## APPENDIX 4

## Comparison between the INQUA scale and the MCS-1930, MM-1931, MM-1956, and MSK-1964 scales

for the comparison with the Japanese JMA scale see Table 1 the text

# MCS Scale

| Intensity | MCS Scale | INQUA Scale |
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| I | **Imperceptible**<br>Noticed only by seismographs. | **No perceptible environmental effects**<br>Extremely rare occurrence of small effects detected only from instrumental observations, typically in the far field of strong earthquakes. |
| II | **Very weak**<br>Noticed only by a very few persons, usually of a nervous disposition who are in perfectly quiet surroundings and who are nearly always on the highest floors of buildings. | **No perceptible environmental effects**<br>Extremely rare occurrence of small effects detected only from instrumental observations, typically in the far field of strong earthquakes. |
| III | **Weak**<br>Even in highly inhabited areas the quake is noticed only by a very small part of the population and only when at home. Is similar to the movement caused by a car going by at a very high speed. People usually recognize it as a seismic phenomenon only after having discussed it among themselves | **No perceptible environmental effects**<br>Primary effects are absent.<br>Extremely rare occurrence of small variations in water level in wells and/or the flow-rate of springs, typically in the far field of strong earthquakes. |
| IV | **Moderate**<br>People outside of buildings do not normally notice the earthquake. It is usually identified by some persons, but not everybody who are inside the buildings, after observing a slight swaying of objects and furniture. Crystal ware and chinaware which are next to one another, shake as if a heavy truck were going along on a badly asphalted road. Windows shake, doors, beams and boards move, ceilings creak. | **No perceptible environmental effects**<br>Primary effects are absent.<br>A very few cases of fine cracking at locations where lithology (e.g., loose alluvial deposits, saturated soils) and/or morphology (slopes or ridge crests) are most prone to this phenomenon.<br>Rare occurrence of small variations in water level in wells and/or the flow-rate of springs.<br>Extremely rare occurrence of small variations of chemical-physical properties of water and turbidity of water in lakes, springs and wells, especially within large karstic spring systems most prone to this phenomenon.<br>Exceptionally, rocks may fall and small landslides may be (re)activated, along slopes where equilibrium is already very unstable, e.g. steep slopes and cuts, with loose or saturated soil.<br>Extremely rare occurrence of karst vault collapses, which may result in the formation of sinkholes, where the water table is shallow within large karstic spring systems.<br>Very rare temporary sea level changes in the far field of strong earthquakes.<br>Tree limbs may shake. |

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| V | **Quite strong**<br>People in the streets or in open spaces notice the earthquake even during daily activities. The earthquake is noticed in flats due to the movements of the whole building. Plants and delicate branches of bushes and trees can be seen moving as if they were blown by the wind. Hanging objects start swaying, e.g. curtains, traffic light, hanging lights and chandeliers which are not very heavy. Bells ring pendulum-clock either stop or sway with higher period. This depends on the direction of the earthquake, wether it is perpendicular or normal to the motion of the oscillation Sometimes pendulum-clocks, which have not worked for a long time start working again Alarm clocks go off. Electric light flickers or goes off due to the movements of the line. Small quantities of liquid, in containers filled to the rim, spill. Knik-knaks and similar objects are knocked over. Objects leaning against walls and light furniture can be slightly moved from their places. Furniture shakes, doors and windows can break. Most people sleeping are woken up. People sometimes even run out of the buildings into the streets. | **Marginal effects on the environment**<br>Primary effects are absent.<br>A few cases of fine cracking at locations where lithology (e.g., loose alluvial deposits, saturated soils) and/or morphology (slopes or ridge crests) are most prone to this phenomenon.<br>Extremely rare occurrence of significant variations in water level in wells and/or the flow-rate of springs.<br>Rare occurrence of small variations of chemical-physical properties of water and turbidity of water in lakes, springs and wells.<br>Rare small rockfalls, rare rotational landslides and slump earth flows, along slopes where equilibrium is unstable, e.g. steep slopes, with loose or saturated soil.<br>Extremely rare cases of liquefaction (sand boil), small in size and in areas most prone to this phenomenon (hihgly susceptible, recent, alluvial and coastal deposits, shallow water table).<br>Extremely rare occurrence of karst vault collapses, which may result in the formation of sinkholes, where the water table is shallow within large karstic spring systems.<br>Occurrence of landslides under sea (lake) level in coastal areas.<br>Rare temporary sea level changes in the far field of strong earthquakes.<br>Tree limbs may shake. |
| VI | **Strong**<br>Everybody notices the earthquake with fright, so that many of them run into the streets. Some people feel them falling. Liquids move quite a lot. Pictures, books and similar objects fall from the walls and shelves. Chinaware breaks. Quite stable furnishings and even isolated pieces of furniture are moved or fall over. Bell of small churches and chapels ring and tower clocks strike. Well-built houses shows slight damages, e.g. cracks in the plaster, mouldings and walls renderings fall. Major, but not destructive damages, occur on not very well-built buildings. Some bricks and tiles can fall. | **Modest effects on the environment**<br>Primary effects are absent.<br>*Occasionally thin, millimetric, fractures are observed in loose alluvial deposits and/or saturated soils; along steep slopes or riverbanks they can be 1-2 cm wide. A few minor cracks develop in paved (asphalt / stone) roads.*<br>Rare occurrence of significant variations in water level in wells and/or the flow-rate of springs.<br>Rare occurrence of variations of chemical-physical properties of water and turbidity of water in lakes, springs and wells.<br>Rockfalls and landslides up to ca. $10^3$ $m^3$ can occur, especially where equilibrium is unstable, e.g. steep slopes and cuts, with loose / saturated soil, or weathered / fractured rocks. The area affected by them is usually less than 1 $km^2$.<br>*Rare cases of liquefaction (sand boil), small in size and in areas most prone to this phenomenon (hihgly susceptible, recent, alluvial and coastal deposits, shallow water table).*<br>Extremely rare occurrence of karst vault collapses, which may result in the formation of sinkholes.<br>Occurrence of landslides under sea level in coastal areas.<br>Occasionally significant waves are generated in still waters.<br>*In wooded areas, trees shake; a very few unstable limbs may break and fall, also depending on species and state of health.* |

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| VII | **Very strong**<br>Quite a few damages are caused on objects and furniture in flats, even heavy pieces. These fall over and/or break. Big bells toll. Watercourses, ponds and water bodies get wavy and cloudy due to the movements of the slime on the bottom. Parts of sand and gravel shores disappear. The water levels of the wells vary. Moderated damages occur to quite a few well-built buildings, e.g. small cracks in the walls. Quite big pieces of plastering and bricks fall. A lot of tiles fall. Quite a few chimneys are damaged by cracks, fallen tiles and stones. Chimneys, which were already damaged, fall on the roofs damaging them. Decoration of towers and high buildings, which were not very well applied, fall. Quite a lot of damages are caused to the plastering and structures of houses. Single houses not very well built or restored, fall down. | **Appreciable effects on the environment**<br>Primary effects observed very rarely. Limited surface faulting, with length of tens of meters and centimetric offset, may occur associated with volcano-tectonic earthquakes.<br>*Fractures up to 5-10 cm wide are observed commonly in loose alluvial deposits and/or saturated soils; rarely in dry sand, sand-clay, and clay soil fractures up to 1 cm wide. Centimetric cracks common in paved (asphalt or stone) roads.*<br>Rare occurrence of significant variations in water level in wells and/or the flow rate of springs. Very rarely, small springs may temporarily run dry or be activated.<br>Quite common occurrence of variations of chemical-physical properties of water and turbidity of water in lakes, springs and wells.<br>Scattered landslides occur in prone areas; where equilibrium is unstable (steep slopes of loose / saturated soils; rock falls on steep gorges, coastal cliffs) their size is sometimes significant ($10^3$ – $10^5$ $m^3$); in dry sand, sand-clay, and clay soil, the volumes are usually up to 100 $m^3$. Ruptures, slides and falls may affect riverbanks and artificial embankments and excavations (e.g., road cuts, quarries) in loose sediment or weathered / fractured rock. The affected area is usually less than 10 $km^2$.<br>*Rare cases of liquefaction, with sand boils up to 50 cm in diameter, in areas most prone to this phenomenon (hihgly susceptible, recent, alluvial and coastal deposits, shallow water table).*<br>Possible collapse of karst vaults with the formation of sinkholes, even where the water table is deep.<br>Occurrence of significant landslides under sea level in coastal areas.<br>Waves may develop in still and running waters.<br>In wooded areas, trees shake; several unstable branches may break and fall, also depending on species and state of health. |

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| VIII | **Ruinous**<br>Whole tree trunks sway lively or fall down. Very heavy pieces of furniture are moved far from their original places or even knocked over. Statues, milestones placed in the ground or even in churches, cemeteries, and parks rotate on their pedestals or are knocked down. Solid town walls of stones are opened and knocked down. Severe damages occur in about a fourth of the houses; some fall down and quite a few become uninhabitable. Most part of the framing falls in buildings. Wooden houses are either crushed or knocked down. In particular the falling of the church towers and smoke stacks cause much higher damages to the nearby buildings than the earthquake itself. Cracks are formed in slopes and the ground. Sand and slime in wet grounds come out. | **Considerable effects on the environement**<br>*Primary effects observed rarely. Ground ruptures (surface faulting) may develop, up to several hundred meters long, with offsets generally smaller than 5 cm, particularly for very shallow focus earthquakes, such as volcano-tectonic events. Tectonic subsidence or uplift of the ground surface with maximum values on the order of a few centimeters may occur.*<br>*Fractures up to 25 - 50 cm wide are commonly observed in loose alluvial deposits and/or saturated soils; in rare cases fractures up to 1 cm can be observed in competent dry rocks. Decimetric cracks common in paved (asphalt or stone) roads, as well as small pressure undulations. Springs can change, generally temporarily, their flow-rate and/or elevation of outcrop. Some small springs may even run dry. Variations in water level are observed in wells. Water temperature often change in springs and/or wells. Water in lakes and rivers frequently become muddy.*<br>Small to moderate ($10^3$ – $10^5$ $m^3$) landslides widespread in prone areas; rarely they can occur also on gentle slopes; where equilibrium is unstable (steep slopes of loose / saturated soils; rock falls on steep gorges, coastal cliffs) their size is sometimes large ($10^5$ – $10^6$ $m^3$). Landslides can occasionally dam narrow valleys causing temporary or even permanent lakes. Ruptures, slides and falls affect riverbanks and artificial embankments and excavations (e.g., road cuts, quarries) in loose sediment or weathered / fractured rock. The affected area is usually less than 100 $km^2$.<br>*Liquefaction may be frequent in the epicentral area, depending on local conditions; sand boils up to ca. 1 m in diameter; apparent water fountains in still waters; localised lateral spreading and settlements (subsidence up to ca. 30 cm), with fissuring parallel to waterfront areas (river banks, lakes, canals, seashores).*<br>Karst vaults may collapse, forming sinkholes. Frequent occurrence of landslides under the sea level in coastal areas.<br>Significant waves develop in still and running waters.<br>*Trees shake vigorously; some branches or rarely even tree-trunks in very unstable equilibrium may break and fall. In dry areas, dust clouds may rise from the ground in the epicentral area.* |

