Insegnamento/ Modulo	CFU	SSD	Tipologia	Docente	Descrizione
Dynamics of Structures	6	ICAR/08	Caratterizzante		Definition of SDOF system characteristics. External force and earthquake excitations. Classical solution of second order linear ODE's. Undamped and damped free vibration, energy in free vibration. Undamped and damped systems, resonance, energy dissipated in viscous damping, equivalent viscous damping. Response to unit impulse, arbitrary force and step force, response spectrum. Newmark's method, stability and accuracy. Rigid body assemblages, distributed parameter systems, Rayleigh method. Simple MDOF systems, dynamic forces, reduction of DOF's, static condensation. Natural vibration modes and frequencies, orthogonality and normalization of modes, modal expansion, free vibration response of MDOF systems, eigenvalue problem, vector iteration methods. Construction of damping matrix, Rayleigh damping. Modal response analysis of undamped and damped systems, element forces, modal contribution factors.
Applied Mathematics	6	MAT/05 - MAT/08	Affine		Numerical solution of boundary value problems for Partial Differential Equations (Pde). Numerical solution of initial value problems for Ordinary Differential equations (Ode). Reminders on Linear Algebra. Numerical solution of linear systems: direct methods. Numerical solution of linear systems: iterative methods. Solution of nonlinear equations/systems Approximation of functions and data. Numerical integration:
Reinforced Concrete Structures	6	ICAR/09	Caratterizzante		The course covers a wide spectrum of subjects ranging from preliminary reminder of basic reinforced concrete member mechanics to more advanced design problems of r.c. stuctures subjected to generic loading. Creep and shrinkage. Strength design for bending, shear, torsion, bi-axial bending and normal force of linear members. Local and global instability. Service behavior (deflection control, crack control, stress control). Strut and tie models for D regions. Joints in frames. Structural walls. R.c. slabs. Punching shear. Foundation structural elements.
Computational Mechanics	6	ICAR/08	Caratterizzante		This course aims at giving a concise introduction to the basic concepts of nonlinear mechanics of solids and at providing the basic ingredients to perform simulations of solid mechanics problems at large strains via the finite element method. Contents Basics of nonlinear mechanics; Kinematics; Equilibrium; Hyperelastic constitutive laws; Elements of numerical analysis; Solution of nonlinear equations and systems; Matlab implementation of basic algorithms; Nonlinear finite elements; Basic concepts; Application to 1D rods at large strains (and Matlab implementation); Application to 2D plane strain problems at large strains (and Matlab implementation); Use of a commercial nonlinear finite element code.
Foundation Engineering and Earth Retaining Structures	6	ICAR/07	Caratterizzante		Topics include general design criteria of foundation systems according to Italian building code and Eurocode 7. Ultimate capacity and settlements of shallow foundations. Soil-structure interaction under static conditions (Winkler method). Bearing capacity of shallow foundations under earthquake loading. Deep foundations. Ultimate capacity of single piles and of pile groups subjected to axial and lateral loading. Settlements of deep foundations. Interaction and group effects under static conditions. Introduction to dynamic-soil structure interaction for shallow and piled foundations. Kinematic and inertial interaction. Earth-retaining structures. Review of active and passive earth pressures. Coulomb and Rankine theories. Drainage systems. Seismic earth pressure. Mononobe-Okabe and Wood theories. Stability analysis of gravity walls. Cantilever and anchored sheet piles. Performance-based design and capacity design philosophy applied to geotechnical engineering. Newmark method to compute the response of gravity walls. An introduction to reliability analyses in geotechnical engineering.
Probability and Statistics for Engineering Applications	6	ICAR/09	Caratterizzante		Most problems in the different fields of Civil Engineering cannot be fully and efficiently addressed without knowledge of probability and statistics. This course intends to address basic probability notions and different probabilistic models applied to civil engineering. Concept and definition of random variables and different functions of random variables will be covered in the initial part of the course. Afterwards, focus is given to commonly used probability distribution functions in civil engineering. Discussions on statistics and sampling are presented towards the last part of the course. In this part, goodness of fit tests, regression and correlation analyses, estimation of distribution parameters from statistics, hypothesis testing and their significance will be discussed. Finally basics of Monte Carlo simulation will also be covered. Each topic is discussed with reference to different application problems and their solutions in different fields of civil engineering, such as Structural Engineering, Earthquake Engineering, Transportation Engineering, Water Resources and Environmental Engineering, and Geotechnical Engineering.

