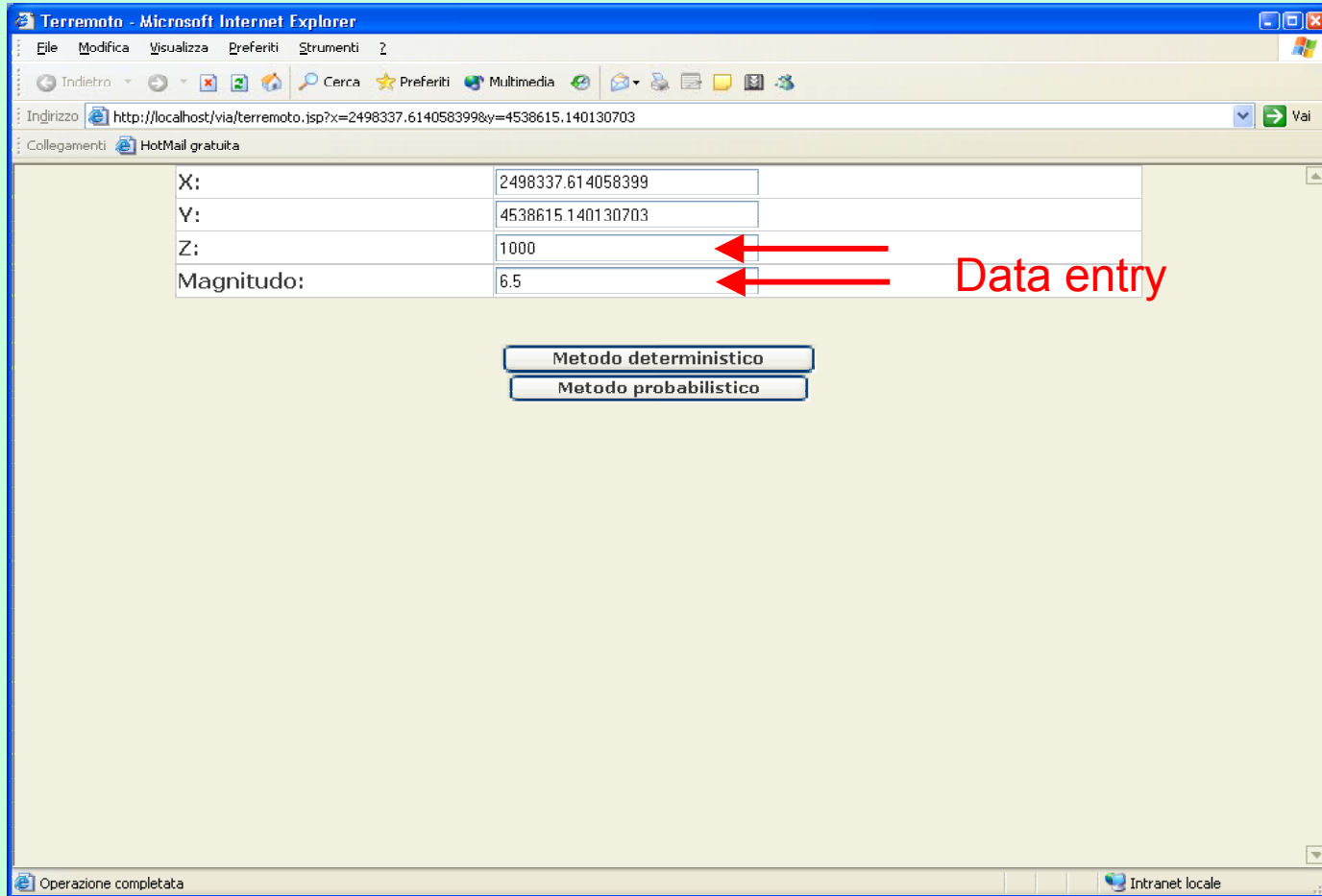
recno	SPALLE	TRATTO	NOME	PGA_COLLAS	PGA_SNERVA
1	no	TRATTO 5	DENTECANE	0.900000000000	0.240000000000

Operazione completata Intranet locale

Layout of the Web GIS Java software based



Choice of the method



Progetto VIA - Microsoft Internet Explorer

Indirizzo: <http://localhost/via/>

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 e-mail: diet@unipv.it

Starting point → A

epicentre

Arriving point → B

road network

search legend

redraw

Cut set 2	Pf. 0.1377888
Tronco 1	Pf. 0.7408
Ponte 3	Pf. 0.28
Ponte 4	Pf. 0.4
Ponte 5	Pf. 0.4

Intranet locale

The road network is composed of several sections, which connect all the nodes of the network. Several bridges can be located along each section.