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| IX | **Destructive**<br>About half of the stone houses are severely destroyed; quite a few collapse, most of them become uninhabitable. Framed houses are destroyed at the foundations and crushed. The fact that beams are torn away from their original places can often cause major damages to the buildings. | **Natural effects leave significant and permanent traces in the environment**<br>*Primary effects observed commonly. Ground ruptures (surface faulting) develop, up to a few km long, with offsets generally smaller than 10 - 20 cm. Tectonic subsidence or uplift of the ground surface with maximum values in the order of a few decimeters may occur.*<br>*Fractures up to 50 - 100 cm wide are commonly observed in loose alluvial deposits and/or saturated soils; in competent rocks they can reach up to 10 cm. Significant cracks common in paved (asphalt or stone) roads, as well as small pressure undulations.*<br>Springs can change their flow-rate and/or elevation of outcrop to a considerable extent. Some small springs may even run dry. Variations in water level are observed in wells.<br>Water temperature often change in springs and/or wells. Water in lakes and rivers frequently become muddy.<br>*Landsliding widespread in prone areas, also on gentle slopes; where equilibrium is unstable (steep slopes of loose / saturated soils; rock falls on steep gorges, coastal cliffs) their size is frequently large ($10^5$ $m^3$), sometimes very large ($10^6$ $m^3$). Landslides can dam narrow valleys causing temporary or even permanent lakes. Riverbanks, artificial embankments and excavations (e.g., road cuts, quarries) frequently collapse. The affected area is usually less than 1000 $km^2$.*<br>*Liquefaction and water upsurge are frequent; sand boils up to 3 m in diameter; apparent water fountains in still waters; frequent lateral spreading and settlements (subsidence of more than ca. 30 cm), with fissuring parallel to waterfront areas (river banks, lakes, canals, seashores).*<br>Karst vaults of relevant size collapse, forming sinkholes.<br>Frequent large landslides under the sea level in coastal areas.<br>*Large waves develop in still and running waters. Small tsunamis may reach the coastal areas with tidal waves up to 50 - 100 cm high.*<br>Trees shake vigorously; branches or even tree-trunks in unstable equilibrium frequently break and fall.<br>In dry areas dust clouds may rise from the ground.<br>In the epicentral area, small stones may jump out of the ground, leaving typical imprints in soft soil. |

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| X | **Completely destructive**<br>Very severe destruction of about ¾ of the buildings; most of them fall down. Very severe damages occur on solid wooden buildings and bridges; some of then are destroyed. Bank, dams, etc. are highly damaged. Railways are bent slightly and pipes (water, gas and water pipes) are cut off or broken or crushed. Cracks are formed in paved and asphalted streets, which are furthermore uplifted due to the pressure. Cracks, which width can be up to several decimetres form in thin, and above all, wet ground. In particular cracks almost a metre wide form parallel to watercourses. Not only does soil slide down hillslopes, but boulders roll down towards the valley. Rocks falls from the river embankments and cliffs. Sandy and muddy shores are moved, causing not important changes to the landscape. The water level of the wells varies continually. Rivers, canals, lakes , etc. become very wavy. | **Environmental effects become dominant**<br>*Primary ruptures become leading. Ground ruptures (surface faulting) can extend for several tens of km, with offsets reaching 50 - 100 cm and more (up to ca. 1-2 m in case of reverse faulting and 3-4 m for normal faulting). Gravity grabens and elongated depressions develop; for very shallow focus earthquakes, such as volcano-tectonic events, rupture lengths might be much lower. Tectonic subsidence or uplift of the ground surface with maximum values in the order of few meters may occur.*<br>*Large landslides and rock-falls (> $10^5$ – $10^6$ $m^3$) are frequent, practically regardless to equilibrium state of the slopes, causing temporary or permanent barrier lakes. River banks, artificial embankments, and sides of excavations typically collapse. Levees and earth dams may even incur serious damage. The affected area is usually up to 5000 $km^2$.*<br>Many springs significantly change their flow-rate and/or elevation of outcrop. Some may run dry or disappear, generally temporarily. Variations in water level are observed in wells.<br>Water temperature often change in springs and/or wells. Water in lakes and rivers frequently become muddy.<br>*Open ground cracks up to more than 1 m wide are frequent, mainly in loose alluvial deposits and/or saturated soils; in competent rocks opening reach several decimeters. Wide cracks develop in paved (asphalt or stone) roads, as well as pressure undulations.*<br>*Liquefaction, with water upsurge and soil compaction, may change the aspect of wide zones; sand volcanoes even more than 6 m in diameter; vertical subsidence even > 1m; large and long fissures due to lateral spreading are common.*<br>Large karst vaults collapse, forming great sinkholes.<br>Frequent large landslides under the sea level in coastal areas.<br>*Large waves develop in still and running waters, and crash violently into the shores. Running (rivers, canals) and still (lakes) waters may overflow from their beds. Tsunamis reach the coastal areas, with tidal waves up to a few meters high.*<br>Trees shake vigorously; branches or even tree-trunks very frequently break and fall, if already in unstable equilibrium.<br>In dry areas, dust clouds may rise from the ground.<br>*Stones, even if well anchored in the soil, may jump out of the ground, leaving typical imprints in soft soil.* |

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| XI | **Catastrophic**<br><br>Entire stone buildings collapse. Only very well-built stone buildings or isolated (and very elastic) wooden huts manage to stand up to the earthquake. Even very solid and big bridges collapse due to the fall of stone pillars or iron ones which give away. Embankments and dams are taken to pieces. Railway lines are severely bent and crushed. Pipes in the ground are torn away from one another and are not longer repairable. Big movements of various extension occur in the ground, the intensity of which is determined by the type of terrain. Big cracks and cleavages are opened. In soft and marshy terrains the instability is mostly horizontal and vertical, thus causing the overflow of sandy and slimy water. Grounds crumbling and rock fall. | **Environmental effects become essential for intensity assessment**<br>*Primary surface faulting can extend for several tens of km up to more than 100 km, accompanied by offsets reaching several meters. Gravity graben, elongated depressions and pressure ridges develop. Drainage lines can be seriously offset. Tectonic subsidence or uplift of the ground surface with maximum values in the order of numerous meters may occur.*<br>*Large landslides and rock-falls (> $10^5$ – $10^6$ m3) are frequent, practically regardless to equilibrium state of the slopes, causing many temporary or permanent barrier lakes. River banks, artificial embankments, and sides of excavations typically collapse. Levees and earth dams incur serious damage. Significant landslides can occur at 200 – 300 km distance from the epicenter. Primary and secondary environmental effects can be observed over territory as large as 10000 $km^2$.*<br>Many springs significantly change their flow-rate and/or elevation of outcrop. Frequently, they may run dry or disappear altogether. Variations in water level are observed in wells.<br>Water temperature often change in springs and/or wells. Water in lakes and rivers frequently becomes muddy.<br>*Open ground cracks up to several meters wide are very frequent, mainly in loose alluvial deposits and/or saturated soils. In competent rocks they can reach 1 m. Very wide cracks develop in paved (asphalt or stone) roads, as well as large pressure undulations.*<br>*Liquefaction changes the aspect of extensive zones of lowland, determining vertical subsidence possibly exceeding several meters, numerous large sand volcanoes, and severe lateral spreading features.*<br>Very large karst vaults collapse, forming sinkholes.<br>Frequent large landslides under the sea level in coastal areas.<br>*Large waves develop in still and running water, and crash violently into the shores. Running (rivers, canals) and still (lakes) waters may overflow from their beds. Tsunamis reach the coastal areas with tidal waves up to many meters high.*<br>*Trees shake vigorously; many tree branches break and several whole trees are uprooted and fall.*<br>In dry areas dust clouds may arise from the ground.<br>*Stones and small boulders, even if well anchored in the soil, may jump out of the ground leaving typical imprints in soft soil.* |

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| XII | **Absolutely catastrophic**<br>No artifact can resist. The landscape change completely. Superficial and underground watercourses undergo the most different changes: waterfalls appear, water bodies disappear, rivers change their course. | **Environmental effects are now the only tool enabling intensity to be assessed**<br>*Primary surface faulting can extend for several hundreds of km up to 1000 km, accompanied by offsets reaching several tens of meters. Gravity graben, elongated depressions and pressure ridges develop. Drainage lines can be seriously offset. Landscape and geomorphological changes induced by primary effects can attain extraordinary extent and size (typical examples are the uplift or subsidence of coastlines by several meters, appearance or disappearance from sight of significant landscape elements, rivers changing course, origination of waterfalls, formation or disappearance of lakes).*<br>*Large landslides and rock-falls (> $10^5$ – $10^6$ $m^3$) are frequent, practically regardless to equilibrium state of the slopes, causing many temporary or permanent barrier lakes. River banks, artificial embankments, and sides of excavations typically collapse. Levees and earth dams incur serious damage. Significant landslides can occur at more than 200 – 300 km distance from the epicenter. Primary and secondary environmental effects can be observed over territory larger than 50000 $km^2$.*<br>Many springs significantly change their flow-rate and/or elevation of outcrop. Frequently, they may run dry or disappear altogether. Variations in water level are observed in wells.<br>Water temperature often changes in springs and/or wells. Water in lakes and rivers frequently becomes muddy.<br>*Ground open cracks are very frequent, up to one meter or more wide in the bedrock, up to more than 10 m wide in loose alluvial deposits and/or saturated soils. These may extend up to several kilometers in length.*<br>*Liquefaction occurs over large areas and changes the morphology of extensive flat zones, determining vertical subsidence exceeding several meters, widespread large sand volcanoes, and extensive severe lateral spreading features.*<br>Very large karst vaults collapse, forming sinkholes.<br>Frequent very large landslides under the sea level in coastal areas.<br>*Large waves develop in still and running water, and crash violently into the shores. Running (rivers, canals) and still (lakes) waters overflow from their beds; watercourses change the direction of flow. Tsunamis reach the coastal areas with tidal waves up to tens of meters high.*<br>Trees shake vigorously; many tree branches break and many whole trees are uprooted and fall.<br>In dry areas dust clouds may arise from the ground.<br>Even large boulders may jump out of the ground leaving typical imprints in soft soil. |

