CONFERENZA DELLE REGIONI
E DELLE PROVINCE AUTONOME

PROTEZIONE CIVILE
Presidenza del Consiglio dei Ministri
Dipartimento della Protezione Civile

SEISMIC MICROZONATION

LAND USE GUIDELINES FOR AREAS WITH ACTIVE AND CAPABLE FAULTS (ACF)

VERSION 1.0

Conference of the Regions
and Autonomous Provinces of Italy

Presidency of the Council of Ministers
of the Italian Republic

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Technical Commission on Seismic Microzonation
(article 5, comma 7, OPCM 13 November 2010, n. 3907)
Graphic and Data Archiving Standards

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Land Use Guidelines for Areas with Active and Capable Faults (ACF)

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Edited by
Fabrizio Bramerini (CPD, Civil Protection Department), Sergio Castenetto (CPD, Civil Protection Department), Margherita Giuffrè (CNR-IGAG , Italian National Research Council), Giuseppe Naso (CPD, Civil Protection Department), Edoardo Peronace (CNR-IGAG , Italian National Research Council).

Working Group
Paolo Boncio (University of Chieti-Pescara), Giacomina Di Salvo (CNR-IGAG), Mauro Dolce (Civil Protection Department), Valter Fabietti (University of Chieti-Pescara), Paolo Galli (Civil Protection Department), Maria Ioannilli (University of Rome – Tor Vergata), Gaetano Manfredi (University of Naples – Federico II), Claudio Modena (University of Padua), Massimo Olivieri (University of Rome – La Sapienza), Gabriele Scarascia Mugnozza (University of Rome – La Sapienza).

Developed by the Technical Commission on Seismic Microzonation, nominated with DPCM 21 April 2011
Mauro Dolce (CPD, President), Fabrizio Bramerini (CPD), Giovanni Calcagni (National Council of Geologists), Umberto Capriglione (Unified Conference), Sergio Castenetto (CPD, technical secretary), Marco Iachetta (UNCEM), Giuseppe Ianniello (Ministry of Infrastructure and Transport), Luigi Cotzia (National Council of Architects, Planners, Landscape Architects and Conservators), Luca Martelli (Unified Conference), Ruggero Moretti (National Board of Surveyors), Giuseppe Naso (CPD), Luca Odevaine (UPI), Antonio Ragonesi (ANCI), Fabio Sabetta (CPD), Raffaele Solustri (National Council of Engineers), Elena Speranza (CPD).

Representative of the Regions and Autonomous Provinces
Fernando Calamita (Abruzzo), Rocco Onorati (Basilicata), Giuseppe Iiritano (Calabria), Fiorella Galluccio (Campania), Luca Martelli (Emilia-Romagna), Claudio Garlatti (Friuli-Venezia-Giulia), Antonio Colombi (Lazio), Daniele Bottero (Liguria), Francesca De Cesare (Lombardy), Pierpaolo Tiberi (The Marche), Rossella Monaco (Molise), Vittorio Giraud (Piedmont), Angelo Lobefaro (Apulia), Andrea Motti (Umbria), Massimo Baglione (Tuscany), Massimo Broccolato (Valle d'Aosta), Enrico Schiavon (Veneto), Giovanni Spampinato (Sicily), Saverio Cocco (Autonomous Province of Trento), Claudio Carrara (Autonomous Province of Bolzano).

The following also contributed to the work of the Technical Commission
Giuliano Basso (Veneto region), Paolo Cappadona (National Council of Geologists), Marina Credali (Lombardy), Silvio De Andrea (Lombardy), Eugenio Di Loreto (National Council of Geologists), Giacomo Di Pasquale (CPD), Raffaela Giraldi (Calabria), Sebastiano Gissara (ANCI), Salvatore La Mendola (National Council of Architects, Planners, Landscape Architects and Conservators), Norman Natali (Umbria), Isabella Trulli (Apulia), Giuseppe Zia (National Council of Engineers).

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Technical Support Group
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Technical coordination of the Inter-Regional Government Commission on Infrastructure, Mobility and Territorial – Housing and Urban Planning Sector
Anna Abate (Coordinator – Basilicata), Virna Bussadori (Autonomous Province of Bolzano), Roberto Gabrielli (Emilia-Romagna), Giuliana De Vito, Marina Aiello (Lazio), Cinzia Gandolfi (Tuscany), Evelina Stefani (Autonomous Province of Trento), Chantal Treves (Valle D'Aosta), Claudio Perin (Veneto)

Art Director
Maurilio Silvestri

Design and Desktop Publishing
Claudia Illuzzi

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PREFACE

In the Guidelines for Seismic Microzonation (GSM; Gruppo di Lavoro MS, 2008; English version: SM Working Group, 2015), the hazard of surface faults was discussed in the **Technical Files** where, for the first time in Italy, a respect zone of 15+15 m was forecast in the case of certain active and capable faults, and 75+75 m for an uncertain fault. The file provides indications relative to surface faulting and defines a fault as "active" when it demonstrates evidence of at least one activation in the last 40 ka. Paleoseismologic analyses are recommended to determine its geometric and seismogenic behaviour. Most notably, the material includes no examination of planning limitations to be introduced in areas affected by surface ruptures.

Following the L'Aquila earthquake of 2009, an active and capable fault (Paganica fault) affected a portion of the territory occupied by various elements (buildings, roads, *lifelines*, etc.), encouraging the Abruzzo Regional Government to ask the Italian Civil Protection Department (CPD) to work together to define criteria for managing areas in proximity to this fault. The CPD began constituting a Task Force composed of different experts (geologists, structural engineers and architects-planners) to deal with the problem in general terms and define guidelines for managing hazards associated with surface faulting for the purpose of Seismic Microzonation. This document represents the synthesis of their work, structured in the form of operative guidelines for use by territorial administrators and planners.

The guidelines deal exclusively with physical phenomena related to surface rupturing, omitting other hazards closely related to active faults, including dynamic near fault effects, for example.

The guidelines pursue the general objectives of:

- defining a procedure for gathering accurate information on risks deriving from the presence of active and capable faults;
- risk mitigation planning in the presence of active and capable faults for areas with plans for development and for developed areas;
- defining general criteria and operating procedures, in coordination with State, Regional and Local Entities.

The document is composed of two parts.

PART ONE defines the physical phenomena of active and capable faults and/or potentially active and capable faults and describes an operative technical procedure for establishing the shape and dimensions of fault zones.

In particular, Part One of the document takes into account the following general principles:

- avoiding the indication of active and capable faults (ACF) in SM studies when not sufficiently supported by robust and scientific data;
- linking the identification of ACF to the typology and quality of geological investigations carried out;
- defining the level of uncertainty of results, to be taken into account in the classification of ACF;
- schematically representing the geometry of areas of surface rupture and deformation;
- standardising procedures for the construction of ACF zones;

- stringently linking the identification and description of ACF to the levels of study of the GSM (SM Working Group, 2015)

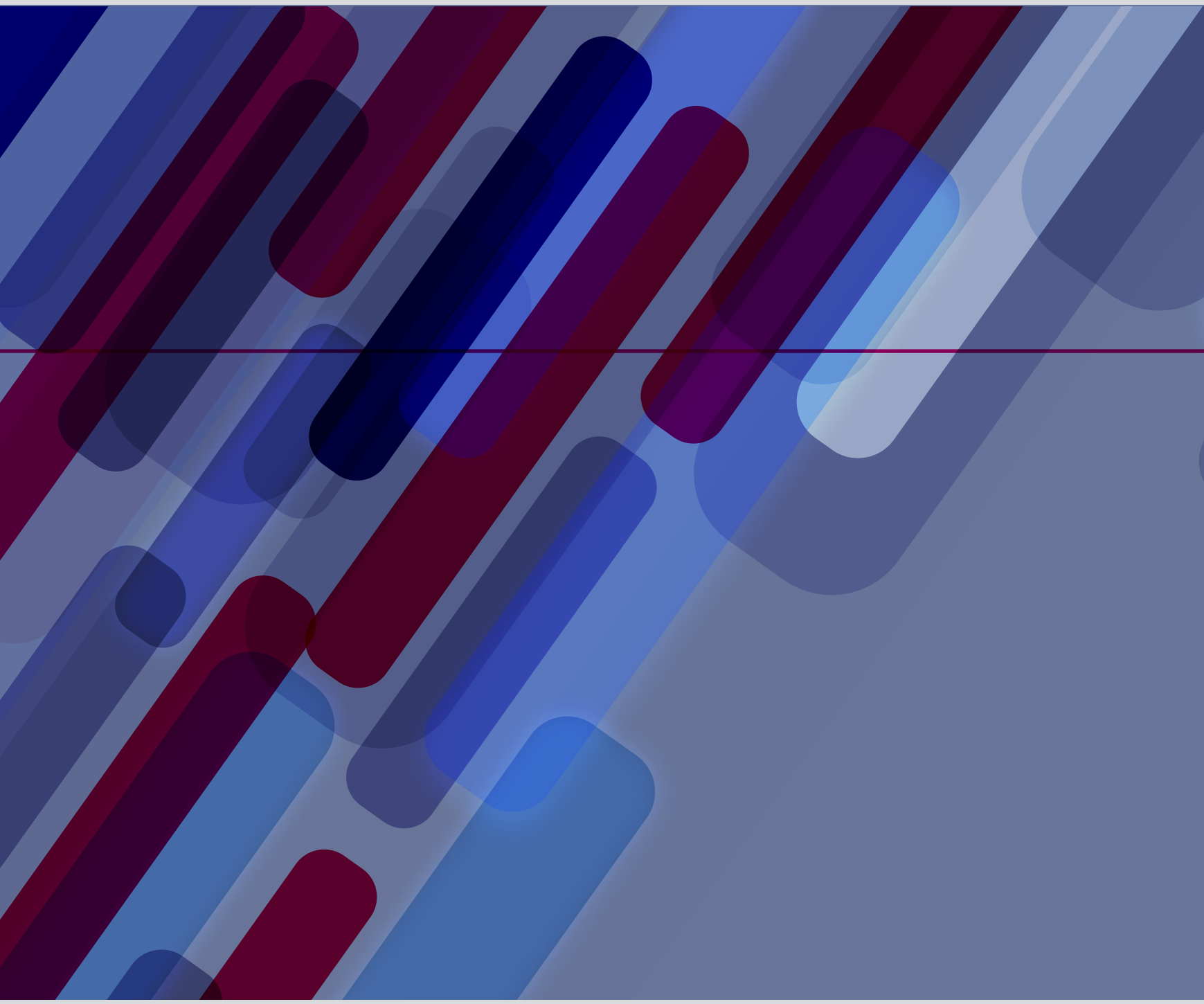
It must also be noted that data referred to recurrence times of active and capable faults, even when available, has not been utilised for their classification.

PART TWO covers land uses in areas with active and capable faults, in relation to urban planning and building/construction classes. This section concludes with a brief description of the roles played by public institutions in this process.

The Appendixes provide a selction data complementary to the text and relevant examples; for information on how data was depicted and recorded, please see the Graphic and Data Archiving Standards, version 4.0b (http://www.protezionecivile.gov.it/resources/cms/documents/StandardMS_4_0b.pdf).

These guidelines constitute an integration and closer examination of the GSM (SM Working Group, 2015), and are made available to the Regions and Autonomous Provinces so that they can be used as an operational tool to define the prescribed level.

The Regions may adapt the urban planning terminology (areas, city planning categories, minimum units of intervention, etc.) adopted in these guidelines to those used in their own urban planning instruments and, depending on available financial resources, define the time required for in-depth analyses of their own geology at level 3 SM studies. Local authorities may distinguish mitigation objectives based on specific relative conditions of risk.



A DESCRIPTION OF THE PHYSICAL PHENOMENON AND ACTIVE AND CAPABLE FAULT ZONES

Part I

1 GENERAL TERMINOLOGY

This section contains definitions of selected terms related to the physical phenomenon of active and capable faults.

- **Active Fault, Capable of Rupturing the Topographic Surface (ACF)**

  In accordance with the GSM (SM Working Group, 2015), a fault is considered **active** if it has been active at least once in the last 40 ka (upper part of the Late Pleistocene-Holocene). An active fault is considered **capable** when it reaches the topographic surface, producing a fracture/dislocation of the ground-level. This definition refers to the rupture on the main fault plain (on which there is the greatest dislocation).

- ***Hanging Wall (HW) and Footwall (FW) of an Active and Capable Fault***

  In normal and reverse faults, the *hanging wall* is the block standing above the fault plain. The footwall is the block below the fault plain (Fig. A1). In 'pure' strike-slip faults the *hanging wall* and *footwall* have not been detected.

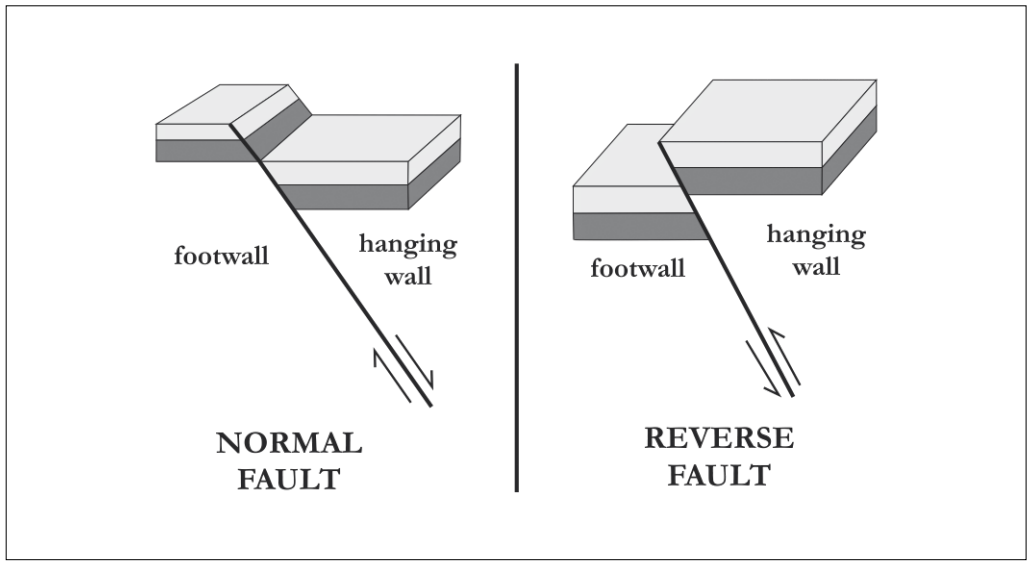


Figure A1 → **Examples of a *hanging wall* and *footwall*.**

- **Potentially Active and Capable Faults (PACF)**

  A fault for which studies demonstrate an involvement of sediments from the Middle-Late Pleistocene, but not necessarily of deposits more recent than 40 ka.

- **Transfer Zone**

  An area in which the trace of a fault disappears only to reappear in an adjacent area. Transfer zones may also contain fragile and ductile secondary deformations of deposits accommodating, as a whole, a transfer of the deformation between the two main fault zones (ex. among two *en-echelon* fault segments).

- **Surface evidence of an active and capable fault**

  The intersection between the active and capable fault and the topographical surface.

- **Coseismic phenomena linked to surface faulting**

  Permanent topographic deformations accompanying the main surface of rupture: secondary faults, fractures, folds, bulges, differential dislocations of the sediments along the line of rupture, etc.

2 CLASSIFICATION OF ACTIVE AND CAPABLE FAULTS (ACF)

ACFs can be classified in two categories depending on the uncertainties tied to their identification (Table A1):

CATEGORY (ACF_x)[1]	DEFINITION OF THE ACF_x	EXPLANATORY NOTES
ACF_a	Certain and Defined	The main surface of rupture and related coseismic phenomena related are recognised as certain. This category includes secondary tectonic structures and transfer areas between distinct segments of an ACF.
ACF_b	Uncertain	The elements comprising an ACF and related coseismic phenomena cannot be mapped with certainty and/or in detail due to the absence of data or because they cannot be identified (transfer zones, gap, erosion, sedimentary cover, etc.)

Table A1 → **Descriptive categories of active and capable faults and coseismic phenomena (ACF_x).**

It should be noted that the same active and capable fault can have differential segments classified as ACF_a and ACF_b.

The identification of the ACF category will be possible following investigations specific to each level of knowledge and of SM described in the following chapter.

3 POTENTIALLY ACTIVE AND CAPABLE FAULTS (PACF)

Potentially Active and Capable Faults (PACF) will be represented on the Geo-Technical Map of Seismic Microzonation (GTM_SM; see, Standard of Representation and Computer Archiving, version 4.0b).

For these faults, identified with the aid of scientific literature or during field surveys for the GTM_SM mapping, no zoning is expected on the level 1 SM map.

In level 3 SM studies, such faults will be studied with appropriate investigations in order to identify any activity in the last 40 ka, as well as to precisely define their geometry.