Seismic Hazard and Applied Seismology	6	GEO/10	Affine		Earthquake generation: Earth structure, plate tectonics, fault rupture and elastic rebound; seismic waves and ray theory. Earthquake observation: seismographs and seismograms; hypocentral location; fault plane solution; magnitude and seismic moment; instrumental and historical seismicity, macroseismic scales. Elements of seismic hazard: surface fault rupture; tsunami; liquefaction; landslides; ground shaking. Earthquake strong-motion: intensity scales and isoseismal maps; accelerographs and accelerograms; strong-motion parameters; engineering characterisation of seismic input; ground-motion prediction; near-source effects; attenuation relationships. Seismic hazard analysis: deterministic hazard assessment; probabilistic hazard assessment; hazard mapping and zonation; site effects; hazard-consistent earthquake scenarios.
Geotechnical Earthquake Engineering	6	ICAR/07	Caratterizzante		Review of seismic hazard, risk, vulnerability and exposure. Macro- and micro- zonation of a territory. Ground motion intensity measures. Fourier analysis and response spectra. Signal processing of earthquake records. FFT algorithm, aliasing and Nyquist criterion. Spectrograms. Introduction to seismometry. Analog and digital instruments, strong-motion accelerometric datasets. Basic concepts of elasto dynamics. P and S waves, stationary oscillations. Propagation of elastic waves in heterogeneous continua. Fermat’s principle and Snell’s law. Zoeppritz equations. Rayleigh and Love surface waves. Introduction to Biot’s theory and Gassmann equations. Ground response analyses. Concept of transfer function. Material damping. Examples of ground amplification. Linear and linear-equivalent ground response analyses. Introduction to fully non-linear analyses. CFL stability condition and grid dispersion. Topographic amplification. Basin effects. Site characterization and microzonation. Experimental measurement of dynamic properties of soils. Geophysical seismic tests. Phenomena of seismic geotechnical risk. Liquefaction and cyclic mobility. Critical state theory. Constitutive modeling of dynamic behaviour of soils. Simplified methods for the assessment of liquefaction susceptibility and ground deformation. Co-seismic and post-seismic instability of natural slopes. Pseudo-static analyses and Newmark method. Mitigation measures.
Nonlinear Response Analysis	6	ICAR/09	Caratterizzante		Structures respond elastically for minor earthquakes and start experiencing damage, and thus behave nonlinearly, for earthquakes of increasing intensity. Structural design of new structures is currently based on linear elastic analysis. Nonlinear analyses are becoming increasing attractive for seismic assessment of existing structures, as modern building codes encourage designers to use more advanced tools. The course will consider different modeling assumptions (mostly frame vs continuum modeling) for structures, and will discuss pros and cons of different approaches and how different models describe the actual behavior of structures. The main goal of the course is to provide students with skills that can be applied to both research and practice for analyzing structures. The class will focus on the theory of linear nonlinear structural analysis, with particular emphasis on available computational models, their characteristics and limitations. Modeling alternatives and their effect on the model output will be discussed. The course will also present the nonlinear methods of analysis prescribed by the seismic design codes and available in the published literature. The final goal is to leave attendees with a firm idea of the importance of the modeling assumptions and the methods of analyses that are used to analyze a structure mainly with respect to the actual behaviors of structures under seismic loads.
Fundamentals of Seismic Design	6	ICAR/09	Caratterizzante		The course will start with a review on the dynamic behaviour of linear and nonlinear single-degree-of-freedom systems, which represents the basis to understand seismic design. Afterwards the conceptual seismic design of structures will be addressed. Core of the course will be the discussion of current (force-based) and developing (displacement-based, or performance-based) seismic design philosophies including the tools required for their realization and verification. Capacity design principles, necessary to ensure a satisfactory and dependable hierarchy of ductile inelastic deformations will be explained with emphasis on the design and detailing of reinforced concrete structures. A further focus will be on the characterisation of the force-deformation behaviour of reinforced concrete structural elements as well as the modelling and analysis of reinforced concrete structures with nonlinear finite element approaches.