## Modified Mercalli Scale of 1931

| Intensity | Modified Mercalli Scale of 1931 | INQUA Scale |
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| I | Not felt - or, except rarely under especially favourable circumstances. Under certain conditions, at and outside the boundary of the area which a great shock is felt: sometimes birds, animals, reported uneasy or disturbed; sometimes dizziness or nausea experienced; sometimes trees, structures, liquids, bodies of water, may sway - doors may swing, very slowly. | **No perceptible environmental effects**<br>Extremely rare occurrence of small effects detected only from instrumental observations, typically in the far field of strong earthquakes. |
| II | Felt indoors by few, especially on upper floors, or by sensitive, or nervous persons. Also, as in grade I, but often more noticeably: sometimes hanging objects may swing, especially when delicately suspended; sometimes trees, structures, liquids, bodies of water, may sway, doors may swing, very slowly; sometimes birds, animals, reported uneasy or disturbed; sometimes dizziness or nausea experienced. | **No perceptible environmental effects**<br>Extremely rare occurrence of small effects detected only from instrumental observations, typically in the far field of strong earthquakes. |
| III | Felt indoors by several, motion usually rapid vibration. Sometimes not recognized to be an earthquake at first, duration estimated in some cases. Vibration like that due to passing of light, or lightly loaded trucks, or heavy trucks some distance away. Hanging objects may swing slightly. Movement may be appreciable on upper levels of tall structures. Rocked standing motor cars slightly | **No perceptible environmental effects**<br>Primary effects are absent.<br>Extremely rare occurrence of small variations in water level in wells and/or the flow-rate of springs, typically in the far field of strong earthquakes. |
| IV | Felt indoors by many, outdoors by few. Awakened few, especially light sleepers. Frightened no one, unless apprehensive from previous experience. Vibration like that due to passing of heavy, or heavily loaded trucks. Sensation like heavy body striking building, or falling of heavy objects to inside. Rattling of dishes, windows, doors; glassware and crockery clink and clash. Creaking of walls, frame, especially in the upper range of this grade. Hanging objects swing, in numerous instances. Disturbed liquids in open vessels slightly. Rocked standing motor cars slightly. | **No perceptible environmental effects**<br>Primary effects are absent.<br>A very few cases of fine cracking at locations where lithology (e.g., loose alluvial deposits, saturated soils) and/or morphology (slopes or ridge crests) are most prone to this phenomenon.<br>Rare occurrence of small variations in water level in wells and/or the flow-rate of springs.<br>Extremely rare occurrence of small variations of chemical-physical properties of water and turbidity of water in lakes, springs and wells, especially within large karstic spring systems most prone to this phenomenon.<br>Exceptionally, rocks may fall and small landslides may be (re)activated, along slopes where equilibrium is already very unstable, e.g. steep slopes and cuts, with loose or saturated soil.<br>Extremely rare occurrence of karst vault collapses, which may result in the formation of sinkholes, where the water table is shallow within large karstic spring systems.<br>Very rare temporary sea level changes in the far field of strong earthquakes.<br>Tree limbs may shake. |

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| V | Felt indoors by practically all, outdoors by many or most. Outdoors direction estimated. Awakened many, or most. Frightened few - slight excitement, a few ran outdoors. Buildings trembled throughout. Broke dishes, glassware, to some extent. Cracked windows - in some cases, but not generally. Overturned small or unstable objects, in many instances, with occasional fall. Hanging objects, doors, swing generally or considerably. Knocked pictures against walls, or swung them out of place. Opened or closed, doors, shutters, abruptly. Pendulum clocks stopped, started, or ran fast, or slow. Moved small objects, furnishings, the latter to slight extent. Spilled liquids in small amounts from well-filled open containers. Trees, bushes, shaken slightly. | **Marginal effects on the environment**<br>Primary effects are absent.<br>A few cases of fine cracking at locations where lithology (e.g., loose alluvial deposits, saturated soils) and/or morphology (slopes or ridge crests) are most prone to this phenomenon.<br>Extremely rare occurrence of significant variations in water level in wells and/or the flow-rate of springs.<br>Rare occurrence of small variations of chemical-physical properties of water and turbidity of water in lakes, springs and wells.<br>Rare small rockfalls, rare rotational landslides and slump earth flows, along slopes where equilibrium is unstable, e.g. steep slopes, with loose or saturated soil.<br>Extremely rare cases of liquefaction (sand boil), small in size and in areas most prone to this phenomenon (hihgly susceptible, recent, alluvial and coastal deposits, shallow water table).<br>Extremely rare occurrence of karst vault collapses, which may result in the formation of sinkholes, where the water table is shallow within large karstic spring systems.<br>Occurrence of landslides under sea (lake) level in coastal areas.<br>Rare temporary sea level changes in the far field of strong earthquakes.<br>Tree limbs may shake. |
| VI | Felt by all, indoors and outdoors. Frightened many, excitement general, some alarm, many ran outdoors. Awakened all. Persons made to move unsteadily. Trees, bushes, shaken slightly to moderately. Liquid set in strong motion. Small bells rang -church, chapel, school etc. Damage slight in poorly built buildings. Fall of plaster in small amount. Cracked plaster somewhat, especially fine cracks chimneys in some instances. Broke dishes, glassware, in considerable quantity, also some windows. Fall of knick-knacks, books, pictures. Overturned furniture, in many instances. Moved furnishings of moderately heavy kind. | **Modest effects on the environment**<br>Primary effects are absent.<br>*Occasionally thin, millimetric, fractures are observed in loose alluvial deposits and/or saturated soils; along steep slopes or riverbanks they can be 1-2 cm wide. A few minor cracks develop in paved (asphalt / stone) roads.*<br>Rare occurrence of significant variations in water level in wells and/or the flow-rate of springs.<br>Rare occurrence of variations of chemical-physical properties of water and turbidity of water in lakes, springs and wells.<br>Rockfalls and landslides up to ca. $10^3$ $m^3$ can occur, especially where equilibrium is unstable, e.g. steep slopes and cuts, with loose / saturated soil, or weathered / fractured rocks. The area affected by them is usually less than 1 $km^2$.<br>*Rare cases of liquefaction (sand boil), small in size and in areas most prone to this phenomenon (hihgly susceptible, recent, alluvial and coastal deposits, shallow water table).*<br>Extremely rare occurrence of karst vault collapses, which may result in the formation of sinkholes.<br>Occurrence of landslides under sea level in coastal areas.<br>Occasionally significant waves are generated in still waters.<br>*In wooded areas, trees shake; a very few unstable limbs may break and fall, also depending on species and state of health.* |

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| VII | Frightened all - general alarm, all ran outdoors. Some, or many, found it difficult to stand. Noticed by persons driving motor cars. Trees and bushes shaken moderately to strongly. Waves on ponds, lakes, and running water. Water turbid from mud stirred up. Incaving to some extent of sand or gravel stream banks. Rang large church bells, etc. Suspended objects made to quiver. Damage negligible in buildings of good design and construction, slight to moderate in well-build ordinary buildings, considerable in poorly build or badly designed buildings, abode houses, old walls (especially where laid up without mortar), spires, etc. Cracked chimneys to considerable extent, walls to some extent. Fall of plaster in considerable to large amount, also some stucco. Broke numerous windows, furniture to some extent. Shook down loosened brickwork and tiles. Broke weak chimneys at the roof-line (sometimes damaging roof. Fall of cornices from towers and high buildings. Dislodged bricks and stones. Overturned heavy furniture, with damage from breaking. Damage considerable to concrete irrigation ditches. | **Appreciable effects on the environment**<br>Primary effects observed very rarely. Limited surface faulting, with length of tens of meters and centimetric offset, may occur associated with volcano-tectonic earthquakes.<br>*Fractures up to 5-10 cm wide are observed commonly in loose alluvial deposits and/or saturated soils; rarely in dry sand, sand-clay, and clay soil fractures up to 1 cm wide. Centimetric cracks common in paved (asphalt or stone) roads.*<br>Rare occurrence of significant variations in water level in wells and/or the flow rate of springs. Very rarely, small springs may temporarily run dry or be activated.<br>Quite common occurrence of variations of chemical-physical properties of water and turbidity of water in lakes, springs and wells.<br>Scattered landslides occur in prone areas; where equilibrium is unstable (steep slopes of loose / saturated soils; rock falls on steep gorges, coastal cliffs) their size is sometimes significant ($10^3$ – $10^5$ $m^3$); in dry sand, sand-clay, and clay soil, the volumes are usually up to 100 $m^3$. Ruptures, slides and falls may affect riverbanks and artificial embankments and excavations (e.g., road cuts, quarries) in loose sediment or weathered / fractured rock. The affected area is usually less than 10 $km^2$.<br>*Rare cases of liquefaction, with sand boils up to 50 cm in diameter, in areas most prone to this phenomenon (hihgly susceptible, recent, alluvial and coastal deposits, shallow water table).*<br>Possible collapse of karst vaults with the formation of sinkholes, even where the water table is deep.<br>Occurrence of significant landslides under sea level in coastal areas.<br>Waves may develop in still and running waters.<br>In wooded areas, trees shake; several unstable branches may break and fall, also depending on species and state of health. |