1 The generic category of an ACF is indicated as ACF_x.

4 ACTIVE AND CAPABLE FAULT ZONES

When at least two of the **preliminary conditions** cited below are verified, it is necessary to conduct a detailed study (i.e. aerophotogeological interpretation, land survey, geophysical analysis, paleoseismologic analyses) with the purpose of identifying any surface traces of an active and capable fault.

The preliminary conditions required to follow a detailed study on ACFs are:

- the area subject to SM studies falls within an epicentral area of historical earthquakes with Mw >5.5 (cf. CPT11, 2011; a maximum indication may also be provided by the national seismic classification of the study area; http://www.protezionecivile.gov.it/jcms/en/classificazione.wp?request_locale=en);
- scientific literature indicates the presence of faults involving Late Pleistocene-Holocene sediments;
- evidence of recent fault activity discovered on the geological field is reported during geological surveying for GTM_SM maps.

Generally, the elements indicative of recent fault activity are geomorphological (anomalies in the shape of landscape, diversion of stream or other linear elements, fault scarps) or, obviously, tectonic (faults that displace Late Pleistocene-Holocene sediments). Once the trend of the surface fault is identified, it is necessary to employ a paleoseismologic approach to ascertain recent activity and define the plano-altimetric trace of the fault.

This consists in the excavation of serial trenches through the fault which allow for an analytical study of the faulted deposits, a scanning of the faulting events and the amount of displacement. Dating of the deposits must be conducted through chronometric (generally radiometric) and/or, if necessary, archaeological dating. Dating of faulted levels and of those which eventually seal off the deformation, is essential to ensure fault activity. If the fault is sealed off by deposits older than 40 ka, the fault is likely considered inactive or, in any case, low risk (unless it does not interfere with elements of intrinsic high risk, such as nuclear power plants or important industrial facilities).

Paleoseismologic analyses may be preceded and followed by geognostic analyses and geophysical surveys. For example, Electrical Resistivity Tomography (ERT) is a useful tool for tracing a surface fault with precision, and also for identifying suitable sites for excavation of paleoseismologic trenches.

Based on these elements, the following procedure for the study of active and capable faults in the SM study level context (SM Working Group, 2015) is suggested.

4.1 Attention Zone (AZ_{ACF} at Level 1)

A homogenous microzone (Level 1; SM Working Group, 2015) of ACFs is constructed to contain the **supposed** trace of the main surface of rupture and **probable** surface deformation phenomenon related to the main surface of rupture.

This zone is termed **AZ_{ACF} (Attention Zone)** and will mandatorily refer to specific analyses at Level 3 (SM Working Group, 2015).

The **minimum informative elements** considered for the identification of an **AZ_{ACF}** at Level 1 consists of:

- reports and geological studies made by specialists and reported in scientific literature, though not sufficiently analysed (for example, in terms of the scale of representation of the information) to be classified as "specific informative elements" (paragraph 4.2)
- geological and/or geomorphological elements detected in the field by geologists during geological surveying for the GTM_SM maps. Such elements, however, must be validated by experts in the filed of active tectonics.

At least one of the minimum informative elements is necessary to identify an AZ_{ACF}.

4.2 Susceptibility Zone and Respect Zone (SZ_{ACF} and RZ_{ACF} at Level 3)

The homogeneous microzones (Level 3; SM Working Group, 2015) of ACFs can be of two types:

1. **Susceptibility Zone of an ACF_x (SZ_{ACF})**

   Areas showing traces of the main surface rupture of an active and capable fault and other possible secondary tectonic structures associated with the main surface rupture, as well as transfer zones among distinct segments of fault.

   It should be specified that this zone must be defined for those active and capable faults in which the available information, both previous and specifically acquired, does not allow for the conclusive definition of the main segment of the fault and the secondary elements associated with it.

   SZ_{ACF} will be traced for ACF_a and ACF_b.

   The area can be asymmetrical with respect to the trace (*footwall* and *hanging wall* of the fault; see Chap. 5).

2. **Respect Zone of an ACF_x (RZ_{ACF})**

   The area identified around the segment of the main surface rupture of the active and capable fault, accurately identified; the RZ_{ACF} can be traced exclusively for the ACF_a.

   The area may be asymmetrical with respect to the trace (*footwall* and *hanging wall* of the fault; see Chap. 5).

   The RZ_{ACF} is contained in the SZ_{ACF}, though there is no overlap between the two zones.

   Dimensioning criteria are illustrated in Chapter 5.

The collection of **specific informative elements** for the identification of an ACF_x at Level 3 (SM Working Group, 2015) pursues the following objectives:

- evaluating how recent its activity is. At this level of study for potentially active and capable faults (Chapter 3), the necessary investigations must serve to define the upper chronological interval to their activity (paleoseismologic investigations and faulted sediments dating);
- to locate *de visu* (directly in the trenches and/or in a geophysical profile) the surface trace of the active and capable fault;
- to define the maximum dislocation expected on the surface[2], the expected magnitude and the recurrence time of the fault;

2 The value of maximum dislocation expected on the surface (DISL), defined by paleoseismic studies, must be inserted into the database as reported in the Graphic and Data Archiving Standards Version 4.0.

- to establish the geometry of the ACF_x, highlighting any different approaches in the event it operates in post-event conditions with reference, for example, to systems for monitoring shifting/differential settlement.

The initial assumption, which is essential, is that future ruptures will occur along pre-existing ACFs. Four groups of surveys necessary for this level of analysis have been defined (Table A2). These investigations follow a temporal sequence during the studies. These groups of investigation are of increasing significance, passing from the first to the fourth group. Ideally, the complete sequence provides a more detailed framework of the geological, structural and geometrical arrangement of the ACF_x. It is indispensable to carry out the investigations of the Ind_4 group for potentially active and capable faults.

ID	INVESTIGATIVE GROUP	INVESTIGATIONS
Ind_1	Aerophotogrammetry Analyses	Aerial photographs, orthophotos, LiDAR images, satellite images
Ind_2	Geological and Geomorphological Surveys	Field surveys and related cartography
Ind_3	Geophysical and Geognostic Investigations	ERT, reflection and refraction seismology, GPR, borehole and trench
Ind_4	Paleoseismology	Paleoseismologic trenches and chronometric datings of faulted sediments

Table A2 → **Surveys for the Study of an ACF, Grouped by Typology and Importance (Group Ind_4 = Maximum importance).**

Appendix A1 presents two examples (respectively for Level 1 SM and Level 3) of the contents of the reports, elaborations and results of investigations related to the study of active and capable faults. Based on the survey results reported above, it is possible to define the ACF_x in detail and associate it with one of the two descriptive categories provided in Table A1.

5 ZONE DIMENSIONS

Active and capable faults, associated deformations and zones must be mapped at a scale not inferior to 1:5000.

The AZ_{ACF} are polygons represented on SM1 maps.

The RZ_{ACF} and SZ_{ACF} are polygons represented on SM3 maps.

The specifics of storage and representation are reported in the Graphic and Data Archiving Standards 4.0b.

An example of the procedure for the geometric construction of a zone is reported in Appendix A2.

Dimensioning of the zones is based on three cognitive elements of general reference described in detail in Appendix A3:

- detailed description of physical phenomena;
- scientific literature, with reference to physical phenomena;
- foreign regulations.

The following is a description of the procedure for sizing the zones **(Fig. A2)**.

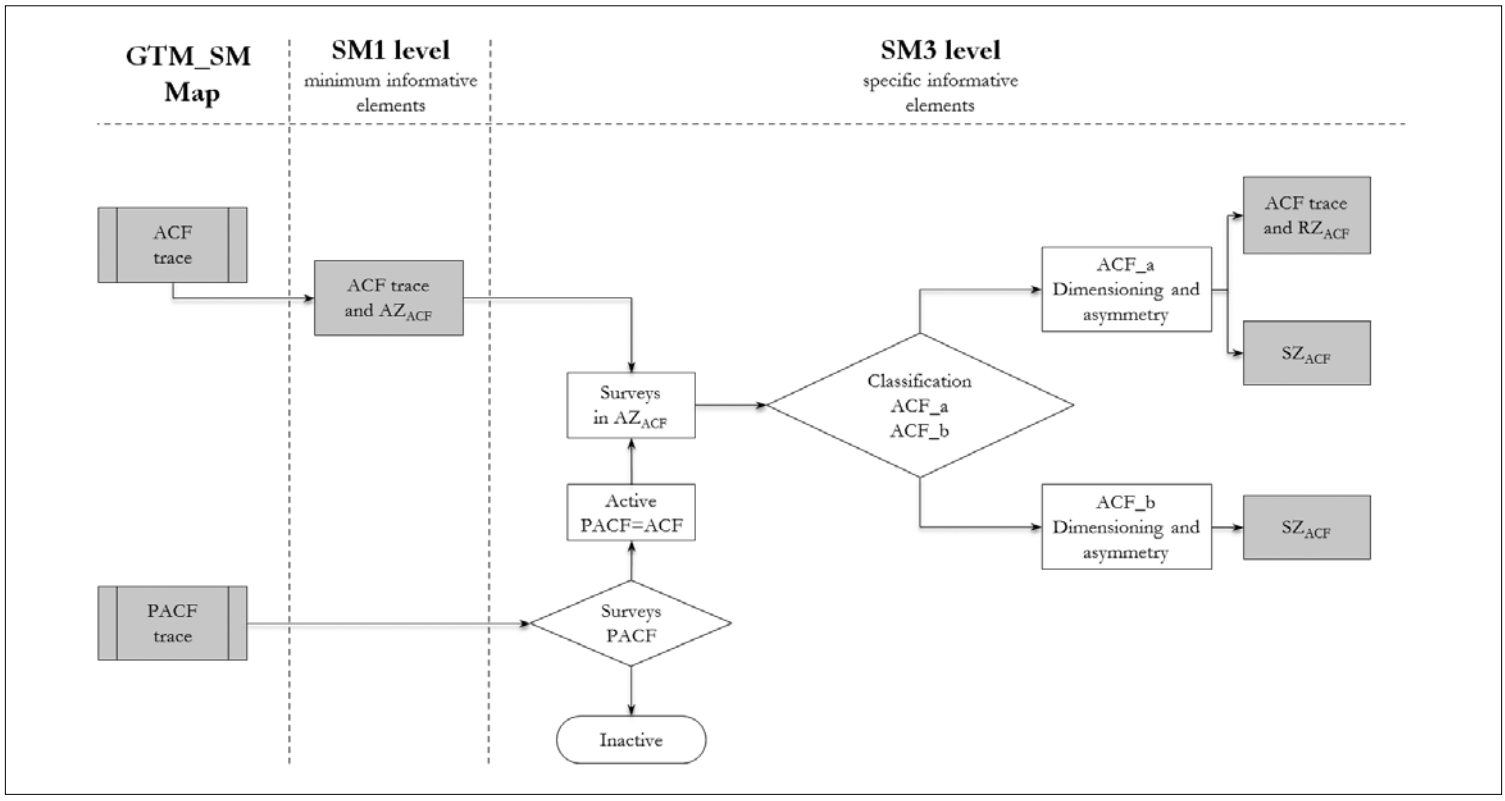


Figure A2 → Procedure for dimensioning fault zones at different levels of analysis of SM studies.

1 AZ_{ACF} (Level 1 SM)

The Attention Zone (AZ_{ACF}) is constructed on the basis of minimum informative elements (paragraph 4.1) and therefore its size must account for a greater degree of uncertainty.

The AZ_{ACF} has a recommended dimension of 400 m (200 + 200 m), straddling the trace of the main surface rupture of the active and capable fault. A smaller amplitude of such a zone is discouraged, unless clear and documented geological evidence justifies a different perimeter. The definition of this zone must refer to in-depth analyses with the acquisition of specific informative elements at Level 3 (SM Working Group, 2015).

2 SZ_{ACF} (Level 3 SM)

The Susceptibility Zone (SZ_{ACF}) must be identified for all types of ACF_x (ACF_a and ACF_b).

The following is a summary of the procedure:

a. Define the category of complexity of the ACF_x **(Table A1)**;

b. In the case of ACF_a, a 160-meter wide SZ_{ACF} straddling the main rupture surface and transfer zones among distinct segments of the fault is recommended. In the case of ACF_b, a 300-meter wide SZ_{ACF} straddling the main supposed surface of rupture and the supposed transfer zones;

i. With regards to the transfer zones between distinct segments of a certain fault (ACF_a), only when fragile and /or ductile deformations (certain transfer zones) are identified and mapped with certainty, will it be possible to define an SZ_{ACF} of 160 m from the perimeter of the envelope of such deformations;

ii. With regards to the transfer zones between distinct segments of an uncertain fault or between a certain segment (ACF_a) and an uncertain one (ACF_b), an SZ_{ACF} can be defined by graphically connecting the widest zones (uncertain) with those of a lesser width (certain) wherever present;

c. Depending on the type (level of significance of the investigations in **Table A2**), number and location on the ground (with respect to the fault trace) of the investigations made during the course of level 3 SM studies, the SZ_{ACF} can be reduced with respect to the recommended dimensions defined above to a minimum acceptable value of 160 m in the case of ACF_b and equal to 0 in the case of ACF_a;

d. Define the possible asymmetry of the SZ_{ACF} **(Table A3)**.

The SZ_{ACF} may be asymmetric with respect to the main surface of rupture of the active and capable fault, or rather the SZ_{ACF} can "cover" FW and HW in a differentiated way. Standard values of the relationship between the FW and HW areas of the zone are reported in **Table A3**.

3. RZ_{ACF} (Level 3 SM)

FAULT TYPE	FW:HW RATIO
Normal fault	1:4
Reverse fault	1:2
Strike-Slip fault	1:1

Table A3 → Indicative ratio between FW and HW areas in the case of asymmetry of the SZ_{ACF}.

A 30-meter wide Respect Zone (RZ_{ACF}) is mandatory only for ACF_a straddling the main rupture surface.

The RZ_{ACF} can be contained in the SZ_{ACF}, though there is no overlap between the two zones.

The RZ_{ACF} can also be asymmetrical according to the same principles of the SZ_{ACF} **(Table A3)**.

A summary of the dimensions of the zones is reported in **Table A4**.

SM LEVEL	LEVEL 1 SM	LEVEL 3 SM		
CATEGORY (ACF_x)	AZ_{ACF}	$SZ_{ACF\ RACC}$	$SZ_{ACF\ MIN}$	RZ_{ACF}
ACF_a	400	160	0	30
ACF_b	400	300	160	n.d.

Table A4 → Recommended and minimum dimensions in meters for fault zones in the SM studies ($SZ_{ACF,RACC}$ = Recommended value; n.d. =not defined).

6 EXAMPLES OF ACTIVE AND CAPABLE FAULTS AND ASSOCIATED ZONES

Three examples are reported:

1. Identification of the AZ_{ACF} for an active and capable fault composed of two segments, one certain and the other supposed, in an Level 1 SM study (Fig. A3).

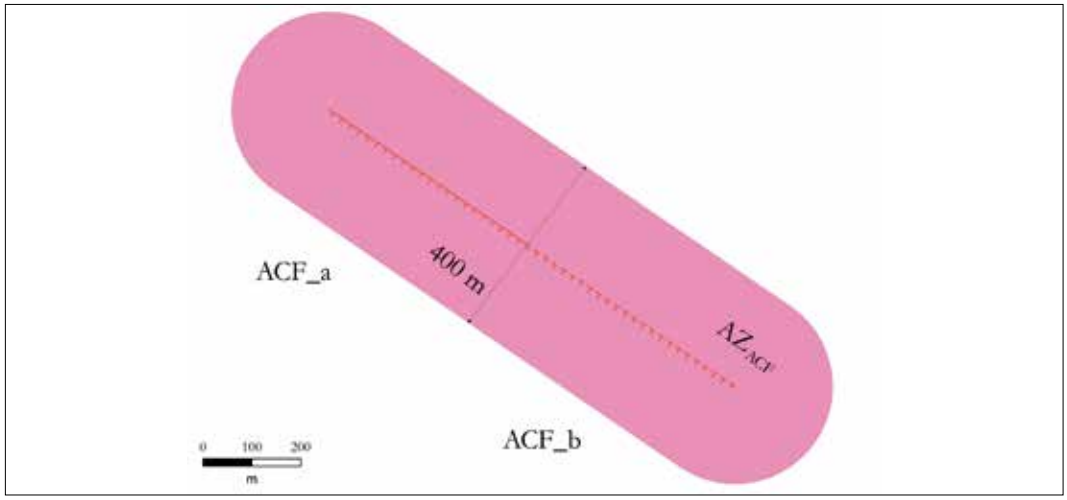


Figure A3 → **Example of an AZ_{ACF} in an Level 1 MS study (Map of Seismically Homogeneous Microzones) ($SZ_{ACF\ RACC}$= Recommended value; n.d. =not defined).**

SM LEVEL	LEVEL 1 SM	LEVEL 3 SM		
CATEGORY (ACF_x)	AZ_{ACF}	$SZ_{ACF\ RACC}$	$SZ_{ACF\ MIN}$	RZ_{ACF}
ACF_a	**400**	160	0	30
ACF_b	**400**	300	160	n.d.