The behaviour of each section is considered as binary: functioning (practicable) and non-functioning (impassable)

Failure of the network after a seismic event is defined as the lack of connectivity between the two selected points **A** and **B** of the net.

To estimate the failure probability of the network, **minimal cut-sets** theory is employed.

A **minimal cut-set** is defined as the set of sections strictly necessary to cut the connection between the two selected points **A** and **B** of the net.

For a redundant net several minimal cut-sets exist. With all the possible minimal cut-sets known, the network failure probability is evaluated by means of the Ditlevsen bounds.

Progetto VIA - Microsoft Internet Explorer

Indirizzo <http://localhost/via/>

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 e-mail: diet@unipv.it

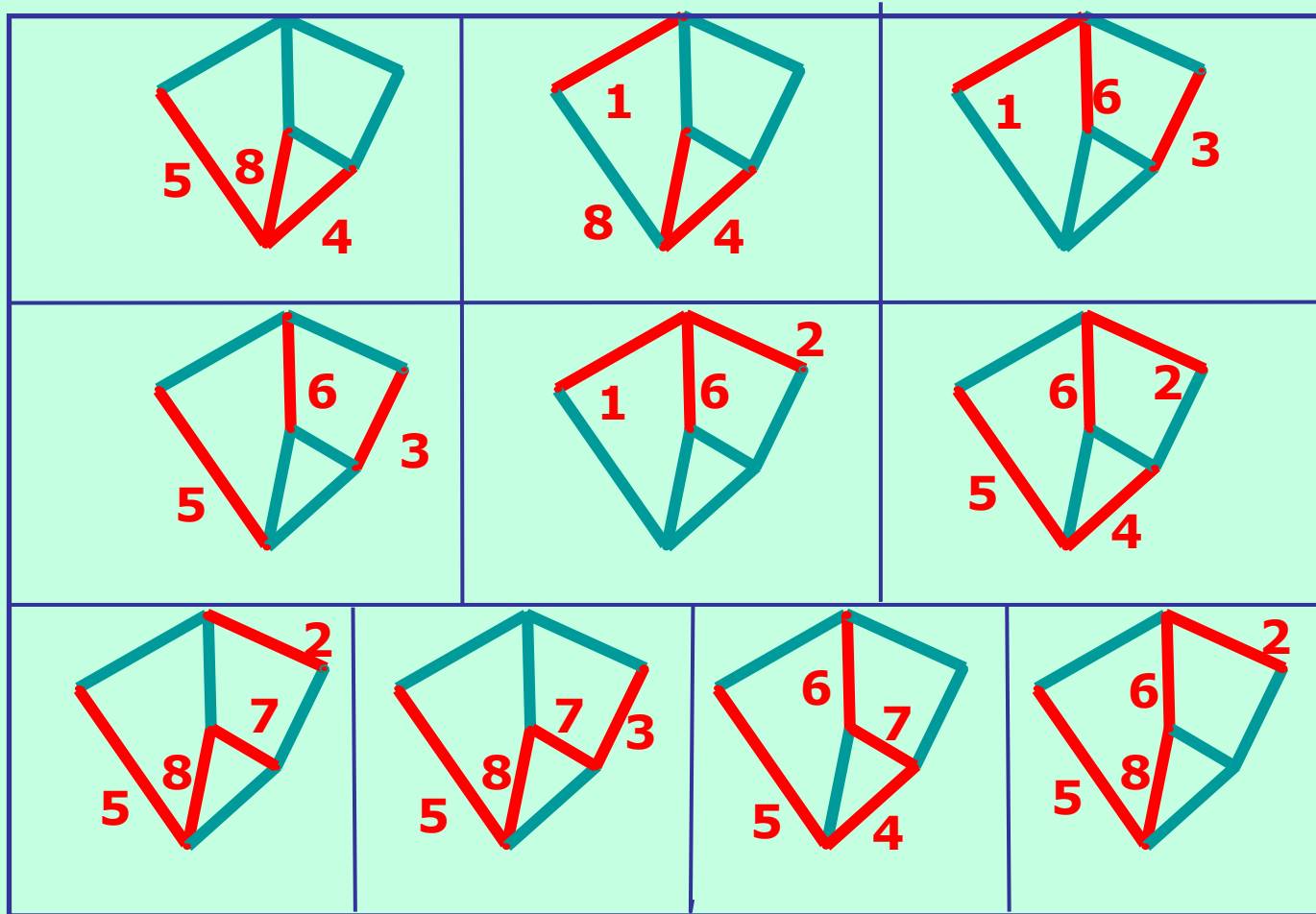
Selection of the minimal cut sets

tratto4
 tratto5
 tratto6
 cities
 area_test
 campania_gauss

redraw

Cut set 0		Pf 0.3735409919999999	
Tronco 1		Pf 0.7408	
Ponte 3		Pf 0.28	
Ponte 4		Pf 0.4	
Ponte 5		Pf 0.4	