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| VIII | Fright general - alarm approaches panic. Disturbed persons driving motor cars. Trees shaken strongly - branches, trunks, broken off, especially palm trees. Ejected sand and mud in small amounts. Changes: temporary, permanent; in flow of springs and wells; dry wells renewed flow; in temperature of spring and well waters. Damage slight in structures (brick) built especially to withstand earthquakes. Considerable in ordinary substantial buildings, partial collapse: racked, tumbled down, wooden houses in some cases; threw out panel walls in frame structures, broke off decayed piling. Fall of walls. Cracked, broke, solid stone walls seriously. Wet ground to some extent, also ground on steep slopes. Twisting, fall, of chimneys, columns, monuments, also factory stack, towers. Moved conspicuously, overturned, very heavy furniture. | **Considerable effects on the environement**<br>*Primary effects observed rarely. Ground ruptures (surface faulting) may develop, up to several hundred meters long, with offsets generally smaller than 5 cm, particularly for very shallow focus earthquakes, such as volcano-tectonic events. Tectonic subsidence or uplift of the ground surface with maximum values on the order of a few centimeters may occur.*<br>*Fractures up to 25 - 50 cm wide are commonly observed in loose alluvial deposits and/or saturated soils; in rare cases fractures up to 1 cm can be observed in competent dry rocks. Decimetric cracks common in paved (asphalt or stone) roads, as well as small pressure undulations.*<br>*Springs can change, generally temporarily, their flow-rate and/or elevation of outcrop. Some small springs may even run dry. Variations in water level are observed in wells. Water temperature often change in springs and/or wells. Water in lakes and rivers frequently become muddy.*<br>Small to moderate ($10^3$ – $10^5$ $m^3$) landslides widespread in prone areas; rarely they can occur also on gentle slopes; where equilibrium is unstable (steep slopes of loose / saturated soils; rock falls on steep gorges, coastal cliffs) their size is sometimes large ($10^5$ – $10^6$ $m^3$). Landslides can occasionally dam narrow valleys causing temporary or even permanent lakes. Ruptures, slides and falls affect riverbanks and artificial embankments and excavations (e.g., road cuts, quarries) in loose sediment or weathered / fractured rock. The affected area is usually less than 100 $km^2$.<br>*Liquefaction may be frequent in the epicentral area, depending on local conditions; sand boils up to ca. 1 m in diameter; apparent water fountains in still waters; localised lateral spreading and settlements (subsidence up to ca. 30 cm), with fissuring parallel to waterfront areas (river banks, lakes, canals, seashores).*<br>Karst vaults may collapse, forming sinkholes. Frequent occurrence of landslides under the sea level in coastal areas.<br>Significant waves develop in still and running waters.<br>*Trees shake vigorously; some branches or rarely even tree-trunks in very unstable equilibrium may break and fall. In dry areas, dust clouds may rise from the ground in the epicentral area.* |

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| IX | Panic general. Cracked ground conspicuously. Damage considerable in (masonry) structure build especially to withstand earthquakes: threw out of plumb some wood-frame houses build especially to withstand earthquakes; great in substantial (masonry) buildings, some collapse in large part; or wholly shifted frame buildings off foundations, racked frames; serious to reservoirs; underground pipes sometimes broken. | **Natural effects leave significant and permanent traces in the environment**<br>*Primary effects observed commonly. Ground ruptures (surface faulting) develop, up to a few km long, with offsets generally smaller than 10 - 20 cm. Tectonic subsidence or uplift of the ground surface with maximum values in the order of a few decimeters may occur.*<br>*Fractures up to 50 - 100 cm wide are commonly observed in loose alluvial deposits and/or saturated soils; in competent rocks they can reach up to 10 cm. Significant cracks common in paved (asphalt or stone) roads, as well as small pressure undulations.*<br>Springs can change their flow-rate and/or elevation of outcrop to a considerable extent. Some small springs may even run dry. Variations in water level are observed in wells.<br>Water temperature often change in springs and/or wells. Water in lakes and rivers frequently become muddy.<br>*Landsliding widespread in prone areas, also on gentle slopes; where equilibrium is unstable (steep slopes of loose / saturated soils; rock falls on steep gorges, coastal cliffs) their size is frequently large ($10^5$ $m^3$), sometimes very large ($10^6$ $m^3$). Landslides can dam narrow valleys causing temporary or even permanent lakes. Riverbanks, artificial embankments and excavations (e.g., road cuts, quarries) frequently collapse. The affected area is usually less than 1000 $km^2$.*<br>*Liquefaction and water upsurge are frequent; sand boils up to 3 m in diameter; apparent water fountains in still waters; frequent lateral spreading and settlements (subsidence of more than ca. 30 cm), with fissuring parallel to waterfront areas (river banks, lakes, canals, seashores).*<br>Karst vaults of relevant size collapse, forming sinkholes.<br>Frequent large landslides under the sea level in coastal areas.<br>*Large waves develop in still and running waters. Small tsunamis may reach the coastal areas with tidal waves up to 50 - 100 cm high.*<br>Trees shake vigorously; branches or even tree-trunks in unstable equilibrium frequently break and fall.<br>In dry areas dust clouds may rise from the ground. In the epicentral area, small stones may jump out of the ground, leaving typical imprints in soft soil. |

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| X | Cracked ground, especially when loose and wet, up to widths of several inches; fissures up to a yard in width ran parallel to canal and stream banks. Landslides considerable from river banks and steep coasts. Shifted sand and mud horizontally on beaches and flat land. Changed level of water in wells. Threw water on banks of canals, lakes, rivers, etc. Damage serious to dams, dikes, embankments. Severe to well-build wooden structures and bridges, some destroyed. Developed dangerous cracks in excellent brick walls. Destroyed most masonry and frame structures, also their foundations. Bent railroad rails slightly. Tore apart, or crushed endwise, pipe lines buried in earth. Open cracks and broad wavy folds in cement pavements and asphalt road surfaces. | **Environmental effects become dominant**<br>*Primary ruptures become leading. Ground ruptures (surface faulting) can extend for several tens of km, with offsets reaching 50 - 100 cm and more (up to ca. 1-2 m in case of reverse faulting and 3-4 m for normal faulting). Gravity grabens and elongated depressions develop; for very shallow focus earthquakes, such as volcano-tectonic events, rupture lengths might be much lower. Tectonic subsidence or uplift of the ground surface with maximum values in the order of few meters may occur.*<br>*Large landslides and rock-falls (> $10^5$ – $10^6$ $m^3$) are frequent, practically regardless to equilibrium state of the slopes, causing temporary or permanent barrier lakes. River banks, artificial embankments, and sides of excavations typically collapse. Levees and earth dams may even incur serious damage. The affected area is usually up to 5000 $km^2$.*<br>Many springs significantly change their flow-rate and/or elevation of outcrop. Some may run dry or disappear, generally temporarily. Variations in water level are observed in wells.<br>Water temperature often change in springs and/or wells. Water in lakes and rivers frequently become muddy.<br>*Open ground cracks up to more than 1 m wide are frequent, mainly in loose alluvial deposits and/or saturated soils; in competent rocks opening reach several decimeters. Wide cracks develop in paved (asphalt or stone) roads, as well as pressure undulations.*<br>*Liquefaction, with water upsurge and soil compaction, may change the aspect of wide zones; sand volcanoes even more than 6 m in diameter; vertical subsidence even > 1m; large and long fissures due to lateral spreading are common.*<br>Large karst vaults collapse, forming great sinkholes.<br>Frequent large landslides under the sea level in coastal areas.<br>*Large waves develop in still and running waters, and crash violently into the shores. Running (rivers, canals) and still (lakes) waters may overflow from their beds. Tsunamis reach the coastal areas, with tidal waves up to a few meters high.*<br>Trees shake vigorously; branches or even tree-trunks very frequently break and fall, if already in unstable equilibrium.<br>In dry areas, dust clouds may rise from the ground.<br>*Stones, even if well anchored in the soil, may jump out of the ground, leaving typical imprints in soft soil.* |

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| XI | Disturbances in ground many and widespread, varying with ground material. Broad fissures, earth slumps, and land slips in soft, wet ground. Ejected water in large amounts charged with sand and mud. Caused sea-waves ("tidal" waves) of significant magnitude. Damage severe to wood-frame structures, especially near shock centers. Great to dams, dikes, embankments, often for long distances. Few, if any (masonry), structures remained standing. Destroyed large well-built bridges by the wrecking of supporting piers, or pillars. Affected yielding wooden bridges less. Bent railroad rails greatly, and thrust them endwise. Put pipe lines buried in earthy completely out of service. | **Environmental effects become essential for intensity assessment**<br>*Primary surface faulting can extend for several tens of km up to more than 100 km, accompanied by offsets reaching several meters. Gravity graben, elongated depressions and pressure ridges develop. Drainage lines can be seriously offset. Tectonic subsidence or uplift of the ground surface with maximum values in the order of numerous meters may occur.*<br>*Large landslides and rock-falls (> $10^5$ – $10^6$ m3) are frequent, practically regardless to equilibrium state of the slopes, causing many temporary or permanent barrier lakes. River banks, artificial embankments, and sides of excavations typically collapse. Levees and earth dams incur serious damage. Significant landslides can occur at 200 – 300 km distance from the epicenter. Primary and secondary environmental effects can be observed over territory as large as 10000 $km^2$.*<br>Many springs significantly change their flow-rate and/or elevation of outcrop. Frequently, they may run dry or disappear altogether. Variations in water level are observed in wells.<br>Water temperature often change in springs and/or wells. Water in lakes and rivers frequently becomes muddy.<br>*Open ground cracks up to several meters wide are very frequent, mainly in loose alluvial deposits and/or saturated soils. In competent rocks they can reach 1 m. Very wide cracks develop in paved (asphalt or stone) roads, as well as large pressure undulations.*<br>*Liquefaction changes the aspect of extensive zones of lowland, determining vertical subsidence possibly exceeding several meters, numerous large sand volcanoes, and severe lateral spreading features.*<br>Very large karst vaults collapse, forming sinkholes. Frequent large landslides under the sea level in coastal areas.<br>*Large waves develop in still and running water, and crash violently into the shores. Running (rivers, canals) and still (lakes) waters may overflow from their beds. Tsunamis reach the coastal areas with tidal waves up to many meters high.*<br>*Trees shake vigorously; many tree branches break and several whole trees are uprooted and fall.*<br>In dry areas dust clouds may arise from the ground.<br>*Stones and small boulders, even if well anchored in the soil, may jump out of the ground leaving typical imprints in soft soil.* |

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| XII | Damage total - practically all works of construction damaged greatly or destroyed. Disturbances in ground great and varied, numerous shearing cracks. Landslides, falls of rock of significant character, slumping of river banks, etc. numerous and extensive. Wrenched loose, tore off, large rock masses. Fault slips in firm rock, with notable horizontal and vertical offset displacements. Water channels, surface and underground, disturbed and modified greatly. Dammed lakes, produced waterfalls, deflected rivers, etc. Waves seen on ground surfaces (actually seen, probably, in some cases). Distorted lines of sight and level. Threw objects upward into the air. | **Environmental effects are now the only tool enabling intensity to be assessed**<br>*Primary surface faulting can extend for several hundreds of km up to 1000 km, accompanied by offsets reaching several tens of meters. Gravity graben, elongated depressions and pressure ridges develop. Drainage lines can be seriously offset. Landscape and geomorphological changes induced by primary effects can attain extraordinary extent and size (typical examples are the uplift or subsidence of coastlines by several meters, appearance or disappearance from sight of significant landscape elements, rivers changing course, origination of waterfalls, formation or disappearance of lakes).*<br>*Large landslides and rock-falls (> $10^5$ – $10^6$ $m^3$) are frequent, practically regardless to equilibrium state of the slopes, causing many temporary or permanent barrier lakes. River banks, artificial embankments, and sides of excavations typically collapse. Levees and earth dams incur serious damage. Significant landslides can occur at more than 200 – 300 km distance from the epicenter. Primary and secondary environmental effects can be observed over territory larger than 50000 $km^2$.*<br>Many springs significantly change their flow-rate and/or elevation of outcrop. Frequently, they may run dry or disappear altogether. Variations in water level are observed in wells.<br>Water temperature often changes in springs and/or wells. Water in lakes and rivers frequently becomes muddy.<br>*Ground open cracks are very frequent, up to one meter or more wide in the bedrock, up to more than 10 m wide in loose alluvial deposits and/or saturated soils. These may extend up to several kilometers in length.*<br>*Liquefaction occurs over large areas and changes the morphology of extensive flat zones, determining vertical subsidence exceeding several meters, widespread large sand volcanoes, and extensive severe lateral spreading features.*<br>Very large karst vaults collapse, forming sinkholes.<br>Frequent very large landslides under the sea level in coastal areas.<br>*Large waves develop in still and running water, and crash violently into the shores. Running (rivers, canals) and still (lakes) waters overflow from their beds; watercourses change the direction of flow. Tsunamis reach the coastal areas with tidal waves up to tens of meters high.*<br>Trees shake vigorously; many tree branches break and many whole trees are uprooted and fall.<br>In dry areas dust clouds may arise from the ground.<br>Even large boulders may jump out of the ground leaving typical imprints in soft soil. |