2. Identification of an active and capable fault with normal kinematics. The fault is composed of two segments: the first is type ACF_a and the second ACF_b. The investigation carried out (Ind_1 and Ind_2 of Table A2) in a significant area around the fault allowed for the definition of a 30-meter wide RZ_{ACF} and a 100-meter wide SZ_{ACF} in segment ACF_a, and 200 m in segment ACF_b. It is important to note the asymmetry of the areas linked to the normal kinematics of the fault (ratio FW/HW= 1:4).

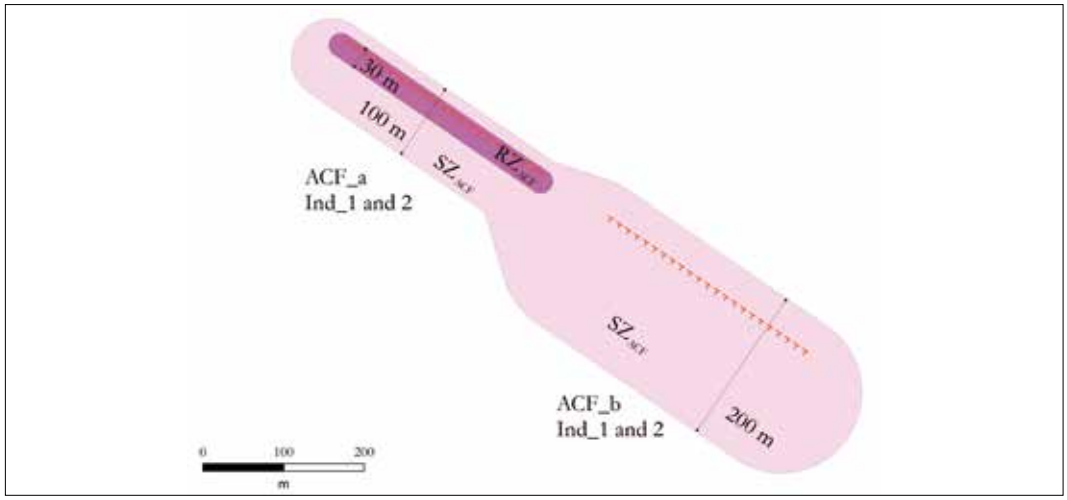


Figure A4 → Example of ACF_a and ACF_b, and related areas for a Level 3 of MS study with Ind_1 and 2 level investigations (SM map) ($SZ_{ACF\ RACC}$= Recommended value; n.d.= not defined).

SM LEVEL	LEVEL 1 SM	LEVEL 3 SM		
CATEGORY (ACF_x)	AZ_{ACF}	$SZ_{ACF\ RACC}$	$SZ_{ACF\ MIN}$	RZ_{ACF}
ACF_a	400	**160**	0	**30**
ACF_b	400	**300**	160	**n.d.**

TYPE OF FAULT	FW:HW RATIO
Normal fault	**1:4**
Inverse fault	1:2
Strike-slip fault	1:1

3 Identification of an active and capable fault with normal kinematics. The fault is composed of two segments: the first is type ACF_a and the second ACF_b. The transfer zone, in which minor elements (second order folds and fractures) have not been precisely identified, is type ACF_b.

The ACF_a was studied with the maximum significant level of investigation (Ind_1, Ind_2, Ind_3, and Ind_4 of Table A2). This allowed for the identification of a 30-meter wide asymmetrical RZ_{ACF} and the cancellation of the value of SZ_{ACF}. The remaining areas were investigated with Ind_1, Ind_2 and Ind_3 type surveys, which allowed for the definition of an asymmetrical SZ_{ACF} with a width of 160 m for the segment of the uncertain fault (ACF_b), which is graphically connected to the RZ_{ACF} so as to also include the transfer zone.

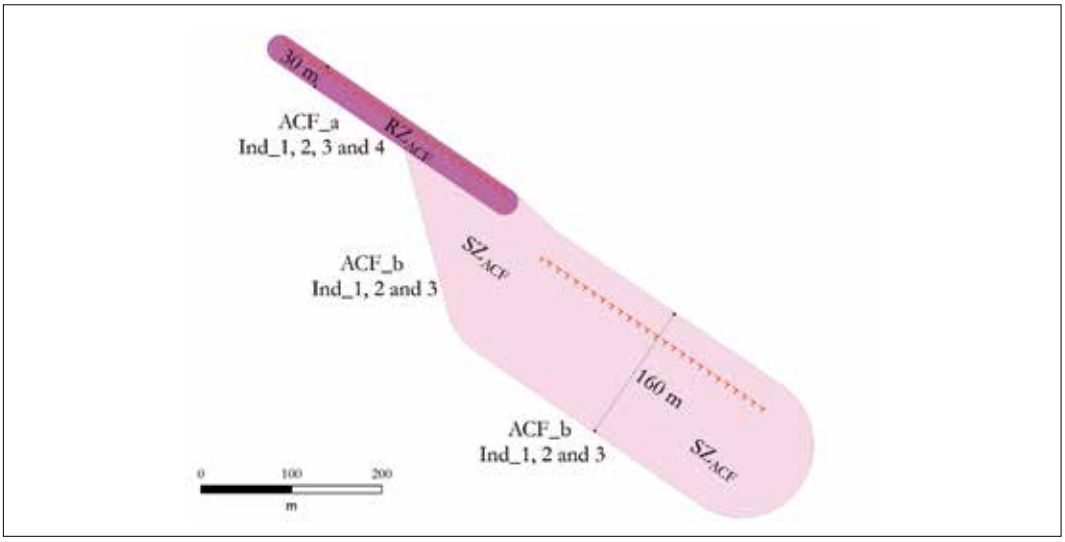
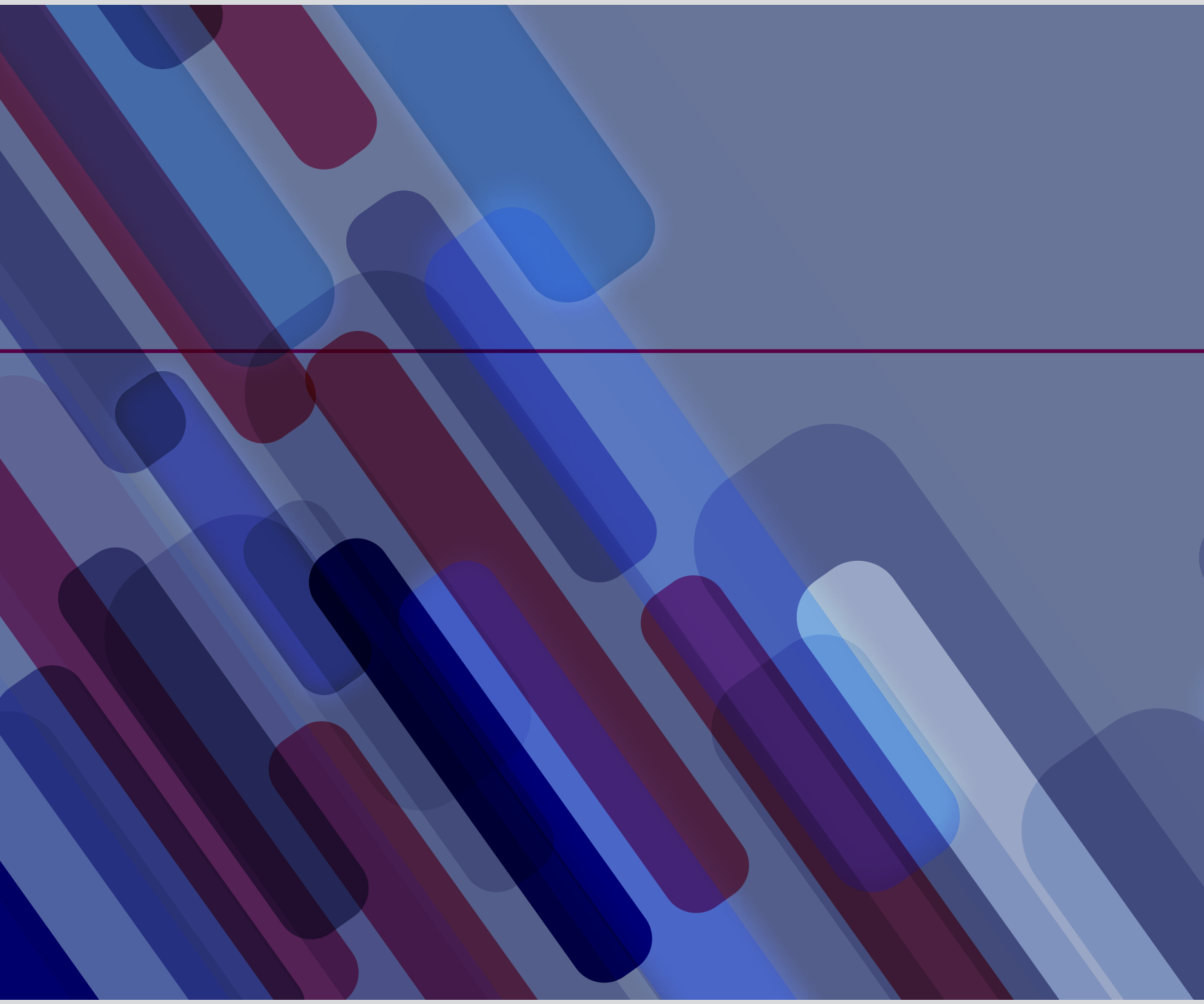


Figure A5 → **Example of ACF_a and ACF_b, and related areas for a Level 3 SM study (SM map) ($SZ_{ACF\ RACC}$= Recommended value; n.d.= not defined).**

SM LEVEL	LEVEL 1 SM	LEVEL 3 SM		
CATEGORY (ACF_x)	AZ_{ACF}	$SZ_{ACF\ RACC}$	$SZ_{ACF\ MIN}$	RZ_{ACF}
ACF_a	400	160	**0**	**30**
ACF_b	400	300	**160**	**n.d.**

TYPE OF FAULT	FW:HW RATIO
Normal fault	**1:4**
Inverse fault	1:2
Strike-slip fault	1:1



LAND USE PLANNING GUIDELINES FOR AREAS WITH ACTIVE AND CAPABLE FAULTS

PART II

7 CATEGORIES OF URBAN AREAS WITH ACTIVE AND CAPABLE FAULTS

The disciplines of urban and territorial planning, when working in areas affected by the presence of active and capable faults, are called upon to regulate land uses and urban transformation programs, taking into account the relationship between the risks of seismic activity and diverse contexts of settlement. SM studies at various levels of GSM are integrated with what is specified by the present guidelines in the context of urban planning instruments.

The definition of these guidelines refers conventionally to **three categories of urban areas**:

Developed Areas (recent or consolidated)

Undeveloped Areas (with plans for development)

Undeveloped Areas (with no Plans for Development)

Each of these three categories is defined by specific characteristics of settlement, infrastructure and use, whose relation with the presence of AZ_{ACF} , SZ_{ACF}, and RZ_{ACF} must be subjected to specific regulations. In particular, the three categories of urban areas may be defined as follows:

- **Developed Areas** (recent or consolidated)
  Urbanised and Developed Areas of varying levels of completion, consolidation and layering. They include historic centres, consolidated fabrics, areas of completion with residential , manufacturing, tertiary and mixed uses.
- **Undeveloped Areas (with plans for development)**
  Undeveloped Areas, partially Developed Areas or areas for planned new settlements – residential, manufacturing, tertiary or mixed use – of buildings, infrastructures and networks. These areas may be found in adjacency to settled areas, or in still un–urbanised contexts.
- **Undeveloped Areas (with no Plans for Development)**
  Unbuildable areas, or areas with limits on development due to use (agricultural lands).

These three categories must be related to the forecasts contained in applicable urban planning instruments and to their actual implementation. With regards to specific content and structure of planning regulations in these areas, each Region will be able to plan suitable matches between the three urban categories and the homogenous areas identified by their respective urban planning instruments[3].

3 An application is reported in Appendix 6. See also the legend on "homogenization" which has been applied in regulatory plans by some municipalities in Abruzzo following the 6 April 2009 earthquake, in: Working group SM-AQ, 2010. *Seismic Microzonation for the Reconstruction of the Aquilan Area*. Abruzzo Region – Civil Protection Department. L'Aquila, Part IV, p. 6 and Fig. 1.2.

8 LAND USE PLANNING GUIDELINES

The Land Use Planning Guidelines and forecasts for transformations in areas with active and capable faults are articulated according to **two types of indications**:

- **indications for urban planning**, when specific regulations are imposed by urban planning instruments, including categories of intervention and allowable uses[4] and methods of implementation;
- **indications for buildings**, referencing earthquake resistance regulations to define possible categories of intervention based on classes of use for existing and new buildings[5].

A table of different types of urban planning indications is proposed with reference to the three urban areas categories defined above and the fault zones in which they fall (Table B1). A column related to infrastructure is reported in the table as a distinct scope, which was not studied in depth here.
Appendix A7 presents a summary of classification.

URBAN PLANNING CATEGORIES		DEVELOPED AREAS (RECENT OR CONSOLIDATED)	UNDEVELOPED AREAS (WITH PLANS FOR DEVELOPMENT)	UNDEVELOPED AREAS (WITH NO PLANS FOR DEVELOPMENT)	INFRASTRUCTURES
Fault Zones	AZ_{ACF}	Obligation to in-depth analyses (8.1.1)	Obligation to in-depth analyses (8.2.1)		Infrastructures Program (8.3)
	SZ_{ACF}	Instability-prone Zones Program (8.1.2)	Limited Intervention (8.2.2)		
	RZ_{ACF}		Prohibited Intervention (8.2.3)		

Table B1 → **Urban Planning Indications.**

8.1 Developed Areas

8.1.1 Mandatory In-Depth Analysis (Developed Areas)

For AZ_{ACF}, in **Developed Areas (recent or consolidated)** for new buildings (on empty lots), the necessary geological investigations must be completed at Level 3 SM (paragraph 4.2 of PART ONE) to identify SZ_{ACF} and RZ_{ACF}. It is a prerogative of the Regions to define possible time limits, depending on available resources, for the completion of these investigations. The absence of in-depth analysis determines the following guideline:

4 Art. 10, comma 2, of the Unified Building Code (T.U. edilizia) (Presidential Decree n. 380/2001) entrusts regional governments with the responsibility for disciplining land uses and modifications via regional legislation. Land uses generally refer to the following categories: residential, industrial and craft-based production, commercial, tourism-hospitality, office space, agricultural.

5 Chapter 2, paragraph 2.4.2 of the NTC (Norme tecniche per le costruzioni, National Building Code) from 2008 lists the following Classes:
Class I: Constructions only occasionally occupied by people and agricultural buildings.
Class II: Constructions with normal occupancy levels that do not contain environmentally harmful material or essential public and social functions. Industries whose activities are not harmful to the environment. Bridges, infrastructures, mobility networks that do not belong to Class III or IV, railway networks whose interruption would not be cause for an emergency. Dams whose collapse would not provoke relevant consequences.
Class III: Constructions with significant occupancy levels. Industries whose activities are harmful to the environment. Extra-urban mobility networks that do not belong to Class IV. Bridges and railway networks whose interruption would be cause for an emergency situation. Dams whose collapse would provoke relevant consequences
Class IV: Constructions containing important public or strategic functions, also in relation to the management of civil protection functions in the event of calamities. Industries whose activities are particularly harmful to the environment. Type A or B mobility networks, as per Ministerial Decree n. 6792 from 5 November 2001, "Norme funzionali and geometriche per la costruzione delle strade" (Functional and Geometric Guidelines for Road Construction), and type C when they belong to routes connecting provincial capitals not served by roads classifiable as type A or B. Bridges and railway networks of critical importance to maintaining communication routes, in particular in the wake of an earthquake. Dams linked to the functioning of aqueducts and hydroelectric facilities.

Building	Intervention Type	Description
Existing	Limited	Excluding regular maintenance, all other types of intervention must provide seismic upgrading and/or retrofitting and/or local strengthening (conforming to current regulations).
New Construction	Prohibited	New construction is not permitted.