Masonry Structures	6	ICAR/09	Caratterizzante		The goal of the course is to provide an introduction to materials, construction practices, structural behavior, analytical methods, and typical code requirements for the seismic design of new masonry buildings and the seismic evaluation and retrofit/rehabilitation of existing ones. Properties of masonry materials: brick, block, mortar, grout and reinforcement. Mechanics of masonry in compression: failure theories, compressive strength, elastic modulus. Behavior of masonry walls subjected to lateral forces and their role in building structural systems excited by earthquake motions. Unreinforced masonry walls: vertical and transverse loadings, shear walls. Reinforced masonry walls: axial force, flexure and shear design, detailing of reinforcement. Confined masonry. Building systems: floor diaphragms, lateral-force distribution to shear walls. Assessment and rehabilitation of existing masonry buildings: sources of vulnerability, knowledge and survey of the structure, methods of analysis, performance criteria. Strategies and techniques for seismicrehabilitation/retrofitting.

Steel Structures	6	ICAR/09	A scelta		Plastic Mechanism Analysis: virtual work; collapse mechanism; lower-bound theorem; upper-bound theorem. Direct Analysis Method of Design: second-order effects, geometric imperfections and notational loads, stiffness reduction due to inelasticity. Seismic Steel Design Philosophy: ductility design, capacity design, force-based vs. displacement-based design. Special Moment Frame Design: cyclic behavior of beam, column, and panel zone; drift limits; connection performance in past earthquakes; moment connection design; capacity design. Special Centrically Braced Frame Design: cyclic behavior of diagonal braces; performance in past earthquakes; effect of frame action; brace connection design. Eccentrically Braced Frame Design: cyclic behavior of links; performance in past earthquakes; capacity design of beams, columns, and braces. Buckling-restrained Braced Frame Design: concept and types of of buckling-restrained braces (BRB); cyclic performance of BRB, design considerations.
Bridge Structures	6	ICAR/09	Caratterizzante		The course will include the damage experience in the past earthquakes, measured and computed structural response of bridges, response of special bridges (arch bridges, cable stayed bridges and suspension bridges), effect of ground motion and soil condition, damping, static and dynamic linear and nonlinear response analysis including idealization, design forces, seismic performance criteria, design of columns, unseating prevention devices and foundations, evaluation of seismic performance of existing bridges, seismic retrofit, seismic isolation, and semi-active control.
Seismic Risk	6	ICAR/09	Caratterizzante		This course will present state-of-the-art methods for computing seismic risk to single structures and portfolios of structures. The first part of the course will deal with the assessment of seismic hazard and earthquake ground motion characterization. The second part of the course will tackle in detail state-of-the art approaches to assess seismic risk of single buildings for both collapse and loss estimation purposes. The techniques that the student will learn are applicable both to the design of new buildings and to the assessment of existing ones. Emphasis will be given to ground motion record selection for structural response estimation. The third and last part will focus on earthquake risk assessment of portfolios of structures. These are typical applications found in the field of catastrophe risk modeling that are heavily used in the insurance/reinsurance industry, capital markets, and disaster risk financing field. Some fundamentals of insurance/reinsurance will also be discussed. Time permitting, we will also discuss the seismic risk assessment of spatially distributed networks and of nuclear power plants. These have special aspects that are not found in the previous applications discussed during the course
Non-structural Elements	6	ICAR/09	A scelta		The main objective of this short course is to familiarize Structural Engineers with current knowledge on the seismic design and analysis of nonstructural components. At the end of the course, Structural Engineers should be able to: - classify the various types of nonstructural components and understand their performance during recent earthquakes; - conduct seismic analysis of nonstructural components by the direct and cascading methods; - understand and apply correctly current regulations and guidelines for the seismic design and specifications of nonstructural components in North America and Europe including the seismic qualification requirements for important nonstructural components that have been introduced recently in building codes; - conduct seismic qualification of nonstructural components by testing, analysis or experience database according to recent building code requirements; - be familiar with the seismic performance and fragility of specific nonstructural components and systems through the review of research case studies.