# Modified Mercalli Scale of 1956

Masonry A, B, C, D. To avoid ambiguity of language, the quality of masonry, brick or otherwise, is specified by the followig lettering(wich has no connection with the conventional Class A, B, C construction)

Classification of masonry:

Masonry A. Good workmanship, mortar, and design; reinforced, especially laterally, and bound together by using steel, concrete, etc.; designed to resist lateral forces.

Masonry B. Good workmanship and mortar; reinforced, but not designed in detail to resist lateral forces.

Masonry C. Ordinary workmanship and mortar; no extreme weaknesses like failing to tie in at corners, but neither reinforced nor designed against horizontal forces

Masonry D. Weak materials, such as adobe; poor mortar; low standards of workmanship; weak orizontally.

| Intensity | Modified Mercalli Scale of 1956 | INQUA Scale |
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| I | Not felt. Marginal and long- period of large earthquakes | **No perceptible environmental effects**<br>Extremely rare occurrence of small effects detected only from instrumental observations, typically in the far field of strong earthquakes. |
| II | Felt by persons at rest, on upper floor, or favourably placed. | **No perceptible environmental effects**<br>Extremely rare occurrence of small effects detected only from instrumental observations, typically in the far field of strong earthquakes. |
| III | Felt indoors. Hanging objects swing. Vibration like passing of light trucks. Duration estimated. May not be recognized as an earthquake. | **No perceptible environmental effects**<br>Primary effects are absent.<br>Extremely rare occurrence of small variations in water level in wells and/or the flow-rate of springs, typically in the far field of strong earthquakes. |
| IV | Hangings objects swing. Vibration like passing of heavy trucks; or sensation of a jolt like a heavy ball striking the walls. Standing motorcars rock. Windows, dishes, doors rattle. Glasses clink. Crockery clashes. In the upper range of grade IV, wooden walls and frames crack. | **No perceptible environmental effects**<br>Primary effects are absent.<br>A very few cases of fine cracking at locations where lithology (e.g., loose alluvial deposits, saturated soils) and/or morphology (slopes or ridge crests) are most prone to this phenomenon.<br>Rare occurrence of small variations in water level in wells and/or the flow-rate of springs.<br>Extremely rare occurrence of small variations of chemical-physical properties of water and turbidity of water in lakes, springs and wells, especially within large karstic spring systems most prone to this phenomenon.<br>Exceptionally, rocks may fall and small landslides may be (re)activated, along slopes where equilibrium is already very unstable, e.g. steep slopes and cuts, with loose or saturated soil.<br>Extremely rare occurrence of karst vault collapses, which may result in the formation of sinkholes, where the water table is shallow within large karstic spring systems.<br>Very rare temporary sea level changes in the far field of strong earthquakes.<br>Tree limbs may shake. |

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| V | Felt outdoors; direction estimated. Sleepers wakened. Liquid disturbed, some spilled. Small unstable objects displaced or upset. Doors swing, close, open. Shutters, pictures move. Pendulum clocks stop, start, change rate. | **Marginal effects on the environment**<br>Primary effects are absent.<br>A few cases of fine cracking at locations where lithology (e.g., loose alluvial deposits, saturated soils) and/or morphology (slopes or ridge crests) are most prone to this phenomenon.<br>Extremely rare occurrence of significant variations in water level in wells and/or the flow-rate of springs.<br>Rare occurrence of small variations of chemical-physical properties of water and turbidity of water in lakes, springs and wells.<br>Rare small rockfalls, rare rotational landslides and slump earth flows, along slopes where equilibrium is unstable, e.g. steep slopes, with loose or saturated soil.<br>Extremely rare cases of liquefaction (sand boil), small in size and in areas most prone to this phenomenon (hihgly susceptible, recent, alluvial and coastal deposits, shallow water table).<br>Extremely rare occurrence of karst vault collapses, which may result in the formation of sinkholes, where the water table is shallow within large karstic spring systems.<br>Occurrence of landslides under sea (lake) level in coastal areas.<br>Rare temporary sea level changes in the far field of strong earthquakes.<br>Tree limbs may shake. |
| VI | Felt by all. Many frightened and run outdoors. Persons walk unsteadily. Windows, dishes, glassware broken. Knickknacks, books, and so on, off shelves. Pictures off walls. Furniture moved or overturned. Weak plaster and masonry D cracked. Small bells ring (church, school). Trees, bushes shaken visibly, or heard to rustle. | **Modest effects on the environment**<br>Primary effects are absent.<br>*Occasionally thin, millimetric, fractures are observed in loose alluvial deposits and/or saturated soils; along steep slopes or riverbanks they can be 1-2 cm wide. A few minor cracks develop in paved (asphalt / stone) roads.*<br>Rare occurrence of significant variations in water level in wells and/or the flow-rate of springs.<br>Rare occurrence of variations of chemical-physical properties of water and turbidity of water in lakes, springs and wells.<br>Rockfalls and landslides up to ca. $10^3$ $m^3$ can occur, especially where equilibrium is unstable, e.g. steep slopes and cuts, with loose / saturated soil, or weathered / fractured rocks. The area affected by them is usually less than 1 $km^2$.<br>*Rare cases of liquefaction (sand boil), small in size and in areas most prone to this phenomenon (hihgly susceptible, recent, alluvial and coastal deposits, shallow water table).*<br>Extremely rare occurrence of karst vault collapses, which may result in the formation of sinkholes.<br>Occurrence of landslides under sea level in coastal areas.<br>Occasionally significant waves are generated in still waters.<br>*In wooded areas, trees shake; a very few unstable limbs may break and fall, also depending on species and state of health.* |

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| VII | Difficult to stand. Noticed by drivers of motor cars. Hangings objects quiver. Furniture broken. Damage to masonry D including cracks. Weak chimneys broken at roof line. Fall of plaster ,loose bricks, stones, tiles, cornices, unbraced parapets, and architectural ornaments. Some cracks in masonry C. Waves on ponds; water turbid with mud. Small slides and caving in along sand or gravel banks. Large bell rising. Concrete irrigation ditches damaged. | **Appreciable effects on the environment**<br>Primary effects observed very rarely. Limited surface faulting, with length of tens of meters and centimetric offset, may occur associated with volcano-tectonic earthquakes.<br>*Fractures up to 5-10 cm wide are observed commonly in loose alluvial deposits and/or saturated soils; rarely in dry sand, sand-clay, and clay soil fractures up to 1 cm wide. Centimetric cracks common in paved (asphalt or stone) roads.*<br>Rare occurrence of significant variations in water level in wells and/or the flow rate of springs. Very rarely, small springs may temporarily run dry or be activated.<br>Quite common occurrence of variations of chemical-physical properties of water and turbidity of water in lakes, springs and wells.<br>Scattered landslides occur in prone areas; where equilibrium is unstable (steep slopes of loose / saturated soils; rock falls on steep gorges, coastal cliffs) their size is sometimes significant ($10^3$ – $10^5$ $m^3$); in dry sand, sand-clay, and clay soil, the volumes are usually up to 100 $m^3$. Ruptures, slides and falls may affect riverbanks and artificial embankments and excavations (e.g., road cuts, quarries) in loose sediment or weathered / fractured rock. The affected area is usually less than 10 $km^2$.<br>*Rare cases of liquefaction, with sand boils up to 50 cm in diameter, in areas most prone to this phenomenon (hihgly susceptible, recent, alluvial and coastal deposits, shallow water table).*<br>Possible collapse of karst vaults with the formation of sinkholes, even where the water table is deep.<br>Occurrence of significant landslides under sea level in coastal areas.<br>Waves may develop in still and running waters.<br>In wooded areas, trees shake; several unstable branches may break and fall, also depending on species and state of health. |

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| VIII | Steering of motor cars affected. Damage to masonry C; partial collapse. Some damage to masonry B; none to masonry A. Fall of stucco and some masonry walls. Twisting, fall of chimneys, factory stacks, monuments, towers, elevated tanks. Frame houses moved on foundation if not bolted down; loose panel walls thrown out. Decayed piling broken off. Branches broken from trees. Changes in flow or temperature of springs and wells. Cracks in wet ground and on steep slopes. | **Considerable effects on the environement**<br>*Primary effects observed rarely. Ground ruptures (surface faulting) may develop, up to several hundred meters long, with offsets generally smaller than 5 cm, particularly for very shallow focus earthquakes, such as volcano-tectonic events. Tectonic subsidence or uplift of the ground surface with maximum values on the order of a few centimeters may occur. Fractures up to 25 - 50 cm wide are commonly observed in loose alluvial deposits and/or saturated soils; in rare cases fractures up to 1 cm can be observed in competent dry rocks. Decimetric cracks common in paved (asphalt or stone) roads, as well as small pressure undulations.*<br>*Springs can change, generally temporarily, their flow-rate and/or elevation of outcrop. Some small springs may even run dry. Variations in water level are observed in wells. Water temperature often change in springs and/or wells. Water in lakes and rivers frequently become muddy.*<br>Small to moderate ($10^3$ – $10^5$ $m^3$) landslides widespread in prone areas; rarely they can occur also on gentle slopes; where equilibrium is unstable (steep slopes of loose / saturated soils; rock falls on steep gorges, coastal cliffs) their size is sometimes large ($10^5$ – $10^6$ $m^3$). Landslides can occasionally dam narrow valleys causing temporary or even permanent lakes. Ruptures, slides and falls affect riverbanks and artificial embankments and excavations (e.g., road cuts, quarries) in loose sediment or weathered / fractured rock. The affected area is usually less than 100 $km^2$.<br>*Liquefaction may be frequent in the epicentral area, depending on local conditions; sand boils up to ca. 1 m in diameter; apparent water fountains in still waters; localised lateral spreading and settlements (subsidence up to ca. 30 cm), with fissuring parallel to waterfront areas (river banks, lakes, canals, seashores).*<br>Karst vaults may collapse, forming sinkholes. Frequent occurrence of landslides under the sea level in coastal areas.<br>Significant waves develop in still and running waters.<br>*Trees shake vigorously; some branches or rarely even tree-trunks in very unstable equilibrium may break and fall. In dry areas, dust clouds may rise from the ground in the epicentral area.* |