8.1.2 Instability-prone Zones Program

For SZ_{ACF} and RZ_{ACF} in **Developed Areas (recent or consolidated)**, within the scope of their own urban planning instruments and according to ordinances and directions of higher-level subjects,local authorities must identify and pursue one or more objectives of the **Instability-prone Zones Program (IZP)**, assuming the contents in their appropriate form to mitigate conditions of risk. The IZP is a complex program of interventions that defines objectives and areas of intervention, together with feasibility and implementation procedures. The IZP concerns all areas susceptible to instability in general, including those also affected by ACFs. Appendix A5 contains a Program outline that can also be used as a checklist of the topics covered. The following guidelines are applicable in the absence of an IZP:

Building	Intervention Type	Description
Existing	Limited	Excluding regular maintenance, all other types of intervention must provide seismic upgrading and/or retrofitting and/or local strengthening (conforming to current regulations).
New Construction	Prohibited	New construction is not permitted.

8.1.2.1 IZP Objective Choice I

The definition of a specific IZP implies the choice of one of the following objectives, differentiated as a function of SZ_{ACF} and RZ_{ACF}:

- Limited Intervention (Objective 1)
- Mandatory or Limited Intervention (Objective 2)
- Mandatory or Prohibited Intervention (Objective 3)
- Prohibited Intervention (Objective 4)

The respective guidelines for each of these objectives are listed below.

8.1.2.1.1 – FIRST HYPOTHESIS: Limited Intervention (Objective 1)

The choice of this objective determines the following guideline:

Building	Intervention Type	Description
Existing	Limited	Excluding regular maintenance, all other types of intervention must provide seismic upgrading and/or retrofitting and/or local strengthening (conforming to current regulations).
New Construction	Limited	New construction is only permitted for Class I use.

8.1.2.1.2 – SECOND HYPOTHESIS: Mandatory or Limited Intervention (Objective 2)

The choice of this objective determines the following guideline:

Building	Intervention Type	Description
Existing	Mandatory	Relocation is not mandatory, but preferred. Excluding regular maintenance, all other types of intervention must provide seismic upgrading and/or retrofitting and/or local strengthening (conforming to current regulations).
New Construction	Limited	New construction is only permitted for Class I use.

8.1.2.1.3 – THIRD HYPOTHESIS: Mandatory or Prohibited Intervention (Objective 3)

The choice of this objective determines the following guideline:

Building	Intervention Type	Description
Existing	Mandatory	Relocation is not mandatory, but preferred. Mandatory interventions (as scheduled by Regional Governments): upgrading and/or seismic retrofitting and/or local strengthening (conforming to current regulations), independent of maintenance requests or other types of requests.
New Construction	Prohibited	New construction is not permitted.

8.1.2.1.4 – FOURTH HYPOTHESIS: Prohibited Intervention (Objective 4)

The choice of this objective determines the following guideline:

Building	Intervention Type	Description
Existing	Relocation	No interventions of any kind may be made to existing buildings as relocation is mandatory.
New Construction	Prohibited	New construction is not permitted.

For historical centres, alongside the above guidelines for Developed Areas (recent or consolidated), the opportunity to introduce a final implementation plan, which provides for interventions of conservation and reuse, compatible with the new conditions of risk occurred, must be evaluated during the arrangement of the IZP.

8.2 Undeveloped Areas

8.2.1 Mandatory In-Depth Analysis (Undeveloped Areas)

Undeveloped Areas (with or without plans for development) located in AZ_{ACF} are governed by a regime of total limitation of any form of development until such time as the studies necessary to identify SZ_{ACF} and RZ_{ACF} have been completed.

Admissible actions in these areas include the design of open spaces, without buildings, serving the functions and activities of adjacent settled and urbanised areas or designed to increase the offering of urban parks, public spaces and private landscaping.

Therefore, the absence of in-depth analysis determines the following guideline:

Building	Intervention Type	Description
Existing	Limited	Excluding regular maintenance, all other types of intervention must provide seismic upgrades and/or retrofitting and/or local strengthening (conforming to current regulations).
New Construction	Prohibited	New construction is not permitted.

8.2.2 Limited Intervention

Undeveloped Areas (with or without plans for development) located in SZ_{ACF} are subject to the following guideline:

Building	Intervention Type	Description
Existing	Mandatory	Relocation is not mandatory, but preferred. Mandatory interventions (as scheduled by Regional Governments): seismic upgrading and/or retrofitting and/or local strengthening (conforming to current regulations), independent of maintenance requests or other types of requests.
New Construction	Limited	New construction is only permitted for Class I use.

8.2.3 Prohibited Intervention

Undeveloped Areas (with or without plans for development) located in RZ_{ACF} admissible actions are the design of open spaces, without construction, serving the functions and activities of adjacent settled and urbanised areas or designed to increase the offering of urban parks, public spaces and private landscaping.

The following guideline is applied:

Building	Intervention Type	Description
Existing	Mandatory	Relocation is not mandatory, but preferred. Mandatory interventions (as scheduled by Regional Governments): seismic upgrading and/or retrofitting and/or local strengthening (conforming to current regulations), independent of maintenance requests or other types of requests.
New Construction	Prohibited	New construction is not permitted.

8.3 Infrastructure Program

Infrastructures, works connected to infrastructural systems and, more in general, planned lifelines must be relocated. If pre-existing or impossible to relocate, a specific program must be developed beforehand, eventually as part of the **Instability-prone Zones Program**. They are subject to inspections, specific investigations and interventions with the purpose of minimising risk.

9 GUIDELINES FOR POST-EARTHQUAKE RECONSTRUCTION AREAS

In a post-earthquake reconstruction area, the more onerous condition of damaged structures and the necessity to provide plans and regulations specific to the entire area subject to seismic activity, must be added to the previously described guidelines.

Therefore, the first of the previous categories of urban areas (Developed Areas – recent or consolidated) must be integrated with a classification of buildings (minimum unit of intervention) based on levels of damage and vulnerability. A condensed outline of this classification can be found in Appendix 7.

9.1 Developed Areas

9.1.1 Mandatory In-Depth Analysis (Developed Areas)

In **Developed Areas (recent or consolidated)**, in the case of AZ_{ACF}, the following guidelines are defined for reconstruction or restoration in the absence of in-depth analysis:

Building	Intervention Type	Description
Damage (slight, medium-severe, very heavy)	Prohibited	No interventions of any kind may be made to existing buildings.

9.1.2 Instability-prone Zones Program

As already planned for SZ_{ACF} and RZ_{ACF}, in **Developed Areas (recent or consolidated)**, the following indications must be added.

The following guidelines are applicable in the absence of an IZP:

Building	Intervention Type	Description
Damage (slight, medium-severe, very heavy)	Prohibited	No interventions of any kind may be made to existing buildings.

9.1.2.1 Objective Choice of the IZP

The definition of a specific IZP implies the choice of one of the following objectives:

- Mandatory or Limited Intervention (Objective 1)
- Mandatory or Limited Intervention (Objective 2)
- Mandatory or Prohibited Intervention (Objective 3)
- Prohibited Intervention (Objective 4)

The respective guidelines for each of these objectives are listed below:

9.1.2.1.1 – FIRST HYPOTHESIS: Mandatory or Limited Intervention (Objective 1)

The choice of this objective determines the following guideline:

In RZ_{ACF}

Building	Intervention Type	Description
Damage (slight, medium -severe, very heavy)	Mandatory	Relocation is not mandatory, but preferred. Mandatory interventions (as scheduled by Regional Governments): seismic upgrading and/or retrofitting and/or local strengthening (conforming to current regulations), independent of maintenance requests or other types of requests.

In SZ_{ACF}

Building	Intervention Type	Description
Damage (slight, medium -severe, very heavy)	Limited	Any type of intervention must provide (as scheduled by the Region) seismic upgrading and/or retrofitting and/or local strengthening (conforming to current regulations).

9.1.2.1.2 – SECOND HYPOTHESIS: Mandatory Intervention or Relocation (Serious Damage) (Objective 2)

The choice of this objective determines the following guideline:

In RZ_{ACF}

Building	Intervention Type	Description
Damage (slight, medium-severe, very heavy)	Relocation	No intervention of any kind may be made to existing buildings, which are subject to mandatory relocation.

In SZ_{ACF}

Building	Intervention Type	Description
Damage (slight, medium -severe, very heavy)	Mandatory	Relocation is not mandatory, but preferred. Mandatory interventions (as scheduled by Regional Governments): seismic upgrading and/or retrofitting and/or local strengthening (conforming to current regulations), independent of maintenance requests or other types of requests.
Damage (very heavy)	Relocation	No intervention of any kind may be made to existing buildings, which are subject to mandatory relocation.

9.1.2.1.3 – THIRD HYPOTHESIS: Mandatory Intervention or Relocation (Mildly Serious or Serious Damage) (Objective 3)

The choice of this objective determines the following guideline:

In RZ_{ACF}

Building	Intervention Type	Description
Damage (slight, medium-severe)	Relocation	No intervention of any kind may be made to existing buildings, which are subject to mandatory relocation.

In SZ_{ACF}

Building	Intervention Type	Description
Damage (slight)	Mandatory	Relocation is not mandatory, but preferred. Mandatory interventions (as scheduled by Regional Governments): upgrading and/or seismic retrofitting and/or local strengthening (conforming to current regulations), independent of maintenance requests or other types of requests.
Damage (medium-severe, very heavy)	Relocation	No intervention of any kind may be made to existing buildings, which are subject to mandatory relocation.

9.1.2.1.4 – FOURTH HYPOTHESIS: Relocation (Objective 4)

The choice of this objective determines the following guideline:

In RZ_{ACF} and SZ_{ACF}

Building	Intervention Type	Description
Damage (slight, medium-severe, very heavy)	Relocation	No intervention of any kind may be made to existing buildings, which are subject to mandatory relocation.

10 THE ROLES OF PUBLIC INSTITUTIONS

The roles of Public Institutions can be summarised as follows:

State Government:

- Formulation of definitions, guidelines and general criteria for Regional Governments and Local Authorities;
- Determination of financial expenses for the investigations and in-depth analyses requested for ACF studies at Level 1 SM and for the production of risk mitigation programs for instable zones;
- Establishment of general technical criteria for defining AZ_{ACF}, SZ_{ACF}, RZ_{ACF};
- Definition of general land use planning criteria in AZ_{ACF}, SZ_{ACF} ,RZ_{ACF};
- Proposal and implementation of updates to the GSM (SM Working Group, 2015);
- Promoting the arrangement of a georeferenced database of ACFs;
- Working with the Regions to define methods and operative tools for the evaluation of ACFs, identified in SM1 studies.

Regional Governments and Autonomous Provinces of Italy:

- Adoption of general criteria established by State Government and approved by the Conference of the Regions and Autonomous Provinces of Italy;
- Formulation of additional specific criteria in relation to regional peculiarities;
- Examination and proposal of integrations and observations and/or approval of studies for active and capable faults already defined within the regional territory, in coordination with State Government (Level 1 SM);
- Promoting and coordinating studies to define new active and capable faults within the regional territory to be transmitted to State Government (Level 3 SM);
- Mapping AZ_{ACF}, SZ_{ACF} and RZ_{ACF} (Level 1 and 3 SM) ;
- Working with State Government to define methods and operative tools for the evaluation of ACFs, identified in SM1 studies.
- Requesting Local Authorities to inform and notify citizens of the location of AZ_{ACF}, SZ_{ACF} and RZ_{ACF} and the specific criteria for land use inside these zones.

Local Authorities (Municipal Governments):

- Adopting the specific criteria formulated by the Regional Governments and Autonomous Provinces of Italy;
- Regulating land use inside AZ_{ACF}, SZ_{ACF} and RZ_{ACF};
- Arranging an Instability-prone Zones Program in advance for areas affected by ACF;
- Working with the Regions and Autonomous Provinces to inform citizens about the identification of AZ_{ACF}, SZ_{ACF} and RZ_{ACF} and specific land use criteria inside these areas.

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APPENDIX A1
REPORT CONTENTS

General Report for Level 1 SM (Map of Seismically Homogeneous Microzones)

Table of Contents (Active and Capable Faults)

1. Introduction
   Objectives of the study
2. Seismotectonic structure of the area
   Seismicity, historical seismicity and paleoseismicity
3. Description of the site
   Geology, geomorphology, vegetation, anthropic structures and other factors that may influence the choice of methods and the interpretation of results
4. Minimum informative elements
   a. Geological indications and detailed studies by experts in specialised literature
   b. Geological and/or geomorphological elements surveyed in situ by geologists, during geological-technical surveys for SM mapping
5. Results based on the minimum informative elements
   a. Localisation of active and capable faults and/or potentially active and capable faults
   b. Fault type
   c. Localisation of secondary breakage and coseismic phenomena
   d. Critical issues
6. Boundaries and description of AZ_{ACF}
   a. AZ_{ACF}
   b. Project guidelines for the collection of specific informative elements
7. General Conclusions
8. Bibliography
9. Tables and Appendixes

General Report for Level 3 SM (SM map)

Table of Contents (Active and Capable Faults)

1. Introduction
   Objectives of the study
2. Seismotectonic structure of the area
   seismicity, historical seismicity and paleoseismicity
3. Description of the area
   geology, geomorphology, vegetation, anthropic structures and other factors that may influence the choice of methods and the interpretation of results
4. Specific informative elements
   a. Review of published and unpublished material regarding the site
   b. Aerial photography analyses

c. Geophysical and geognostic investigations

d. Paleoseismic trenches

- Datings (radiometric, stratigraphic, tephrochronological, paleomagnetic,...)

5. Results based on specific informative elements

a. Localisation of active and capable faults, of secondary breakage and coseismic phenomena

b. Characteristic parameters of the fault

- Maximum dislocation expected
- Expected magnitude
- Recurrence times

6. Boundaries and Descriptions of SZ_{ACF} and RZ_{ACF}

a. SZ_{ACF}

b. RZ_{ACF}

7. General Conclusions

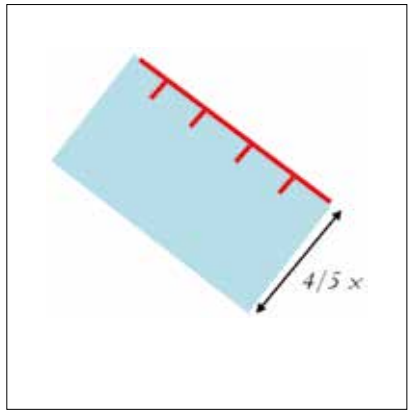
8. Bibliography

9. Tables and Appendixes

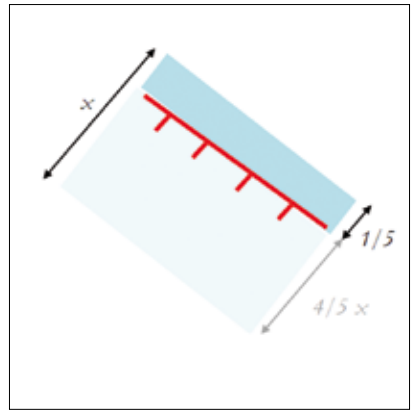
APPENDIX A2
AN EXAMPLE OF THE GEOMETRIC CONSTRUCTION OF AN ACF ZONE

Example of the geometric construction of a zone

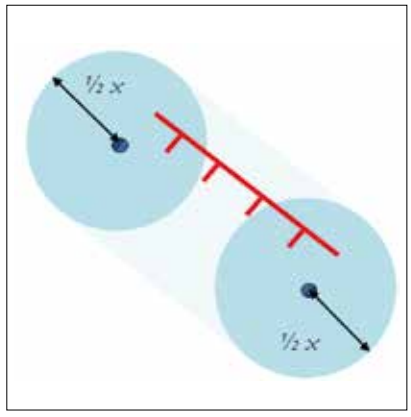
The procedure for constructing an asymmetrical ACF zone (SZ_{ACF} and RZ_{ACF}) for normal or inverse faults includes the creation of a **buffer** zone with a dimension x, straddling the segment of the fault considered in accordance with the following *steps* (the example deals with a normal fault – FW:HW ratio =1:4).



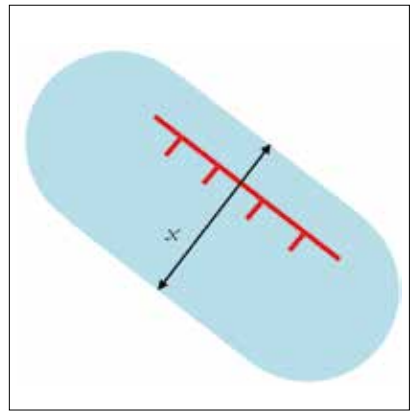
STEP 1 flat-sided buffer to the left, equal to 4/5 of the dimension of the zone *(x)*.



STEP 2 flat-sided buffer to the right, equal to 1/5 of the dimension of the zone *(x)*.



STEP 3 circular buffer zone along the median points of the short sides of the polygons obtained in the previous *step*, equal to 1/2 the dimension of the zone *(x)*.



STEP 4 fusion of all polygons to obtain an asymmetrical polygon with respect to the segment of the fault, equal to the dimensions *(x)* of the zone.