Seismic Isolation	6	ICAR/09	A scelta		The main objective of this course is to introduce structural engineers to the basic principles of passive supplemental damping and seismic isolation systems and to their implementation into real structures for enhanced seismic protection. An introduction on the basic earthquake engineering principles and energy formulation needed to understand the impact of different supplemental damping and isolation techniques on the performance of structures is first provided. The focus is then set on theoretical and applied knowledge on various supplemental damping and seismic isolation systems that have demonstrated potential at raising the performance of buildings and bridges under earthquake ground motions while keeping construction costs reasonable. The course will cover hysteretic dampers, viscous and visco-elastic dampers, self-centering systems, tuned-mass dampers, elastomeric, lead-rubber, metallic and sliding bearings and will present their physical behaviour, analytical modelling, experimental investigations and practical implementations. Design strategies and methods are also presented for each of the supplemental damping and seismic isolation systems.
Active Tectonics	6	GEO/03	A scelta		Structural geology: basic concepts. The principal structures of deformation of the rocks. Plate tectonics and mountain building. GPS velocity maps. Rock strength and rheology of the lithosphere. Earthquakes and fault systems geometry.

					Earthquakes and rock friction. Elastic rebound or seismic-cycle model. Earthquake focal mechanisms. Geology of source region. Earthquake focus and rupture. Paleoseismology. Pre-seismic, co-seismic, and post-seismic behaviors of the crust. Tectonic and geomorphology of active thrust, normal and strike-slip fault systems. Seismic coupling concepts. Main parameters for characterizing faults: strike, dip, length, width, rake, slip rates. Surface effects of buried active faults and consequent landscape evolution. Differencesbetweenactive, seismogenic and capablefaults.
Geomatics and GIS	6	GEO/04	Affine		Modern RS and GIS technology and data streams provide the synoptic, time-sequential views of the Earth that these research activities require. I propose here to offer a comprehensive course of instruction through which both science students as well as students in related disciplines in other departments may benefit from the intellectual activity and technological resources currently available. The basis of this program would be a course in Remote Sensing (RS) and Geographic Information Systems (GIS) theory and application. I envision a highly interactive environment in which students will be taught the technical basis for RS and GIS and then be introduced to a wide range of applications employing the data, methodologies and computing resources currently available.
Natural Disasters and Risk Management	6	GEO/05	A scelta		Basic process geology – how and why does this type of event happens Basic facts – what happens during this event and how does the event evolve in time and space Examples – what are some important examples that amplify our understanding of this event. Knowledge and uncertainties – what do we know and what don't know about this type of event. Mitigation/preparedness – what can be done to prepare for/mitigate against this type of event. Prediction/forecasting – what are the tools that can be used to predict/forecast this type of event Events: Earthquakes, Tsunamis, Volcanoes, Landslides/Avalanches, Intense Precipitation, Floods, Subsidence, Delta Retreat, Electromagnetic Storms, Droughts, Heat Waves, Wind Storms, Wildfires and massive urban fires, Blizzards, Ice Storms, Hurricanes, Tornadoes, Storm Surges, Glacial Outbursts, Glaciers and glacial melt, Asteroid/Meteorite/Comet Impacts, Nuclear and chemical accidents.
Continuum Mechanics	6	ICAR/01	Caratterizzante		The course introduces to the foundations of continuum mechanics that is at the base of both fluid mechanics and solid mechanics. The initial part is devoted to the basic features of tensor calculus that is adopted to formulate the laws of continuum mechanics. The concept of material continuum is introduced and the Cauchy's stress principle is illustrated; then the analysis of stress at the material point is carried out. The Lagrangian and Eulerian description of the motion is introduced, providing the basis for the analysis of deformation at the material point, with special regard to the small deformation theory. The fundamental laws of continuum mechanics are formulated starting from the conservation principles of mass, momentum and energy. The principal constitutive equations for solids (generalized Hooke's laws) and fluids (Newtonian fluids) are introduced, thus leading to the corresponding governing equations of continuum dynamics. Finally, is illustrated the mathematical approach to the study of the hydraulic damage in some relevant engineering problems involving water waves (both wind generated waves and tsunamis).