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| IX | General panic. Masonry D destroyed; masonry C heavily damaged, sometimes with complete collapse; masonry B seriously damaged. General damage to foundations. Frame structures, if not bolted, shifted off foundations. Frames racked. Conspicuous cracks in ground. In alleviated areas sand and mud ejected, earthquake fountains, sand craters. | **Natural effects leave significant and permanent traces in the environment**<br>*Primary effects observed commonly. Ground ruptures (surface faulting) develop, up to a few km long, with offsets generally smaller than 10 - 20 cm. Tectonic subsidence or uplift of the ground surface with maximum values in the order of a few decimeters may occur.*<br>*Fractures up to 50 - 100 cm wide are commonly observed in loose alluvial deposits and/or saturated soils; in competent rocks they can reach up to 10 cm. Significant cracks common in paved (asphalt or stone) roads, as well as small pressure undulations.*<br>Springs can change their flow-rate and/or elevation of outcrop to a considerable extent. Some small springs may even run dry. Variations in water level are observed in wells.<br>Water temperature often change in springs and/or wells. Water in lakes and rivers frequently become muddy.<br>*Landsliding widespread in prone areas, also on gentle slopes; where equilibrium is unstable (steep slopes of loose / saturated soils; rock falls on steep gorges, coastal cliffs) their size is frequently large ($10^5$ $m^3$), sometimes very large ($10^6$ $m^3$). Landslides can dam narrow valleys causing temporary or even permanent lakes. Riverbanks, artificial embankments and excavations (e.g., road cuts, quarries) frequently collapse. The affected area is usually less than 1000 $km^2$.*<br>*Liquefaction and water upsurge are frequent; sand boils up to 3 m in diameter; apparent water fountains in still waters; frequent lateral spreading and settlements (subsidence of more than ca. 30 cm), with fissuring parallel to waterfront areas (river banks, lakes, canals, seashores).*<br>Karst vaults of relevant size collapse, forming sinkholes.<br>Frequent large landslides under the sea level in coastal areas.<br>*Large waves develop in still and running waters. Small tsunamis may reach the coastal areas with tidal waves up to 50 - 100 cm high.*<br>Trees shake vigorously; branches or even tree-trunks in unstable equilibrium frequently break and fall.<br>In dry areas dust clouds may rise from the ground.<br>In the epicentral area, small stones may jump out of the ground, leaving typical imprints in soft soil. |

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| X | Most masonry and frame structures destroyed with their foundations. Some well-built wooden structures and bridges destroyed. Serious damage to dams, dikes, embankments. Large landslides. Water thrown on banks of canals, rivers, lakes, etc. and mud shifted horizontally on beaches and flat land. Rails bent slightly. | **Environmental effects become dominant**<br>*Primary ruptures become leading. Ground ruptures (surface faulting) can extend for several tens of km, with offsets reaching 50 - 100 cm and more (up to ca. 1-2 m in case of reverse faulting and 3-4 m for normal faulting). Gravity grabens and elongated depressions develop; for very shallow focus earthquakes, such as volcano-tectonic events, rupture lengths might be much lower. Tectonic subsidence or uplift of the ground surface with maximum values in the order of few meters may occur.*<br>*Large landslides and rock-falls (> $10^5$ – $10^6$ $m^3$) are frequent, practically regardless to equilibrium state of the slopes, causing temporary or permanent barrier lakes. River banks, artificial embankments, and sides of excavations typically collapse. Levees and earth dams may even incur serious damage. The affected area is usually up to 5000 $km^2$.*<br>Many springs significantly change their flow-rate and/or elevation of outcrop. Some may run dry or disappear, generally temporarily. Variations in water level are observed in wells.<br>Water temperature often change in springs and/or wells. Water in lakes and rivers frequently become muddy.<br>*Open ground cracks up to more than 1 m wide are frequent, mainly in loose alluvial deposits and/or saturated soils; in competent rocks opening reach several decimeters. Wide cracks develop in paved (asphalt or stone) roads, as well as pressure undulations.*<br>*Liquefaction, with water upsurge and soil compaction, may change the aspect of wide zones; sand volcanoes even more than 6 m in diameter; vertical subsidence even > 1m; large and long fissures due to lateral spreading are common.*<br>Large karst vaults collapse, forming great sinkholes. Frequent large landslides under the sea level in coastal areas.<br>*Large waves develop in still and running waters, and crash violently into the shores. Running (rivers, canals) and still (lakes) waters may overflow from their beds. Tsunamis reach the coastal areas, with tidal waves up to a few meters high.*<br>Trees shake vigorously; branches or even tree-trunks very frequently break and fall, if already in unstable equilibrium.<br>In dry areas, dust clouds may rise from the ground.<br>*Stones, even if well anchored in the soil, may jump out of the ground, leaving typical imprints in soft soil.* |

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| XI | Rails bent greatly. Underground pipelines completely out of service. | **Environmental effects become essential for intensity assessment**<br>*Primary surface faulting can extend for several tens of km up to more than 100 km, accompanied by offsets reaching several meters. Gravity graben, elongated depressions and pressure ridges develop. Drainage lines can be seriously offset. Tectonic subsidence or uplift of the ground surface with maximum values in the order of numerous meters may occur. Large landslides and rock-falls (> $10^5$ – $10^6$ m3) are frequent, practically regardless to equilibrium state of the slopes, causing many temporary or permanent barrier lakes. River banks, artificial embankments, and sides of excavations typically collapse. Levees and earth dams incur serious damage. Significant landslides can occur at 200 – 300 km distance from the epicenter. Primary and secondary environmental effects can be observed over territory as large as 10000 $km^2$.*<br>Many springs significantly change their flow-rate and/or elevation of outcrop. Frequently, they may run dry or disappear altogether. Variations in water level are observed in wells.<br>Water temperature often change in springs and/or wells. Water in lakes and rivers frequently becomes muddy.<br>*Open ground cracks up to several meters wide are very frequent, mainly in loose alluvial deposits and/or saturated soils. In competent rocks they can reach 1 m. Very wide cracks develop in paved (asphalt or stone) roads, as well as large pressure undulations.*<br>*Liquefaction changes the aspect of extensive zones of lowland, determining vertical subsidence possibly exceeding several meters, numerous large sand volcanoes, and severe lateral spreading features.*<br>Very large karst vaults collapse, forming sinkholes. Frequent large landslides under the sea level in coastal areas.<br>*Large waves develop in still and running water, and crash violently into the shores. Running (rivers, canals) and still (lakes) waters may overflow from their beds. Tsunamis reach the coastal areas with tidal waves up to many meters high. Trees shake vigorously; many tree branches break and several whole trees are uprooted and fall.*<br>In dry areas dust clouds may arise from the ground.<br>*Stones and small boulders, even if well anchored in the soil, may jump out of the ground leaving typical imprints in soft soil.* |

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| XII | Damage nearly total. Large rock masses displaced. Lines of sight and level distorted. Objects thrown into the air | **Environmental effects are now the only tool enabling intensity to be assessed**<br>*Primary surface faulting can extend for several hundreds of km up to 1000 km, accompanied by offsets reaching several tens of meters. Gravity graben, elongated depressions and pressure ridges develop. Drainage lines can be seriously offset. Landscape and geomorphological changes induced by primary effects can attain extraordinary extent and size (typical examples are the uplift or subsidence of coastlines by several meters, appearance or disappearance from sight of significant landscape elements, rivers changing course, origination of waterfalls, formation or disappearance of lakes).*<br>*Large landslides and rock-falls (> $10^5$ – $10^6$ $m^3$) are frequent, practically regardless to equilibrium state of the slopes, causing many temporary or permanent barrier lakes. River banks, artificial embankments, and sides of excavations typically collapse. Levees and earth dams incur serious damage. Significant landslides can occur at more than 200 – 300 km distance from the epicenter. Primary and secondary environmental effects can be observed over territory larger than 50000 $km^2$.*<br>Many springs significantly change their flow-rate and/or elevation of outcrop. Frequently, they may run dry or disappear altogether. Variations in water level are observed in wells.<br>Water temperature often changes in springs and/or wells. Water in lakes and rivers frequently becomes muddy.<br>*Ground open cracks are very frequent, up to one meter or more wide in the bedrock, up to more than 10 m wide in loose alluvial deposits and/or saturated soils. These may extend up to several kilometers in length.*<br>*Liquefaction occurs over large areas and changes the morphology of extensive flat zones, determining vertical subsidence exceeding several meters, widespread large sand volcanoes, and extensive severe lateral spreading features.*<br>Very large karst vaults collapse, forming sinkholes. Frequent very large landslides under the sea level in coastal areas.<br>*Large waves develop in still and running water, and crash violently into the shores. Running (rivers, canals) and still (lakes) waters overflow from their beds; watercourses change the direction of flow. Tsunamis reach the coastal areas with tidal waves up to tens of meters high.*<br>Trees shake vigorously; many tree branches break and many whole trees are uprooted and fall.<br>In dry areas dust clouds may arise from the ground. Even large boulders may jump out of the ground leaving typical imprints in soft soil. |

## MSK Scale

*Types of the structures (building not antiseismic)*

Structure A: Buildings in field-stone, rural structures, adobe houses, clay houses.

B: Ordinary brick buildings, buildings of the large block and prefabricated type, half-timbered structures, buildings in natural hewn stone.

C: Reinforced buildings, well-built wooden structures.

Definition of quantity
Single, a few: about 5%

Many: about 50%

Most: about 74%

Classification of damage to buildings

Grade 1: Slight damage. Fine cracks in plaster; fall of small pieces of plaster.

Grade 2: Moderate damage. Small cracks in wall; fall of fairly large pieces of plaster; pantiles slip off; cracks in chimneys; parts of chimneys fall down.

Grade 3: Heavy damage. Large and deep cracks in walls; fall of chimneys.

Grade 4: Destruction. Gaps in walls; parts of buildings may collapse; separate parts of the buildings lose their cohesion; inner walls and filled-in walls of the frame collapse.