APPENDIX A3
ZONE DIMENSIONS

In general terms, zone dimensions are dictated by the following rules. They are listed here in order of decreasing significance:

- detailed description of physical phenomena;
- scientific literature referencing physical phenomena;
- international regulations.

Detailed Description of the Physical Phenomenon

ACF_x can be established during the immediate post-event phase or using **specific informative elements** referring to surface rupture during historic earthquakes.

In Italy, an example of a study of active and capable fault completed during the post-event phase was realised by Boncio et *al.* (2012) for the Paganica fault (L'Aquila). The authors establish values for a *Fault Setback* (S, comparable to RZ_{ACF}) and for an *Earthquake Fault Zone* (EFZ, comparable to SZ_{ACF}), distinct for the *Hanging Wall* (HW) and the *Foot Wall* (FW) of the fault (Table A3.1).

An Italian example of an active and capable fault studied in detail during the prevention phase is the Norcia Fault (Perugia; Galli *et al.*, 2005). The study allowed for the precise recognition of the trend of the active and capable fault on the surface. For the same fault, the work group that contributed to the GSM (SM Working Group, 2015) later defined a *Setback* Zone (S, comparable to RZ_{ACF}; Table A3.1)

AUTHORS	KNOWN FAULT	UNKNOWN FAULT
Boncio *et al.*, 2012	S = 40m HW and S = 15m FW EFZ = 150 m HW and 30 m FW	S = not indicated EFZ = 150 m HW and FW
SM Working Group, 2015; Galli *et al.*, 2005	S = 15 + 15 m	S = 75 + 75 m

Table A3.1 → **Dimensions of fault zones proposed in two Italian cases: Paganica (Boncio et al., 2012) and Norcia (Galli *et al.*, 2005 and SM Working Group, 2015)**

Scientific Literature Referencing Physical Phenomena

Boncio *et al.* (2012) report a large database of coseismic breakage and their distances from the trace of the main surface of rupture for events with different magnitudes and normal prevailing kinematics (Fig. A3.1). An analysis of the figure allows for the following considerations:

- since the database contains a high number of faults with normal components, most of the deformations are placed in the *hanging wall* of the main surface of rupture (Main Fault=MF);
- most deformations are at a distance of less than 150 m from the trace of the main surface of rupture (MF);
- the frequency of ruptures and deformations is very high at a distance between 0 m and 40 m from the trace of the main surface of rupture (MF).

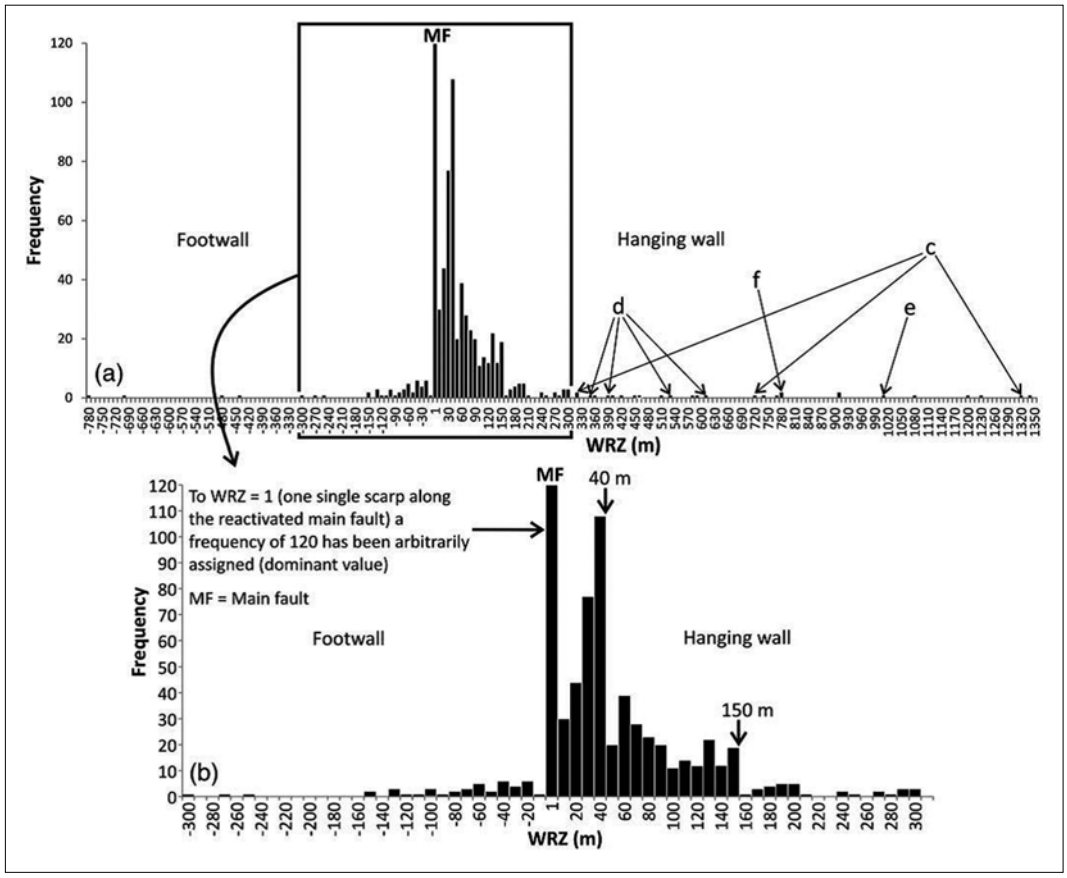


Figure A3.1 → Statistics on the frequency of breakage as a function of the distance from the main fault plane (Boncio et al., 2012). WRZ (*width of the rupture zone*) indicates the width of the zone affected by coseismic ruptures, measured perpendicular to the direction of the main fault (Main Fault, MF).

International Regulations

There are very few international regulations defining the dimensions of the areas around possible ruptures. Table A3.2 lists some values of *Setback* zones or areas with very high limitations on building activity.

COUNTRY (RULE)	SETBACK
California (Alquist-Priolo Act)	Smin = 15+15m
New Zealand (Ministry of Environment)	S = 20+20m
France (Guidelines for Seismic Microzonation Studies)	S = 50+50m for competent rocks S = 200+200 m for unconsolidated ground
Europe (EC8)	It is not possible to construct important buildings in the immediate vicinity of active faults for the safety of the public

Table A3.2 → Dimensions of *Setback* zones in selected international regulations.

APPENDIX A4

A COMPARISON OF KEY ISSUES WITH OTHER REGULATIONS

ISSUE	THIS DOCUMENT	CALIFORNIA (USA) ALQUIST-PRIOLO ACT (2007)	NEW ZEALAND MINISTRY FOR THE ENVIRONMENT (2003)
Fault Activity	Active: Holocene: Upper Late Pleistocene (40 kya) Potentially active: Mid-Late Pleistocene (older than 40 kya)	Active: Holocene (11 kya) Potentially active: Quaternary (1.6 mya)	A fault that has repeatedly ruptured the surface and will in all likelihood do so again
Investigations and Studies	2 categories tied to the further development of SM studies: – Minimum investigations (Lv SM1) – Specific investigations, 4 groups (Lv SM3)	Guidelines governing methods of study comparable to the specific investigations of Lv SM3	Informative references: – District Maps (Regional Council) – Site investigations (other subjects) – Official references (Crown Research Institute)
Overall Evaluation of Uncertainties	2 ACF_x: – Known and defined – Unknown	2 groups: – Well defined – Unknown	3 classes: – Well defined – Distributed – Unknown
Evaluation of Recurrence Intervals	No	No	Yes: 6 classes of recurrence intervals
Zonation	3 types tied to SM studies: AZ_{ACF} = 400 m SZ_{ACF} dimensions depend on uncertainties RZ_{ACF} = 30m	Earthquake Fault Zone (EFZ) = 150 + 150 m from the main fault and 60-90 m from minor faults, well defined Setback Zone = minimum 15+15 m from the fault	Fault Avoidance Zone= 20 + 20 m, from the fault. In-depth studies may allow for a reduction in these dimensions
Evaluation Approach	Seismic risk on city planning and exposure/vulnerability	Seismic Risk	Seismic risk based on exposure/vulnerability
Urban Planning Categories	3 urban categories and 5 types of urban planning limitations	No	No
Building Use Classes	4 classes	No	5 categories
Administrative Procedures, Responsibilities and Roles	Yes	Yes	Yes
Government Structure Responsible for Producing the Document	Civil Protection Department of the Italian Council of Ministers	California Environmental Protection Agency Geological Survey	Ministry for the Environment

APPENDIX A5
UNSTABLE AREAS PLAN OUTLINE

General Purpose

The general purpose of the Instability-prone Zones Program is to reduce the eventual effects of the rupture and dislocation of ground surfaces in urban settlements caused by active and capable faults (ACF).

Subject and Specific Purpose

1. Municipalities with SZ or RZ may prepare a specific Program that verifies and pursues:
   - ☐ delocalisation of all strategic functions and the identification of other locations or new realisations in areas outside the SZ and RZ;
   - ☐ delocalisation of important buildings, as defined in Decree n. 3685/2003, issued by the Head of the Italian Civil Protection Department;
   - ☐ delocalisation of residential functions;
   - ☐ change of the use for Undeveloped Areas (with plans for development), to services and other functions, without construction;
   - ☐ interventions of antiseismic retrofitting or limited rehabilitation of existing buildings;
   - ☐ priorities of intervention among SZ and RZ.

2. This program identifies financial incentives, urban planning incentives and bonuses designed to favour the rapid and complete implementation of interventions of delocalisation with the aim of achieving the highest levels of seismic safety and the qualification of urban areas by interested private subjects.

3. The program includes an analysis of financial requirements for its realisation.

4. The program identifies interventions that may be in accordance with applicable general urban planning instruments or require changes:
   - the program defines a contextual realisation and the completion of related equipment and local infrastructures for mobility in those cases in which the creation of new settlements - primarily residential or productive - is indispensable;
   - when these forecasts are not present in current urban planning regulations, they must be identified adjacent to and in continuity with the existing urban fabric.

5. Sites for the transfer of delocalised buildings and functions must privilege the reuse of existing buildings and abandoned areas in developed areas or those with certain plans for development.

6 Italian National Building Code.

6. The program can also be carried out through specific publicly developed implementation plans, where necessary, to be approved through the Planning Agreement pursuant to Art. 34 of Decree n. 267/2000 [6].

Implementation Tools. Final Implementation Plans.

1. The program identifies areas subject subejct to specific final implementation plans.

2. The final implementation plans as per article 1, discipline urban transformation to be made within SZ and RZ to achieve the general objectives indicated below, which include:
   - renovation works to improve the earthquake resistance of buildings hosting compatible functions;
   - urban rehabilitation works with a particular focus on increasing the network of escape routes and their redundancy;
   - changes to building uses that accommodate strategic functions subject to relocation.

3. The plans identify the Minimum Unit of Intervention, as defined by the Regions, requiring a modifications to urban planning instruments. They establish structural systems, plans and volumetric forms and the most appropriate design characteristics for conserving urban fabrics, together with any other detailed regulation necessary to proceed with the realisation planned interventions. Incentives are offered to the constitution of consortia and agreements between the owners of properties involved in unified interventions, favouring the synergy between the public and private sectors and improving project schedules.

4. The plan identifies the limits for allowable classes of use and intervention types referred to technical norms, in addition to identifying:
   - portions of urban zones intersected by SZ and RZ to be included in the plan in relation to the unity and coherence of the urban context and as a function of the Minimum Unit of Intervention;
   - suitable areas for the relocation of urban functions.

5. With the aim of ensuring the feasibility of an intervention, the decision to adopt a plan must be accompanied by a dedicated report on the full involvement of all interested private subjects, made possible by the stipulation of compensating agreements demonstrating the availability of the necessary financial resources for the implementation of planned interventions.

6. To ensure the full involvement of all interested private subjects, the contents of the plan may be the object of preliminary agreements with private subjects.

7. The framework of understanding and environmental evaluations related to the plan must be presented in accordance with SEA (Strategic Environmental Assessment) legislation, considering seismic microzonation and with particular reference to urbanised areas and those pre-selected for new settlements.

APPENDIX A6
GUIDELINE APPLICATIONS FOR TERRITORIAL MANAGEMENT IN AREAS AFFECTED BY ACTIVE AND CAPABLE FAULTS (ACF)[7]

List of Drawings

Level 1 Microzonation Study

Drawing 1 → Attention Zone (AZ_{ACF}) of an active and capable fault on a map of Seismically Homogenous Microzones (Level 1)

Drawing2 → Synthesis of the Current Master Plan

Drawing 3 → Guidelines for Attention Zones (AZ_{ACF}) of active and capable faults

Level 3 Microzonation Study[8]

Drawing 1 → Susceptibility Zone (SZ_{ACF}) and Respect Zone (RZ_{ACF}) for active and capable faults on a Seismic Microzonation Map (Level 3 SM)

Drawing 2 → Synthesis of the Current Master Plan

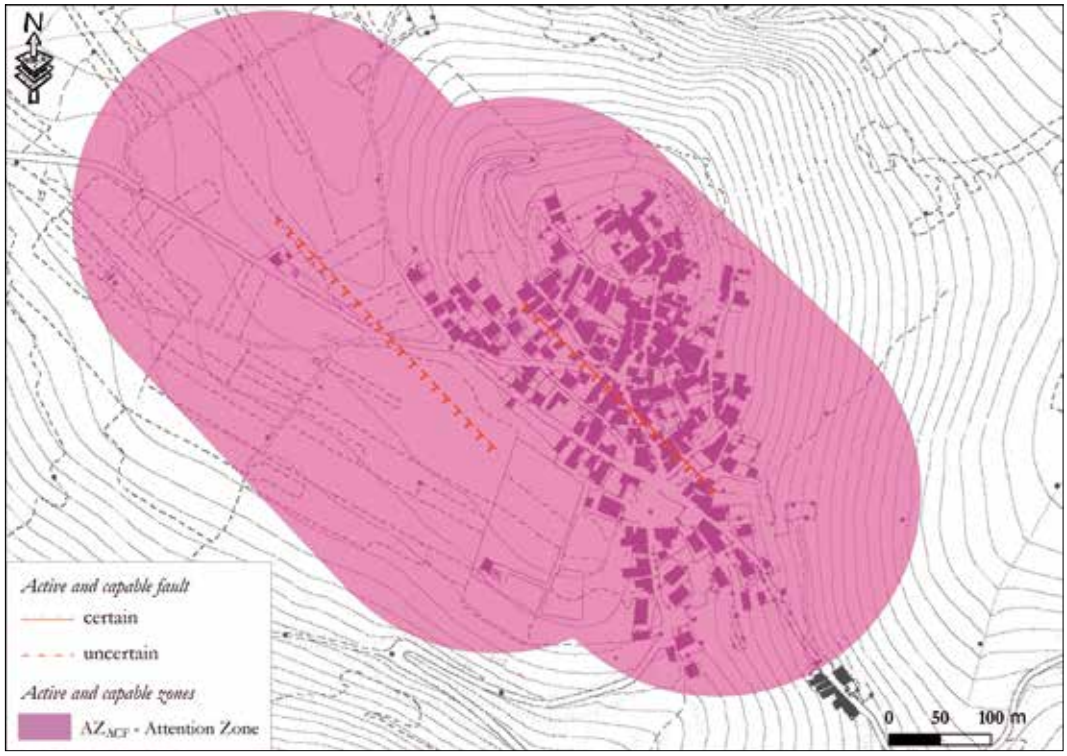
Drawing 3 → Guidelines for Susceptibility Zones (SZ_{ACF}) and Respect Zones (RZ_{ACF}) of active and capable faults (minimum perimeter)

Drawing 4 → Guidelines for Susceptibility Zones (SZ_{ACF}) and Respect Zones (RZ_{ACF}) of active and capable faults (maximum perimeter)

7 Land use guidelines for areas affected by active and capable faults have been applied to a "theoretical" urban centre. The data used for this example (Level 1, Level 3 and urban planning microzonation studies) are aimed at illustrating the procedure to be adopted.

8 The definition of the perimeter of the implementation plan has been formulated here with two hypothesis:
- **Minimum perimeter,** including the elements inside SZ_{ACF} and RZ_{ACF} and those intersected by the border of this latter;
- **Maximum perimeter**, including all of the urban zones intersected by SZ_{ACF} and RZ_{ACF}.