Hydro morphology	6	GEO/04	Affine		Aims: knowledge of fluvial system morphology and their changes, understanding the natural pathways and rates of movement of water and sediment and the role of active and fossil landforms. Moreover, fluvial forms and processes are recognized as a key component of river system in the EU WFD for mitigating flood risk and geomorphic hazard and for a sustainable river management and restoration. Outline: Fluvial system and their component; Geomorphic classification of rivers and streams; Factors controlling channel morphology; Fluvial processes; Channel types; Channel morphology variability and channel adjustment; Material and method to study fluvial geomorphology
Engineering Geology	6	GEO/05	Affine		Aims: to introduce the student to fundamental surface and subsurfaces data in order to develop and understanding engineering geological models for application to engineering works and to geohazards. Basic aspects of engineering geology including map construction and interpretation (e.g. engineering geological mapping units). Significance of ground profiles to engineering design, their origin in various geological settings. Use of surface and subsoil data in creating model of the ground, development of engineering geological models involved in civil engineering projects and in geohazards: conceptual and observational approaches. Some examples of engineering geological models for geohazards assessment in different geological and geomorphological environments.

Fluvial Hydraulics	6	ICAR/01	Caratterizzante		The course will focus on hydraulics of natural streams, solid transport, and related hydrodynamic processes. 1. Basics of Natural Streams Hydrodynamics - Momentum and Energy equations, Turbulence and Velocity Distribution in Natural Streams Flows, Secondary Currents and Dip Phenomenon, Velocity and Bed Shear Stress Distribution in Curved Channels, Shear Stress for Unsteady-Nonuniform Flow. 2. Solid Transport Threshold - Hydrodynamic Drag and Lift on a Solid Grain, Threshold Velocity, Threshold Bed Shear Stress, Probabilistic Concept of Entrainment, Threshold of Nonuniform Sediment Motion. 3. Bed-Load Transport - Empirical Relationships Involving Bed Shear Stress, Discharge or Velocity; Probabilistic Concepts: Einstein’s Model, Engelund and Fredsøe’s Model; Deterministic Concepts: Bagnold’s Model, Yalin’s Model; Fractional Bed Load of Nonuniform Sediments; Sediment Sorting and Streambed Armoring. 4. Suspended-Load Transport - Diffusion Concept: Generalized Advection–Diffusion Equation of Suspended Sediment Motion, Equation for Vertical Distribution of Sediment Concentration, Stratification Effects, Nonequilibrium Sediment Concentration Distribution, Suspended Load. Energy Concept: Velikanov’s Model, Bagnold’s Model, Wu’s Model. Threshold Condition for Sediment Suspension. Wash Load. 5.Total-Load Transport - Einstein’s Model, Bagnold Model, Chang Model. Engelund and Hansen’s Model. Ackers and White’s Model. Total-Load Transport of Nonuniform Sediments. 6. Bedforms - Ripples, Dunes, Antidunes, Chutes and Pools, Bars. Models for Prediction of Bedforms. Resistance to Flow Due to Bedforms: Einstein and Barbarossa’s Method, Karim and Kennedy’s Method, van Rijn’s Method. 7. Meandering and Braiding - Meander Planform Characteristics, Mathematical Modeling of Meandering Rivers (Ikeda and Nishimura’s, Odgaard’s). Braided Rivers. 8. Scour: General Scour, Scour Within Channel Contractions, Scour Near Structures. Scour at Bridge Piers and Abutments. Kinematic Model of Horseshoe Vortex. Scour Depth Prediction and Countermeasures.
Computational Fluid Dynamics	6	ICAR/01	Caratterizzante		The course aims at a knowledge of the fundamentals of the methods for the numerical solution of the equations of fluid motion and of their application to hydraulic phenomena, such as flooding and tsunami wave events. Equations of fluid motion: convection and diffusion phenomena; conservation of mass and momentum; Navier-Stokes, Euler and Shallow-Water equations; characteristic velocity and boundary conditions. Discretization methods: Finite differences; accuracy, stability and numerical diffusion; upwinding; finite volume method. Numerical solution of the Navier-Stokes equations: linearization of convective terms; projection methods; SIMPLE and PISO methods; treatment of free surfaces; the VoF (Volume-of-Fluid) method. Turbulence models: fundamentals of turbulence theory; Reynolds-averaged equations; turbulent kinetic energy and dissipation; k-epsilon method. Smoothed Particle Hydrodynamics: Lagrangian methods; kernel and particle approximation. Boundary conditions in the SPH solution of the Navier-Stokes and Shallow Water equations.