Grade 5: Total damage. Total collapse of buildings.

| Intensity | MSK Scale | INQUA Scale |
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| I | **Not noticeable**<br>The intensity of the vibration is below the limit of sensibility; the tremor is detected and recorded by seismographs only. | **No perceptible environmental effects**<br>Extremely rare occurrence of small effects detected only from instrumental observations, typically in the far field of strong earthquakes. |
| II | **Scarcely noticeable(very slight)**<br>Vibration is felt only by individual people at rest in house, especially on upper floor of buildings. | **No perceptible environmental effects**<br>Extremely rare occurrence of small effects detected only from instrumental observations, typically in the far field of strong earthquakes. |
| III | **Weak, partially observed only**<br>The earthquake is felt indoors by a few people, outdoors only in favourable circumstances. The vibration is like that due to the passing of a light truck. Attentive observers notice a slight swinging of hanging objects, somewhat more heavily on upper floor. | **No perceptible environmental effects**<br>Primary effects are absent.<br>Extremely rare occurrence of small variations in water level in wells and/or the flow-rate of springs, typically in the far field of strong earthquakes. |

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| IV | **Largely observed**<br>The earthquake is felt indoors by many people, outdoors by a few. Here and there people awake, but no one is frightened. The vibration is like that due to the passing of a heavily loaded truck. Windows, doors and dishes rattle. Floors and walls creack. Furniture begins to shake. Hanging objects swing slightly. Liquids in open vessels are slightly disturbed. In standing motor-cars the shock is noticeable. | **No perceptible environmental effects**<br>Primary effects are absent.<br>A very few cases of fine cracking at locations where lithology (e.g., loose alluvial deposits, saturated soils) and/or morphology (slopes or ridge crests) are most prone to this phenomenon.<br>Rare occurrence of small variations in water level in wells and/or the flow-rate of springs.<br>Extremely rare occurrence of small variations of chemical-physical properties of water and turbidity of water in lakes, springs and wells, especially within large karstic spring systems most prone to this phenomenon.<br>Exceptionally, rocks may fall and small landslides may be (re)activated, along slopes where equilibrium is already very unstable, e.g. steep slopes and cuts, with loose or saturated soil.<br>Extremely rare occurrence of karst vault collapses, which may result in the formation of sinkholes, where the water table is shallow within large karstic spring systems.<br>Very rare temporary sea level changes in the far field of strong earthquakes.<br>Tree limbs may shake. |
| V | **Awakening**<br>(a) The earthquake is felt indoors by all, outdoors by many. Many sleeping people awake. A few run outside. Animals become uneasy. Buildings tremble throughout. Hangings objects swing considerably. Pictures knock against walls or swing out of place. Occasionally pendulum clocks stop. Unstable objects may be overturned or shifted. Open doors and windows are thrust open and slam back again. Liquid spills in small amounts from well-filled open containers. The sensation of vibration is like that due to a heavy object falling inside the building.<br>(b) Slight damage of grade I in buildings of type A is possible.<br>(c) Sometimes change in flow of spring. | **Marginal effects on the environment**<br>Primary effects are absent.<br>A few cases of fine cracking at locations where lithology (e.g., loose alluvial deposits, saturated soils) and/or morphology (slopes or ridge crests) are most prone to this phenomenon.<br>Extremely rare occurrence of significant variations in water level in wells and/or the flow-rate of springs.<br>Rare occurrence of small variations of chemical-physical properties of water and turbidity of water in lakes, springs and wells.<br>Rare small rockfalls, rare rotational landslides and slump earth flows, along slopes where equilibrium is unstable, e.g. steep slopes, with loose or saturated soil.<br>Extremely rare cases of liquefaction (sand boil), small in size and in areas most prone to this phenomenon (hihgly susceptible, recent, alluvial and coastal deposits, shallow water table).<br>Extremely rare occurrence of karst vault collapses, which may result in the formation of sinkholes, where the water table is shallow within large karstic spring systems.<br>Occurrence of landslides under sea (lake) level in coastal areas.<br>Rare temporary sea level changes in the far field of strong earthquakes.<br>Tree limbs may shake. |

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| VI | **Frightening**<br>(a)Felt by most, indoors and outdo Many people in buildings are fright and run outdoors. A few persons lose balance. Domestic animals run out of stalls. In a few instances dishes glassware may break, books fall dov Heavy furniture may possibly move small steeple bells may ring..<br><br>(b) Damage of grade 1 is sustained in single buildings of type B and in many of type A. Damage in a few buildings of type A is of grade 2.<br><br>(c) In a few cases cracks up to widths of 1 cm possible in wet ground; in mountains occasional landslides; changes in flow of springs and in level of well-water are observed. | **Modest effects on the environment**<br>Primary effects are absent.<br>*Occasionally thin, millimetric, fractures are observed in loose alluvial deposits and/or saturated soils; along steep slopes or riverbanks they can be 1-2 cm wide. A few minor cracks develop in paved (asphalt / stone) roads.*<br>Rare occurrence of significant variations in water level in wells and/or the flow-rate of springs.<br>Rare occurrence of variations of chemical-physical properties of water and turbidity of water in lakes, springs and wells.<br>Rockfalls and landslides up to ca. $10^3$ $m^3$ can occur, especially where equilibrium is unstable, e.g. steep slopes and cuts, with loose / saturated soil, or weathered / fractured rocks. The area affected by them is usually less than 1 $km^2$.<br>*Rare cases of liquefaction (sand boil), small in size and in areas most prone to this phenomenon (hihgly susceptible, recent, alluvial and coastal deposits, shallow water table).*<br>Extremely rare occurrence of karst vault collapses, which may result in the formation of sinkholes.<br>Occurrence of landslides under sea level in coastal areas.<br>Occasionally significant waves are generated in still waters.<br>*In wooded areas, trees shake; a very few unstable limbs may break and fall, also depending on species and state of health.* |
| VII | **Damage to buildings**<br>(a) Most people are frightened and run outdoors . Many find it difficult to stand. The vibration is noticed by persons driving motor-cars. Large bells ring.<br><br>(b) In many buildings of type C damage of grade 1 is caused; in many buildings of type B damage is of grade 2. Many buildings of type A suffer damage of grade 3, a few of grade 4.In single instances landslips of roadway on step slopes; cracks in roads; seams of pipelines damaged ; cracks in stone walls<br><br>(c) Waves are formed on water, and water is made turbid by mud stirred up. Water levels in wells change, and the flow of springs changes. In a few cases dry springs have their flow restored and existing springs stop flowing. In isolated instances parts of sandy or gravelly banks slip off | **Appreciable effects on the environment**<br>Primary effects observed very rarely. Limited surface faulting, with length of tens of meters and centimetric offset, may occur associated with volcano-tectonic earthquakes.<br>*Fractures up to 5-10 cm wide are observed commonly in loose alluvial deposits and/or saturated soils; rarely in dry sand, sand-clay, and clay soil fractures up to 1 cm wide. Centimetric cracks common in paved (asphalt or stone) roads.*<br>Rare occurrence of significant variations in water level in wells and/or the flow rate of springs. Very rarely, small springs may temporarily run dry or be activated.<br>Quite common occurrence of variations of chemical-physical properties of water and turbidity of water in lakes, springs and wells.<br>Scattered landslides occur in prone areas; where equilibrium is unstable (steep slopes of loose / saturated soils; rock falls on steep gorges, coastal cliffs) their size is sometimes significant ($10^3$ – $10^5$ $m^3$); in dry sand, sand-clay, and clay soil, the volumes are usually up to 100 $m^3$. Ruptures, slides and falls may affect riverbanks and artificial embankments and excavations (e.g., road cuts, quarries) in loose sediment or weathered / fractured rock. The affected area is usually less than 10 $km^2$.<br>*Rare cases of liquefaction, with sand boils up to 50 cm in diameter, in areas most prone to this phenomenon (hihgly susceptible, recent, alluvial and coastal deposits, shallow water table).*<br>Possible collapse of karst vaults with the formation of sinkholes, even where the water table is deep.<br>Occurrence of significant landslides under sea level in coastal areas.<br>Waves may develop in still and running waters.<br>In wooded areas, trees shake; several unstable branches may break and fall, also depending on species and state of health. |

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| VIII | **Destruction of buildings**<br>(a)Fright and panic; also persons driving motor-cars are disturbed. Here and there branches of trees break off. Even heavy furniture moves and partly overturns. Hanging lamps are in part damaged.<br><br>(b)Many buildings of type C suffer damage of grade 2 , a few of grade 3. Many buildings of type B suffer damage of grade 3 and a few of grade 4, and many buildings of type A suffer damage of grade 4 and a few of grade 5.Occasional breakage of pipe seams. Memorials and monuments move and twist. Tombstones overturn. Stone walls collapse. | **Considerable effects on the environement**<br>*Primary effects observed rarely. Ground ruptures (surface faulting) may develop, up to several hundred meters long, with offsets generally smaller than 5 cm, particularly for very shallow focus earthquakes, such as volcano-tectonic events. Tectonic subsidence or uplift of the ground surface with maximum values on the order of a few centimeters may occur.*<br>*Fractures up to 25 - 50 cm wide are commonly observed in loose alluvial deposits and/or saturated soils; in rare cases fractures up to 1 cm can be observed in competent dry rocks. Decimetric cracks common in paved (asphalt or stone) roads, as well as small pressure undulations. Springs can change, generally temporarily, their flow-rate and/or elevation of outcrop. Some small springs may even run dry. Variations in water level are observed in wells.*<br>*Water temperature often change in springs and/or wells. Water in lakes and rivers frequently become muddy.*<br>Small to moderate ($10^3$ – $10^5$ $m^3$) landslides widespread in prone areas; rarely they can occur also on gentle slopes; where equilibrium is unstable (steep slopes of loose / saturated soils; rock falls on steep gorges, coastal cliffs) their size is sometimes large ($10^5$ – $10^6$ $m^3$). Landslides can occasionally dam narrow valleys causing temporary or even permanent lakes. Ruptures, slides and falls affect riverbanks and artificial embankments and excavations (e.g., road cuts, quarries) in loose sediment or weathered / fractured rock. The affected area is usually less than 100 $km^2$.<br>*Liquefaction may be frequent in the epicentral area, depending on local conditions; sand boils up to ca. 1 m in diameter; apparent water fountains in still waters; localised lateral spreading and settlements (subsidence up to ca. 30 cm), with fissuring parallel to waterfront areas (river banks, lakes, canals, seashores).*<br>Karst vaults may collapse, forming sinkholes.<br>Frequent occurrence of landslides under the sea level in coastal areas.<br>Significant waves develop in still and running waters.<br>*Trees shake vigorously; some branches or rarely even tree-trunks in very unstable equilibrium may break and fall.*<br>*In dry areas, dust clouds may rise from the ground in the epicentral area.* |