LEVEL 1 SEISMIC MICROZONATION STUDY



Drawing 1 → **Attention Zone (AZ_{ACF}) of active and capable faults on a map of Seismically Homogenous Microzones (Level 1).**

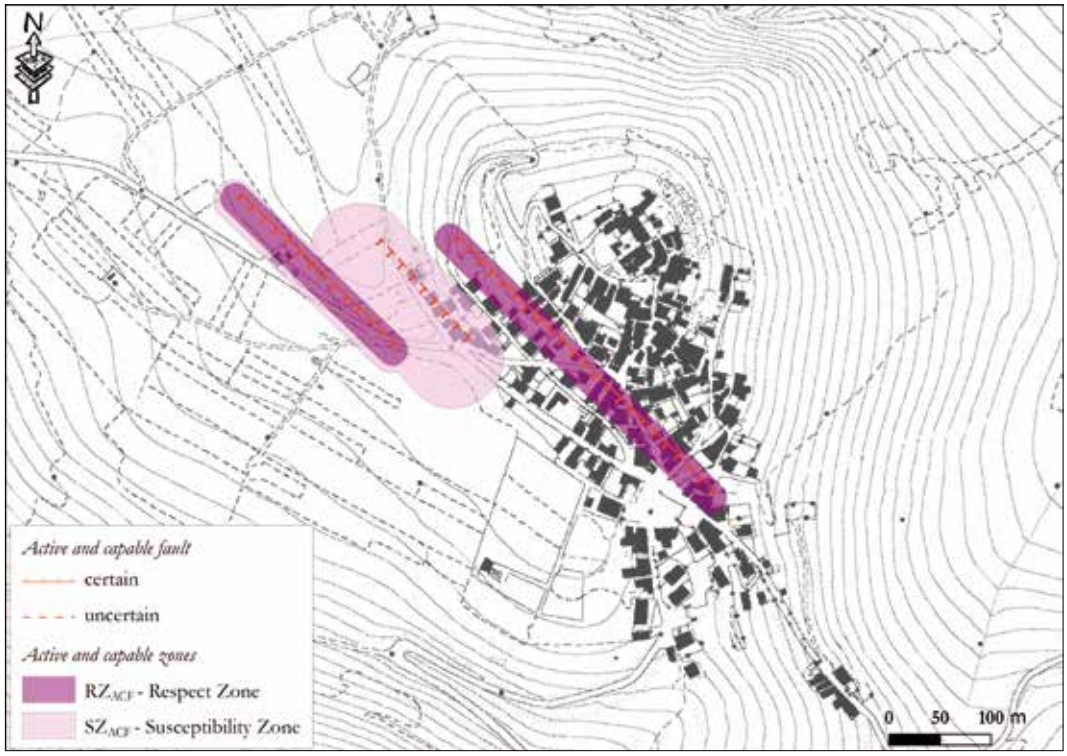
EXPLANATORY NOTES

Active and Capable Fault and Fault Zones

The available information (minimum informative elements) was used to identify a known fault segment, classified as ACF_a, and an unknown fault segment, classified as ACF_b. An attention zone was then defined (AZ_{ACF}) with a 400 meter buffer straddling two segments of the fault.

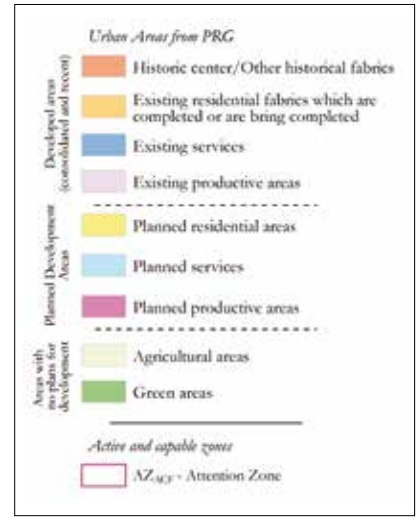
Reference should be made compulsory to specific levels of analysis, specific to Level 3 SM (SM Working Group, 2015).

LEVEL 1 SEISMIC MICROZONATION STUDY



Drawing 2 → **General Regulatory Plan (Master Plan).**

LEGEND



EXPLANATORY NOTES

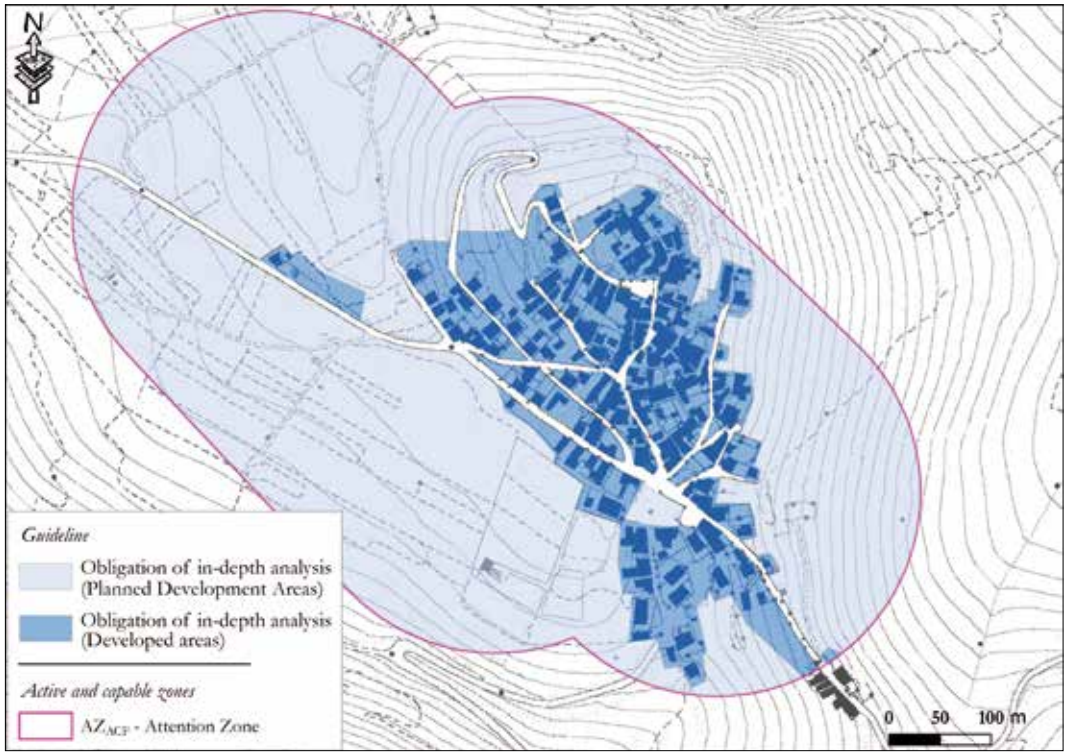
The map refers to a small mountainside settlement characterised by the presence of a dense historic centre and adjoining urban fabric, both complete or being completed. The urban centre develops along a sloping main street, considered the primary axis of expansion of residential, service and production functions.

The "Urban Areas identifed in the PRG (Master Plan)" are articulated according to the three proposed categories of urban areas.

- "Developed Areas (consolidated and recent)" include historic centres and consolidated urban fabrics, completed urban fabrics or those being completed, and all existing buildings destined for services and productive functions;
- "Undeveloped Areas (with plans for development)" refer to zones of residential expansion, services and productive functions;
- "Undeveloped Areas (with no plans for development)" include agricultural areas and public spaces.

Level 1 seismic microzonation shows the presence of an AZ_{ACF} that extends across the entire urban centre.

LEVEL 1 SEISMIC MICROZONATION STUDY



Drawing 3 → **Guidelines for Attention Zones (AZ_{ACF}) of active and capable faults.**

Guidelines (see Table B1)

The land use regulations proposed on the basis of Level 1 SM, in correspondence with AZ_{ACF}, are articulated in two types of indications:

1. **Mandatory In-Depth Analysis (Undeveloped Areas (with plans for development))**

This includes "Undeveloped Areas (with no plans for development)" and "Undeveloped Areas (with plans for development)" They are subject to a system of limitations on building rights that does not authorise any type of transformation until the necessary investigations to identify RZ_{ACF} and SZ_{ACF} have been completed. In these areas, the modifcation of landscaped spaces is permitted, without the construction of volumes, for service functions and activities present in the surrounding areas, settled and urbanised, or to increase the availability of landscaped areas, public spaces and private landscaped areas (cf. Par. 8.2).

The absence of any in-depth analysis determines the following guideline:

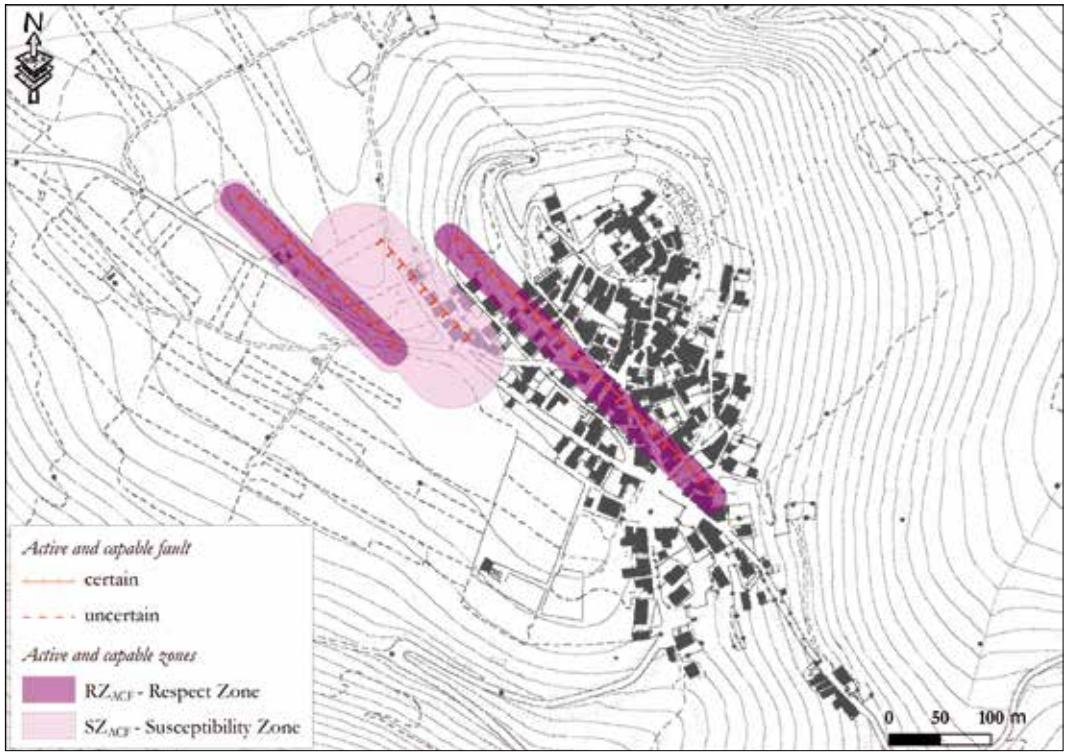
Building	Intervention Type	Description
Existing	Limited	Excluding regular maintenance, all other types of interventions must provide seismic upgrading and/or retrofitting and/or local strengthening (conforming to current regulations).
New construction	Prohibited	New construction is not permitted.

2. Mandatory In-Depth Analysis (Developed Areas)

In the case of AZ_{ACF} in Developed Areas (recent or consolidated), the necessary geological investigations, of Level 3 SM, must be fulfilled for new buildings (in vacant lots) and for those on existing buildings in order to identify the SZ_{ACF} and the RZ_{ACF}. It is a prerogative of the Regions to define eventual time limits for the completion of these investigations. The absence of investigations determines the following guideline:

Building	Intervention Type	Description
Existing	Limited	Excluding regular maintenance interventions, all other types of intervention must provide seismic upgrading and/or retrofitting and/or local strengthening (conforming to current regulations).
New construction	Prohibited	New construction is not permitted.

LEVEL 3 SEISMIC MICROZONATION STUDY



Drawing 1 → Susceptibility Zone (SZ_{ACF}) and Respect Zone (RZ_{ACF}) for active and capable faults on a Seismic Microzonation Map (Level 3 SM).

EXPLANATORY NOTES

Active and Capable Faults and Fault Zones

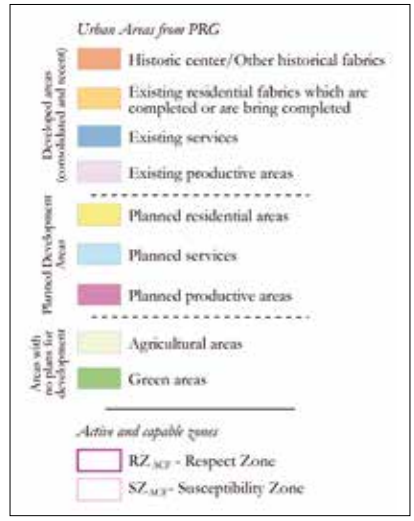
Certain fault segments were classified as ACF_a, together with an asymmetric Respect Zone (RZ_{ACF}) of 30 m (normal fault- FW:HW =1:4 ratio). The mountainous segment was investigated with a significance level of maximum investigation (Ind_1, 2, 3, and 4). Therefore, it was considered appropriate to mark the fault segment with the only RZ_{ACF}. The valley segment, instead, was investigated with Ind_1, 2, and 3 type investigations and with the consequent definition of a 40 meter Susceptibility Zone (SZ_{ACF}) of 40 m, also asymmetrical.

The unknown segment of the fault was classified as ACF_b and an asymmetrical Susceptibility Zone (SZ_{ACF}) of 160 m was defined (normal fault – FW:HW = 1:4 ratio) based on the typology of investigations made in the same segment study (Inv_1 and 2).

LEVEL 3 SEISMIC MICROZONATION STUDY

Drawing 2 → General Regulatory Plan (Master Plan).

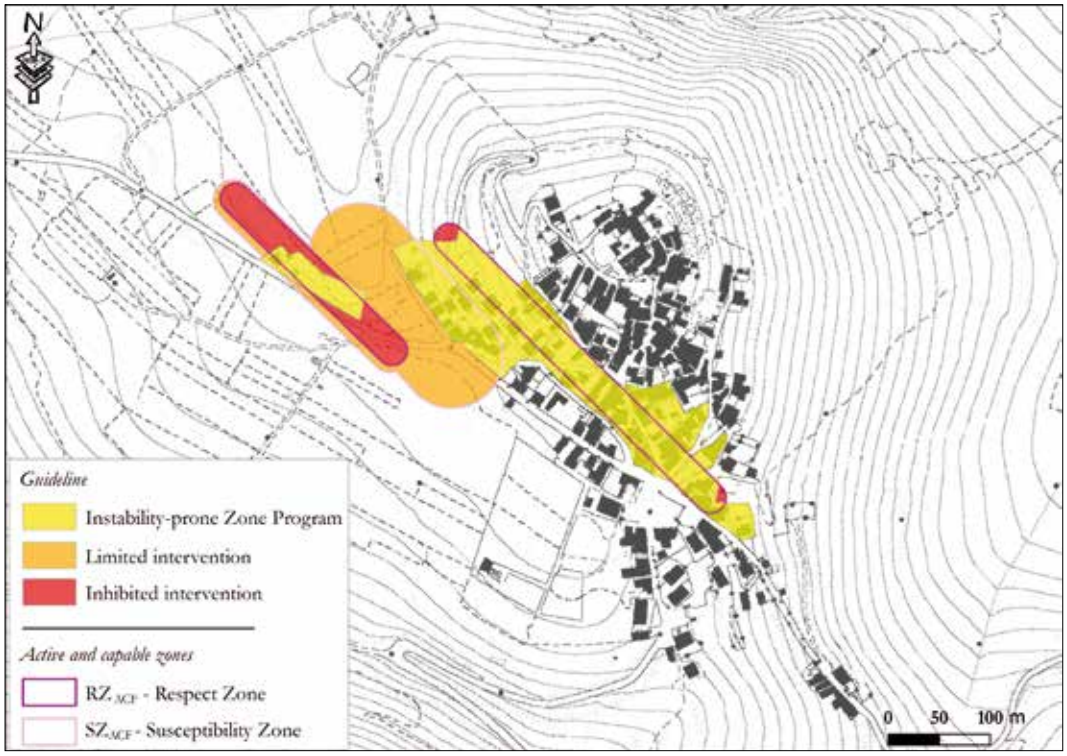
LEGEND



EXPLANATORY NOTES

Level 3 Seismic Microzonation demonstrates the presence of an RZ_{ACF} in "Developed Areas (recent and consolidated)"– in particular in the historic centre and existing residential urban fabric, either complete or being completed, and in existing productive areas – as well as in "Undeveloped Areas (with no plans for development)" and "Undeveloped Areas (with plans for development)"– in particular in service areas, planned productive and residential areas, and agricultural areas. The areas falling inside SZ_{ACF} regard, instead, some of the existing residential urban fabric, either complete or being completed, service areas, planned productive and residential areas and a selection of agricultural areas.

LEVEL 3 SEISMIC MICROZONATION STUDY



Drawing 3 → Guidelines for Susceptibility Zones (SZ_{ACF}) and Respect Zones (RZ_{ACF}) of ACF (minimum perimeter).