Snow Avalanches and Related Mountain Natural Hazards	6	ICAR/02	Caratterizzante		The Earth cryosphere is presently subject to fast changes in mass and dynamics due to the ongoing climate warming. Particularly in the mountain regions of the mid-latitudes, such as the European Alps, these changes are of special relevance, because of their influence on the water cycle and of the potential hazards related to their dynamics. The course will focus on the recent changes occurred in the mountain cryosphere under changing climatic conditions and will investigate the main hazards caused by their current dynamics. In the first part, the course will provide an overview on the main components of the mountain cryosphere, i.e. seasonal snow, glaciers and permafrost, and on their present state in the climate system. Then, the course will focus on the cryosphere-related hazards, especially addressing those caused by shrinking glaciers and degrading permafrost. Among these, attention will be paid on phenomena such as Glacial Lake Outburst Floods (GLOFs), ice-rock avalanches from steep hanging glaciers, rapid geomorphic adjustment of glacial deposits, debris flows, slope instabilities, and rockfalls from frozen rock faces. A number of case histories taken from European Alps and other mountain regions worldwide will be presented and discussed.
Landslides Hazard and Risk	6	GEO/05	Affine		Aims: ability to recognize and characterize different types of slope instabilities; ability to use tools for the landslide hazard and risk assessment; ability to select techniques for monitoring and mitigation of landslide risk Landslide terminologies and classification, deep seated gravitational deformation, rainfall induced landslides. Predisposing and triggering factors, landslide occurrence as a consequence of land use and climate changes. Methodologies of landslide investigation and mapping, landslide inventories. Methods for landslide susceptibility and hazard assessment (initiation and runout): knowledge –driven, data-driven and physically based methods. Evaluation of the performance of landslide zonation map. Magnitude – frequency and landslide intensity-frequency relation. Quantitative landslide risk analysis. Landslide monitoring: ground-based and remote surface displacements measurement techniques, monitoring of hydro-meteorological

					variables. Landslide mitigation: structural and non-structural protection. Lesson learnt from some case histories. The course is integrated and complemented by computer lab exercises concerning landslide hazard and risk assessment and field trip to landslides in the Alps and in the Apennines.
Hydrological Risks	6	ICAR/02	Caratterizzante		The course will give an overview of the models, approaches, problems related with the flood risk assessment. In the first part it will be provided an introduction to the main concepts of the hydrological cycle and the physical mechanism of a flood. In the second part it will be describe a flood risk model in terms of its main component hazard, vulnerability and exposure. During the course there will be presentation on specific applications on the estimation of the defence failure effects, the downscaling of the exposure model, the computation of building damages due to flood and simple tools for the estimation of the extreme events distribution. Introduction to hydrology and flood risk. The main processes of the hydrological cycle. Modelling approaches to compute the discharge in a river. Definition of flood. Statistical methods to describe the extreme events. The Intense-Duration-Frequency curve. The Flood Frequency Curve. Anatomy of a Flood Risk Model. Models for hazard estimation. 1D and 2D hydraulic models. Simplified geomorphological models. The role of the hydraulic defences. Models for the vulnerability estimation. Data and models for the exposure. Generation of stochastic flood events. Floo drisk analysis
Structural measures for flood risk mitigation	6	ICAR/01	Caratterizzante		Structural measures for flood risk mitigation include a wide variety of practical solutions, e.g., levees, reservoirs, floodways, tools for river bank protection and for control of local scour, devices for river training, and special design techniques to be applied to buildings in flood prone areas. Design techniques and selection criteria of risk mitigation measures are discussed throughout this course. 1. Geomorphic assessment of natural streams - field investigation, channel stability assessment, computational design methods. 2. River protection - Stream bank erosion, river training and stabilization, flow control structures, environmental impacts, channel restoration and rehabilitation 3. Bank protection and stabilization - General principles, Riprap design and placement, Bioengineering countermeasures and erosion control, rock-and-wire mattresses, gabions, sacks, concrete blocks, used tires, soil cement 4. Scour protection at bridges and other structures - countermeasures for contraction scour and for local scour. Riprap design for bridge piers and for bridge abutments; Geotextiles filters; grouted ripraps; concrete armor units. 5. Levees - Levees in flood risk management; functions, forms and failure of levees; physical processes and tools for levee assessment and design. Hydraulic design of levees: surface protection measures, spillways, control of seepage and uplift, hydraulics of overtopping flows, mechanics of overflow erosion, erosion protection 6. Structural measures for reducing flood risk to buildings - Avoidance and resistance design options: site layout, landscaping, drainage, boundary walls and fencing, threshold and floor levels. Flood resilient design and construction: general principles, building materials, foundations, walls, doors and windows, fittings, services.