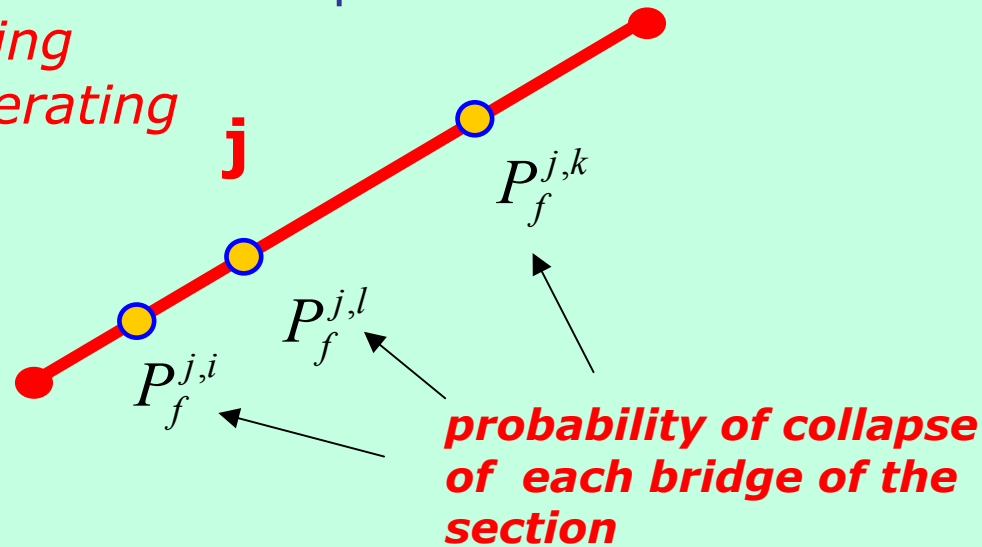
Intranet locale



The Minimal Cut Sets for the given net

For each section two possibilities are assumed:

- *operating*
- *not operating*



$$P_f^j = 1 - \prod_{k=1}^{n_{el}} (1 - P_f^{j,k})$$

Probability of *non functioning* situation of the section **j**

$$P_f^{cut_i} = \prod_{j=\{\text{tronchi} \in \text{cut}_i\}} P_f^j$$

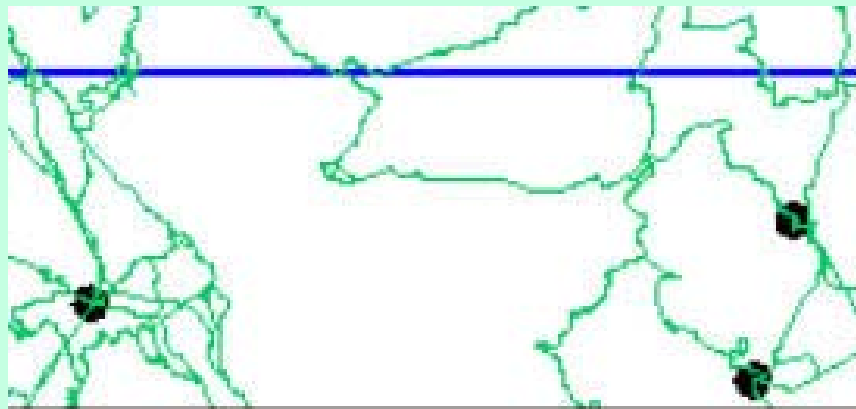
Non operating probability of the cut set j

$$P_f^{cut_{(m,n)}} = \prod_{j=\left[\{\text{tronchi} \in \text{cut}_i\} \cup \{\text{tronchi} \in \text{cut}_i\}\right]} P_f^j$$

Non operating probability of the cut sets m and n

$$P_f^{cut_1} + \sum_{m=2}^{n_{cut}} \max\left(P_f^{cut_m} - \sum_{n=1}^{m-1} P_f^{cut_{mn}}, 0\right) \leq P_f^{rete} \leq P_f^{cut_1} + \sum_{m=2}^{n_{cut}} \left(P_f^{cut_m} - \max_{n < m} P_f^{cut_{mn}}\right)$$

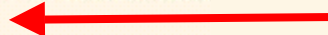
Lower and upper bound probability of the net



- area_test
- campania_gauss

redraw

Limite inferiore P collasso 0.32
Limite superiore P collasso 0.86



http://geomatica.unipv.it/galetto/earthquake_galetto.pdf



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