Guideline – Minimum Hypothesis (see Table B1)

The minimum hypothesis calls for the identification of parts of the urban fabric exceeding the limits of the SZ_{ACF} and RZ_{ACF}, considering the physical continuity of buildings and of the Minimum Units of Intervention. The guideline proposal, based on Level 3 seismic microzonation in correspondence with the SZACF and RZ_{ACF}, consists of three types:

1. Instability-prone Zones Program

An Instability-prone Zones Program (IZP) was defined for SZ_{ACF} and RZ_{ACF} in Developed Areas (recent or consolidated). The absence of an IZP determines the following conditions:

Building	Intervention Type	Description
Existing	Limited	Excluding regular maintenance interventions, all other interventions must provide seismic upgrading and/or retrofitting and/or local strengthening (conforming to current regulations).
New construction	Prohibited	New construction is not permitted.

In the IZP one of the following objectives must be chosen:

- Limited Intervention (Objective 1)
- Mandatory or Limited Intervention (Objective 2)
- Mandatory or Prohibited Intervention (Objective 3)
- Prohibited Intervention (Objective 4)

2. Limited Intervention

In Undeveloped Areas (with plans for development) and in Undeveloped Areas (with no plans for development), the following guideline is expected:

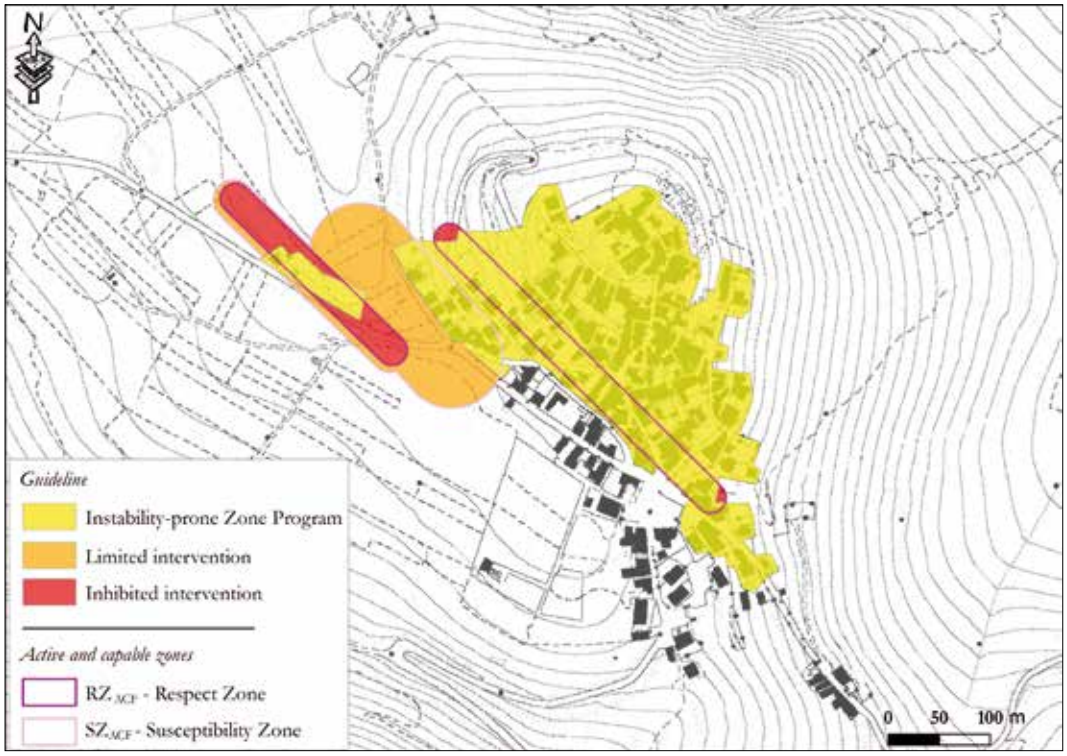
Building	Intervention Type	Description
Existing	Mandatory	Relocation is not mandatory, but preferred. Mandatory interventions (as scheduled by Regional Governments): – intervention of limited upgrading and/or seismic retrofitting and/or local strengthening (conforming to current regulations), independent of maintenance requests or other types of requests.
New Construction	Limited	New construction is only permitted for Class I use.

3. Prohibited Intervention

In Undeveloped Areas (with plans for development) and in Undeveloped Areas (with no plans for development), which fall inside RZ_{ACF}, modifications to landscaped spaces are permitted, without the realisation of new volumes, for service functions and activities present in the surrounding areas, settled and urbanised, or to increase the availability of landscaped areas, public spaces and private landscaped areas. The following guideline is applicable:

Building	Intervention Type	Description
Existing	Mandatory	Relocation is not mandatory, but preferred. Mandatory interventions (as scheduled by Regional Governments): seismic upgrading and/or retrofitting and/or local strengthening (conforming to current regulations), independent of maintenance requests or other types of requests.
New Construction	Prohibited	New construction is not permitted.

LEVEL 3 SEISMIC MICROZONATION STUDY



Drawing 4 → Guidelines for Susceptibility Zones (SZ_{ACF}) and Respect Zones (RZ_{ACF}) of active and capable faults (maximum perimeter).

Guideline – Maximum Hypothesis (see Table B1)

The maximum hypothesis foresees the identification of parts of the urban fabric that exceed the limits of the SZ_{ACF} and RZ_{ACF}, considering the physical continuity of buildings and of the Minimum Units of Intervention, as well as areas with and urabn plan, in order to guarantee homogenous urban intervention. The guideline proposal, based on Level 3 seismic microzonation in correspondence with the SZ_{ACF} and RZ_{ACF}, follows the same indications proposed for the minimum hypothesis (cf. Drawing 3).

APPENDIX A7
SUMMARY DESCRIPTION OF CLASSIFICATIONS

Each urban indication listed in Table B1 (listed here again) is associated with one or more indications relative to the type of intervention for existing buildings or new construction reported in **Table B2**.

URBAN PLANNING CATEGORIES		DEVELOPED AREAS (RECENT OR CONSOLIDATED)	UNDEVELOPED AREAS (WITH PLANS FOR DEVELOPMENT)	UNDEVELOPED AREAS (WITH NO PLANS FOR DEVELOPMENT)	INFRASTRUCTURES
Fault Zones	AZ_{ACF}	Mandatory In-Depth Analyses (8.1.1)	Mandatory In-Depth Analyses (8.2.1)		Infrastructure Program (8.3)
	SZ_{ACF}	Instability-prone Zones Program (8.1.2)	Limited Intervention (8.2.3)		
	RZ_{ACF}		Prohibited Intervention (8.2.4)		

Table B1> Urban Planning Indications

URBAN PLANNING CATEGORIES		DEVELOPED AREAS (RECENT OR CONSOLIDATED)	UNDEVELOPED AREAS (WITH PLANS FOR DEVELOPMENT)	UNDEVELOPED AREAS (WITH NO PLANS FOR DEVELOPMENT)	INFRASTRUCTURES
Fault Zones	AZ_{ACF}	EL – NP	EL – NP		Infrastructure Program
	SZ_{ACF}	EL – NP (EL – NL)	EM – NP		
	RZ_{ACF}	(ER – NL) (ER – NP) (ER – NP)	EM – NP		

LEGEND

Abbreviation	Building	Intervention Type	Description
EL	Existing	Limited	Excluding regular maintenance interventions, all other interventions must provide for upgrading and/or seismic retrofitting and/or local strengthening (conforming to current regulations)
EM	Existing	Mandatory	Relocation is not mandatory, but preferred. Mandatory interventions (as scheduled by the Region): seismic upgrading and/or retrofitting and/or local strengthening (conforming to current regulations), independent of maintenance requests or other types of requests.
ER	Existing	Relocation	No intervention of any kind may be made to existing buildings, which are subject to mandatory relocation.
NL	New Construction	Limited	New construction is permitted only for Class I use.
NP	New Construction	Prohibited	New construction is not permitted.

Table B2 → Indications on the type of intervention for existing buildings or new construction.

With reference to the guidelines for post-earthquake reconstruction zones **(see Chapter 9)** involving Developed Areas (recent or consolidated) **Table B2** is integrated as follows:

URBAN CATEGORIES		DEVELOPED AREAS (RECENT OR CONSOLIDATED)
Fault Zones	AZ_{ACF}	SP – MP – VP
	SZ_{ACF}	SP – MP – VP (SL-ML-VL) (SM-MM-VM) (SM-MR-VM) (LR-MR-VM)
	RZ_{ACF}	(SM-MM-VM) (LR-MR-VM)

Table B3 → Indications on the type of interventions for existing and damaged buildings.

LEGEND

Abbreviation	Building	Intervention Type	Description
SP MP VP	Damaged (Slight, Medium severe, Very heavy)	Prohibited	No intervention of any kind may be made to existing buildings.
SL ML VL	Damaged (Slight, Mildly severe, Very heavy)	Limited	Any type of intervention must provide (as scheduled by Regional Governments) for seismic upgrading and/or retrofitting and/or local strengthening (conforming to current regulations).
SM MM VM	Damaged (Slight, Medium severe, Very heavy)	Mandatory	Relocation is not mandatory, but preferred. Mandatory interventions (as scheduled by the Region): seismic upgrading and/or retrofitting and/or local strengthening (conforming to current regulations), independent of maintenance requests or other types of requests.
SR MR VR	Damaged (Slight, Medium severe, Very heavy)	Relocation	No intervention of any kind may be made to existing buildings, which are subject to mandatory relocation.

Abbreviations relative to the buildings listed above refer to a possible classification based on levels of damage. More articulated classification systems can predict an evaluation of the damage level and the analysis of structural vulnerability.

The methodology for attributing levels of vulnerability and damage utilised by the Municipality of L'Aquila for compensation allocation is presented as an example (Municipality of L'Aquila, Reconstruction Department, Urban and Territorial Planning, *Abruzzo Earthquake, 2009, Instruction Manual, Outline P.E.R. L'Aquila, January 2013).*

The method is based on a damage-vulnerability analysis of buildings using a special project form. The damage-vulnerability correlation leads to the identification of 4 levels, used also as a reference for compensation **(Fig. A7-1)**. Levels are evaluated using the EMS98 scale on the basis of damage detected following an earthquake **(Fig. A7-2)**. Vulnerability is evaluated using rapid assessment criteria to attribute points to each type of construction or construction flaw **(Figures A7-3 and A7-4)**.

Figure A7-1 → Compensation levels (L) based on the correlation between damage and vulnerability.

DAMAGE-VULNERABILITY CORRELATION	MASONRY			REINFORCED CONCRETE		
DAMAGE LEVEL	VULNERABILITY LEVEL			VULNERABILITY LEVEL		
	V1 – low	**V2** – medium	**V3** – high	**V1** – low	**V2** – medium	**V3** – high
D0 = No damage	L0	L0	L1	L0	L0	L1
D1 = Slight damage	L0	L1	L1	L0	L1	L1
D2 = Moderate damage	L1	L1	L2	L1	L1	L2
D3 = Heavy damage	L1	L2	L2	L1	L2	L3
D4 = Very heavy damage	L2	L2	L3	L2	L3	L3
D5 = Destruction	L2	L3	L3	L3	L3	L3

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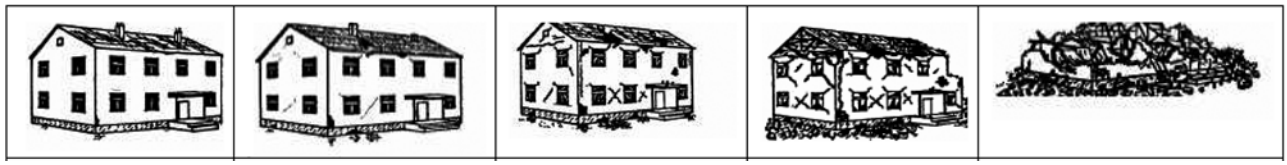
Figure A7-2 → **Definitions of Damage Levels.**

Description of damage levels based on the EMS 98 scale obtained from the conversion of detected damage using the AeDES form:

- **D1 negligible to slight damage** (no structural damage, slight non-structural damage) Hair-line cracks in very few walls. Fall of small pieces of plaster only. Fall of loose stones from upper parts of buildings in very few cases.
- **D2 moderate damage** (slight structural damage, moderate non-structural damage) Cracks in many walls. Fall of fairly large pieces of plaster. Partial collapse of chimneys.
- **D3 substantial to heavy damage** (moderate structural damage, heavy non-structural damage) Large and extensive cracks in most walls. Roof tiles detached. Chimneys fractured at the roof line; failure of individual non-structural elements (partitions, gable walls).
- **D4 very heavy damage** (heavy structural damage, very heavy non-structural damage) Serious failure of walls; partial structural failure of roofs and floors.
- **D5 destruction** (very heavy structural damage) Total or near total collapse.



D1 – slight damage **D2** – moderate damage **D3** – heavy damage **D4** – very heavy damage **D5** – destruction

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A5 CRITERIA ADOPTED TO DETERMINE THE VULNERABILITY

A5.1 Masonry Buildings

Vulnerability is determined by attributing a score to each type of construction or flaw in construction, graded on three levels. High vulnerability (V3) is attributed when the score is greater than or equal to 40, medium vulnerability (V2) is applied to scores between 25 and 40, and low vulnerability (V1) is obtained at scores lower than 25.

Figure A7-3 → **Vulnerability levels of masonry buildings.**

VULNERABILITY LEVEL	SCORE
V3 – high	>40
V2 – average	≥25 - ≤40
V1 – low	<25

Summary table of relative levels of vulnerability.

The table lists the indicators of vulnerability, a judgement and number of points

N.	RAPID VULNERABILITY ASSESSMENT MODEL	V3 = high	V2 = medium	V1 = low	V3	V2	V1
1	masonry quality	chaotic, roughly laid without coursing and and non-horizontal, lacking diatoni...	roughly laid without coursing, split,...	Square, solid brick with coursing, presence of diatoni	12	8	4
2	Quality of the connection between masonry elements at corners and 'T' intersections	absent	irregular	regular rhythm	6	4	2
3	Presence of unsupported masonry, on at least one level, bearing on horizontal structures for at least 10% of the floor surface	present		absent	3	0	0
4	Elevated distance between successive load-bearing walls (maximum ratio distance/wall thickness greater than 14)	>14	≥10;<14	<10	4	3	2
5	Floor plates: connection to vertical load-bearing structures	absent or poorly connected	ineffective connections	well-connected	10	7	5
6	Roof structures: connection to vertical load-bearing structures	absent, poorly connected/heavy	ineffective connections	well-connected	8	6	4
7	Offset floor plates at different levels with a level difference greater than 1/3 of the floor-to-floor height	yes	no	no	4	0	0
8	Lack of connections between non-structural elements and the building structure.	absent	ineffective	effective	4	2	0
9	Position in an aggregate of buildings	end/corner	projecting toward the interior	internal	3	2	1
	Total maximum score				**54**	**34**	**18**

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(...)

A5.2 REINFORCED CONCRETE BUILDINGS

Vulnerability is graded on three levels: high, medium and low. Each flaw in construction is attributed to either class A (principal) or class B (secondary). Vulnerability is high (V3) when at least two class A construction flaws are present, low (V1) when at least 3 class B construction flaws are present and medium (V2) in all other cases.

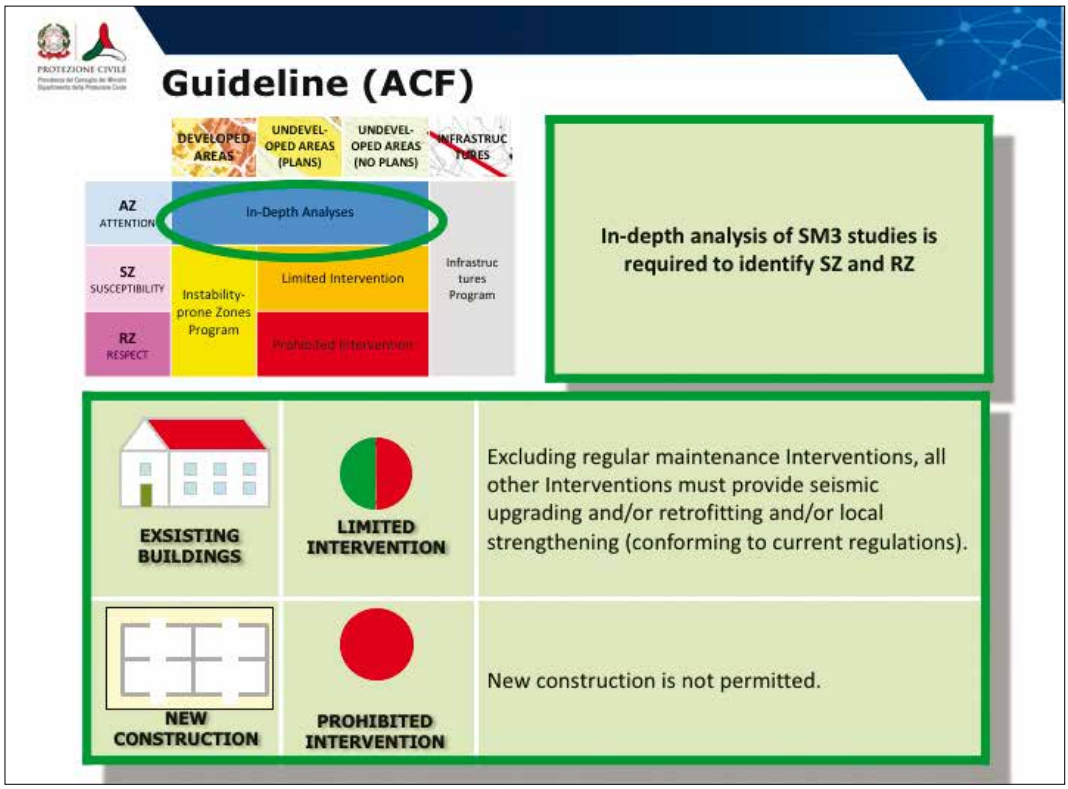
Vulnerability indicators and classes are listed in the table below.