Hydraulic Infrastructures	6	ICAR/02	Caratterizzante		The main objective of this course is to introduce risk and vulnerability issues related to water distribution and sewer systems. Water distribution systems: demand characterization and tank design; surge tanks; design and simulation of water adduction mains; problems of rapidly varied flow; network resolution; network optimal design. Sewer Systems: water drainage outside the channels; gutters and downpipes for rainwaters; domestic waste waters; operation and design of sewer inlets; networks of sewer channels: design and operation; devices for improving the operational efficiency of sewer networks Risk and Vulnerability in Urban Water Systems: concepts of resilience and robustness; pipe breaks and segment isolations; tips for increasing network reliability; quality simulation in water distribution systems; mitigation of the risk connected with contaminant intrusion into water distribution systems.
Flood propagation	6	ICAR/02	Caratterizzante		The course aims at illustrating the classical models used in flood propagation studies, both from the mathematical and from the numerical point of view. Definition of steady and unsteady flow, uniform and varied flow, pipe flow vs open channel flow. De Saint Venant equations (1d) written in divergent and non-divergent form, supplementary terms and coefficients. Initial and boundary conditions. Discontinuous solutions: Bores Simple wave, Dam break waves, simplified channel flow equations. Numerical solution of the unsteady flow equations (method of characteristics, explicit and implicit finite differences methods, numerical integration schemes: predictor corrector, flux splitting, upwind and downwind) accuracy of the

					numerical method, stability analysis. Shallow water equations Model (2D): mesh generation (structured/non structured) Simulation of flow in natural streams: 1D vs 2D models, topological and hydraulic discretization, some computational problems in rivers and floodplains, flooded area mapping techniques. Models calibration and data needs Flood wave propagation through hydraulic singularities. Review of 1D, 2D and coupled 1D/2D flood propagation models Introduction to the use of ORSADEM code and its application to a case study.
Risk Emergency Management and Legislation	6	IUS/02	A scelta		The course aims at presenting and analyzing, in a comparative and international perspective, the role of legal rules and institutions in the context of disaster risk prevention, mitigation, transfer and financing. Topics to be covered include: identification of the main institutional actors; the impact of law on catastrophic risk management across the world; international principles, standards, directives and guidelines developed in the recent years; legal and policy implications of disaster risk financing for governments; public-private initiatives to cover the cost of extreme risks and catastrophe insurance schemes implemented in different jurisdictions; capital market solutions as alternative risk transfer (ART) tools. The course is integrated and complemented by a series of seminars and tutorials.
Earth Surface and Processes	6	GEO/04	A scelta		The knowledge of the geomorphic processes that shape the Earth surface is crucial for environmental management and hazard prevention. The aim of the course is to understand the main processes affecting the landscape on different spatio-temporal scales. Especially we will emphasize on weathering, erosion, transport and deposition processes as well as on the main drivers triggering the dynamics such as climate and tectonics. Additionally, we show how landscapes developed in the past, how they function at present, and how they might change in future. The range of environments addressed in the course include glacial, periglacial, fluvial, Karst and hillslope landscape systems. Finally, we complement the theoretical background by the methodological approaches to assess the above-mentioned processes and landscapes in both a quantitative and a qualitative way.
Project work	3				The student carries out an individual project work under the guidance of a tutor on a selected topic related to any of the subjects related to the curriculum. Such project work will be design/application oriented and will produce a technical report that will be evaluated by the tutor for approval.