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| IX | **General damage to buildings**<br>(a) General panic; considerable damage to furniture. Animals run and fro in confusion and cry.<br><br>(b) Many buildings of type C suffer damage of grade 3, a few of grade 4. Many buildings of type B show damage of grade 4, a few of grade 5 . Many buildings of type A suffer damage of grade 5. Monuments and column falls. Considerable damage to reservoirs; undergrounds pipes partly broken. In individual cases railway lines are bent and roadways damaged.<br><br>(c) On flat land, overflow of water, sand and mud is often observed. Ground cracks to widths of up to 10 cm, on slopes and river banks more than 10 cm; furthermore a large number of slight cracks in ground; falls of rock, many land slides and earth flows; large waves on water. Dry wells renew their flow and existing wells dry up. | **Natural effects leave significant and permanent traces in the environment**<br>*Primary effects observed commonly. Ground ruptures (surface faulting) develop, up to a few km long, with offsets generally smaller than 10 - 20 cm. Tectonic subsidence or uplift of the ground surface with maximum values in the order of a few decimeters may occur. Fractures up to 50 - 100 cm wide are commonly observed in loose alluvial deposits and/or saturated soils; in competent rocks they can reach up to 10 cm. Significant cracks common in paved (asphalt or stone) roads, as well as small pressure undulations.*<br>Springs can change their flow-rate and/or elevation of outcrop to a considerable extent. Some small springs may even run dry. Variations in water level are observed in wells. Water temperature often change in springs and/or wells. Water in lakes and rivers frequently become muddy.<br>*Landsliding widespread in prone areas, also on gentle slopes; where equilibrium is unstable (steep slopes of loose / saturated soils; rock falls on steep gorges, coastal cliffs) their size is frequently large ($10^5$ $m^3$), sometimes very large ($10^6$ $m^3$). Landslides can dam narrow valleys causing temporary or even permanent lakes. Riverbanks, artificial embankments and excavations (e.g., road cuts, quarries) frequently collapse. The affected area is usually less than 1000 $km^2$.*<br>*Liquefaction and water upsurge are frequent; sand boils up to 3 m in diameter; apparent water fountains in still waters; frequent lateral spreading and settlements (subsidence of more than ca. 30 cm), with fissuring parallel to waterfront areas (river banks, lakes, canals, seashores).*<br>Karst vaults of relevant size collapse, forming sinkholes. Frequent large landslides under the sea level in coastal areas.<br>*Large waves develop in still and running waters. Small tsunamis may reach the coastal areas with tidal waves up to 50 - 100 cm high.*<br>Trees shake vigorously; branches or even tree-trunks in unstable equilibrium frequently break and fall.<br>In dry areas dust clouds may rise from the ground.<br>In the epicentral area, small stones may jump out of the ground, leaving typical imprints in soft soil. |

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| X | **General destruction of buildings**<br>(b) Many buildings of type C suffer damage of grade 4, a few of grade 5. Many buildings of type b show damage of grade 5; most of type A have destruction category 5; critical damage to dams and dykes and severe damage to bridges. Railway lines are bent slightly. Underground pipes are broken or bent. Road paving and asphalt show waves.<br><br>(c) In ground, cracks up to widths of more than 10 cm, sometimes up to 1 m. Broad fissures occur parallel to water courses. Loose ground slides from steep slopes. From river banks and steep coasts considerable landslides are possible. In coastal areas displacement of sand and mud; change of water level in wells; water from canals, lakes, rivers etc. thrown on land. New lakes occur. | **Environmental effects become dominant**<br>*Primary ruptures become leading. Ground ruptures (surface faulting) can extend for several tens of km, with offsets reaching 50 - 100 cm and more (up to ca. 1-2 m in case of reverse faulting and 3-4 m for normal faulting). Gravity grabens and elongated depressions develop; for very shallow focus earthquakes, such as volcano-tectonic events, rupture lengths might be much lower. Tectonic subsidence or uplift of the ground surface with maximum values in the order of few meters may occur. Large landslides and rock-falls (> $10^5$ – $10^6$ $m^3$) are frequent, practically regardless to equilibrium state of the slopes, causing temporary or permanent barrier lakes. River banks, artificial embankments, and sides of excavations typically collapse. Levees and earth dams may even incur serious damage. The affected area is usually up to 5000 $km^2$.*<br>Many springs significantly change their flow-rate and/or elevation of outcrop. Some may run dry or disappear, generally temporarily. Variations in water level are observed in wells.<br>Water temperature often change in springs and/or wells.<br>Water in lakes and rivers frequently become muddy.<br>*Open ground cracks up to more than 1 m wide are frequent, mainly in loose alluvial deposits and/or saturated soils; in competent rocks opening reach several decimeters. Wide cracks develop in paved (asphalt or stone) roads, as well as pressure undulations.*<br>*Liquefaction, with water upsurge and soil compaction, may change the aspect of wide zones; sand volcanoes even more than 6 m in diameter; vertical subsidence even > 1m; large and long fissures due to lateral spreading are common.*<br>Large karst vaults collapse, forming great sinkholes.<br>Frequent large landslides under the sea level in coastal areas.<br>*Large waves develop in still and running waters, and crash violently into the shores. Running (rivers, canals) and still (lakes) waters may overflow from their beds. Tsunamis reach the coastal areas, with tidal waves up to a few meters high.*<br>Trees shake vigorously; branches or even tree-trunks very frequently break and fall, if already in unstable equilibrium.<br>In dry areas, dust clouds may rise from the ground.<br>*Stones, even if well anchored in the soil, may jump out of the ground, leaving typical imprints in soft soil.* |

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| XI | **Catastrophe**<br>(b) Severe damage even to well-built buildings, bridges, water dams and railway lines; highways become useless; underground pipes destroyed.<br><br>(c) Ground considerably distorted by broad cracks and fissures, as wells as by movement in horizontal and vertical directions; numerous land slips and falls of rock<br><br>The intensity of the earthquake requires to be investigated in special way. | **Environmental effects become essential for intensity assessment**<br>*Primary surface faulting can extend for several tens of km up to more than 100 km, accompanied by offsets reaching several meters. Gravity graben, elongated depressions and pressure ridges develop. Drainage lines can be seriously offset. Tectonic subsidence or uplift of the ground surface with maximum values in the order of numerous meters may occur.*<br>*Large landslides and rock-falls (> $10^5$ – $10^6$ m3) are frequent, practically regardless to equilibrium state of the slopes, causing many temporary or permanent barrier lakes. River banks, artificial embankments, and sides of excavations typically collapse. Levees and earth dams incur serious damage. Significant landslides can occur at 200 – 300 km distance from the epicenter. Primary and secondary environmental effects can be observed over territory as large as 10000 $km^2$.*<br>Many springs significantly change their flow-rate and/or elevation of outcrop. Frequently, they may run dry or disappear altogether. Variations in water level are observed in wells.<br>Water temperature often change in springs and/or wells.<br>Water in lakes and rivers frequently becomes muddy.<br>*Open ground cracks up to several meters wide are very frequent, mainly in loose alluvial deposits and/or saturated soils. In competent rocks they can reach 1 m. Very wide cracks develop in paved (asphalt or stone) roads, as well as large pressure undulations.*<br>*Liquefaction changes the aspect of extensive zones of lowland, determining vertical subsidence possibly exceeding several meters, numerous large sand volcanoes, and severe lateral spreading features.*<br>Very large karst vaults collapse, forming sinkholes.<br>Frequent large landslides under the sea level in coastal areas.<br>*Large waves develop in still and running water, and crash violently into the shores. Running (rivers, canals) and still (lakes) waters may overflow from their beds. Tsunamis reach the coastal areas with tidal waves up to many meters high.*<br>*Trees shake vigorously; many tree branches break and several whole trees are uprooted and fall.*<br>In dry areas dust clouds may arise from the ground.<br>*Stones and small boulders, even if well anchored in the soil, may jump out of the ground leaving typical imprints in soft soil.* |

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| XII | **Landscape changes**<br>(a) Practically all structures above and below ground are greatly damaged or destroyed<br><br>(c) The surface of the ground is radically changed. Considerable ground cracks with extensive vertical and horizontal movements are observed. Fall of rock and slumping of river banks over wide areas; lakes are dammed; waterfalls appear; and river are deflected.<br><br>The intensity of the earthquake requires to be investigated in a special way. | **Environmental effects are now the only tool enabling intensity to be assessed**<br>*Primary surface faulting can extend for several hundreds of km up to 1000 km, accompanied by offsets reaching several tens of meters. Gravity graben, elongated depressions and pressure ridges develop. Drainage lines can be seriously offset. Landscape and geomorphological changes induced by primary effects can attain extraordinary extent and size (typical examples are the uplift or subsidence of coastlines by several meters, appearance or disappearance from sight of significant landscape elements, rivers changing course, origination of waterfalls, formation or disappearance of lakes).*<br>*Large landslides and rock-falls (> $10^5$ – $10^6$ $m^3$) are frequent, practically regardless to equilibrium state of the slopes, causing many temporary or permanent barrier lakes. River banks, artificial embankments, and sides of excavations typically collapse. Levees and earth dams incur serious damage. Significant landslides can occur at more than 200 – 300 km distance from the epicenter. Primary and secondary environmental effects can be observed over territory larger than 50000 $km^2$.*<br>Many springs significantly change their flow-rate and/or elevation of outcrop. Frequently, they may run dry or disappear altogether. Variations in water level are observed in wells.<br>Water temperature often changes in springs and/or wells. Water in lakes and rivers frequently becomes muddy.<br>*Ground open cracks are very frequent, up to one meter or more wide in the bedrock, up to more than 10 m wide in loose alluvial deposits and/or saturated soils. These may extend up to several kilometers in length.*<br>*Liquefaction occurs over large areas and changes the morphology of extensive flat zones, determining vertical subsidence exceeding several meters, widespread large sand volcanoes, and extensive severe lateral spreading features.*<br>Very large karst vaults collapse, forming sinkholes.<br>Frequent very large landslides under the sea level in coastal areas.<br>*Large waves develop in still and running water, and crash violently into the shores. Running (rivers, canals) and still (lakes) waters overflow from their beds; watercourses change the direction of flow. Tsunamis reach the coastal areas with tidal waves up to tens of meters high.*<br>Trees shake vigorously; many tree branches break and many whole trees are uprooted and fall.<br>In dry areas dust clouds may arise from the ground.<br>Even large boulders may jump out of the ground leaving typical imprints in soft soil. |