High	≥ 2 A	
Medium	other combinations	
Low	≤3 B	

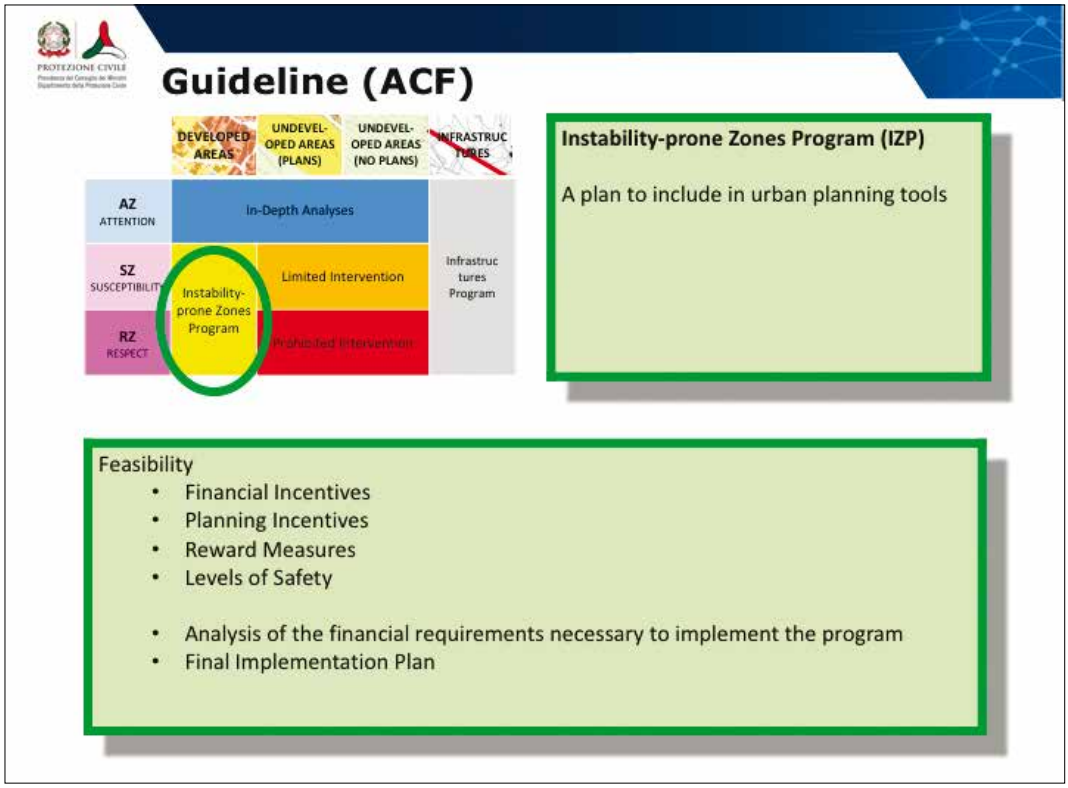
Figure A7-4 → Vulnerability levels of reinforced concrete buildings.

SUMMARY TABLE OF SERIOUS CONSTRUCTION FLAWS		A	B
1	REGULARITY OF THE FLOOR PLAN	X	
2	FLOORPLATE STIFFNESS		X
3	DISTRIBUTION OF INFILL WALLS IN PLAN		X
4	DISTRIBUTION OF INFILL WALLS IN ELEVATION	X	
5	INFILL WALLS OUTSIDE THE STRUCTURAL GRID		X
6	PRESENCE OF SQUAT COLUMNS	X	
7	SHORTCOMINGS IN THE LOAD BEARING STRUCTURE	X	
8	STATE OF CONSERVATION		X
9	ABSENCE OF SEISMIC JOINTS		X
10	COLUMN LOADS	X	
11	CONCRETE STRENGTH	X	
12	CONSTRUCTION PERIOD		X

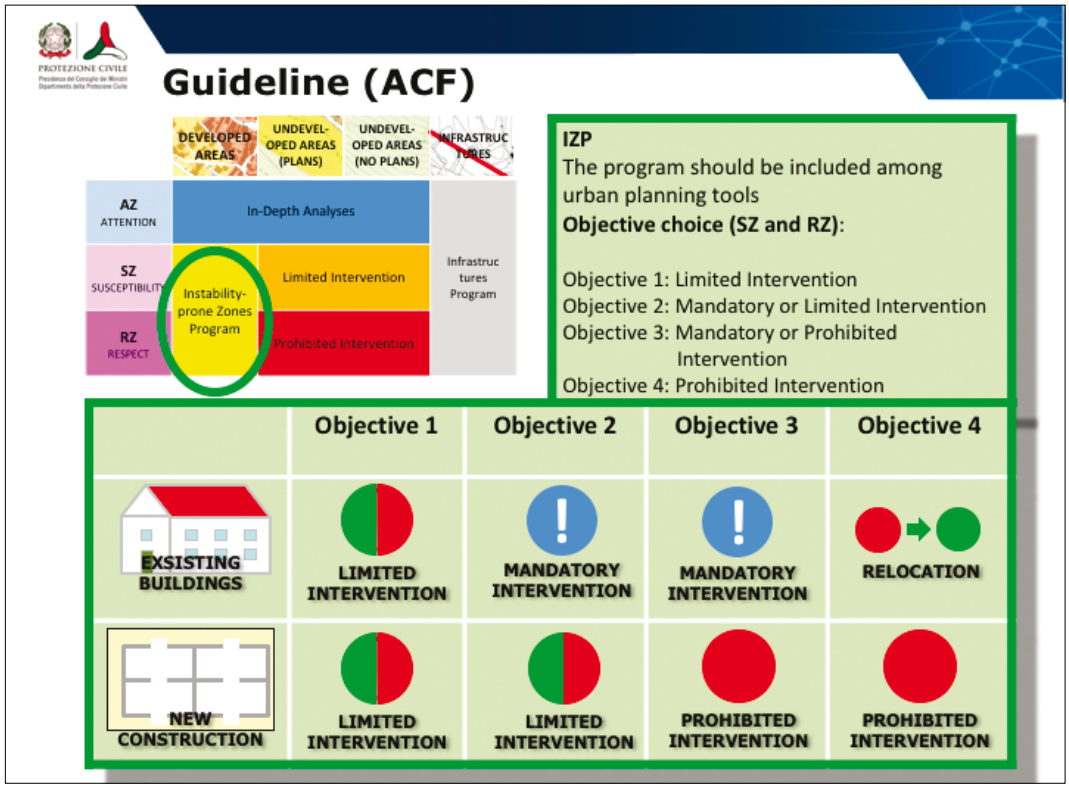
APPENDIX A8
SUMMARY OUTLINE OF GUIDELINES



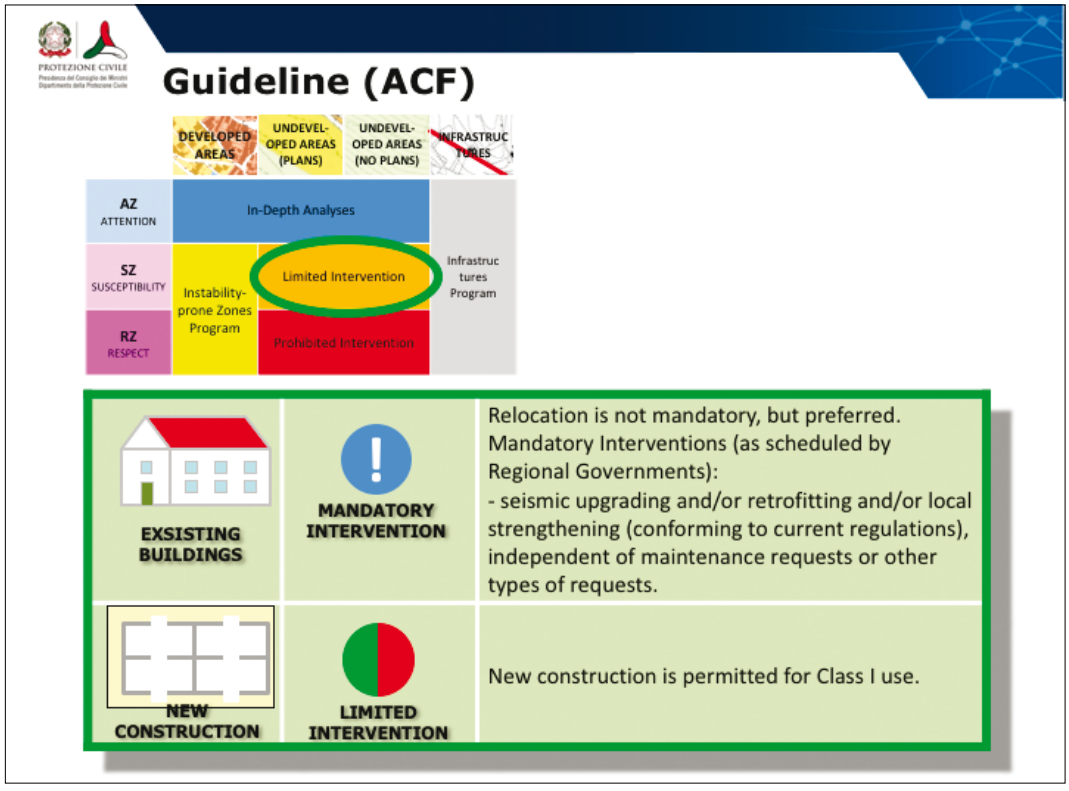
Slide 1 → **Attention Zone: Limited Intervention for existing buildings and prohibition of any new construction.**



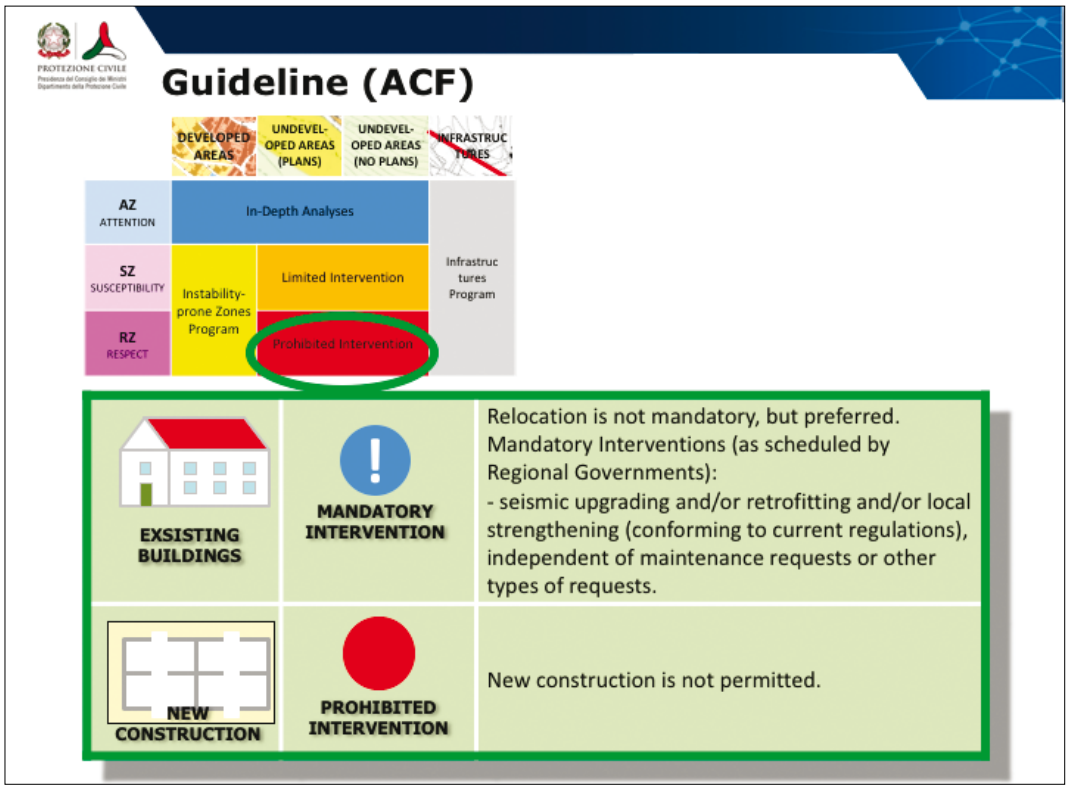
Slide 2 → **Susceptibility Zones and Respect Zones for Developed Areas: Definition of the Instability-prone Zones Program (IZP).**



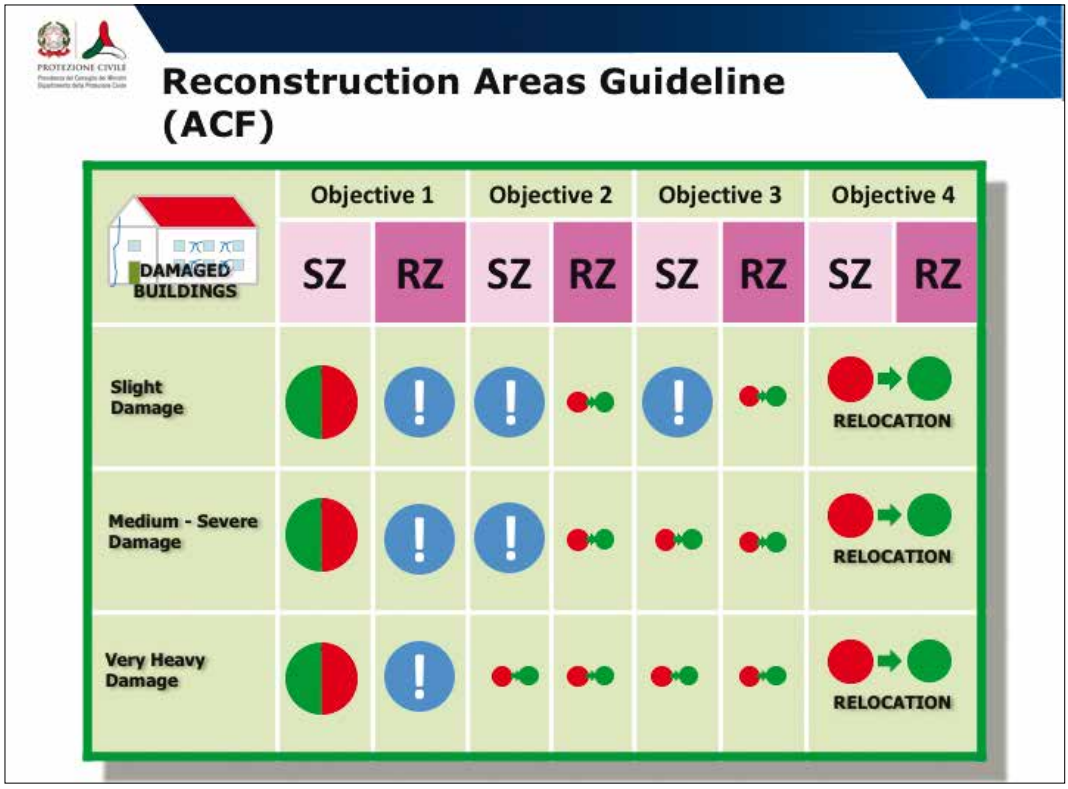
Slide 3 → **Susceptibility Zone and Respect Zone for Developed Areas: IZP Objective Choice.**



Slide 4 → **Susceptibility Zones for Undeveloped Areas (with or without plans for development): Mandatory interventions for existing buildings and Limited Interventions for new construction.**



Slide 5 → Respect Zones for Undeveloped Areas (with or without plans for development): Mandatory interventions for existing buildings and prohibition of any new construction.



Slide 6 → Reconstruction zone guideline, depending on the objective selected for the IZP.

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Via Ulpiano, 11 - Via Vitorchiano, 2 - Rome (IT)
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