**Engineering geology**

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**Engineering geology** is the application of the [geologic sciences](http://en.wikipedia.org/wiki/Geology) to engineering practice for the purpose of assuring that the geologic factors affecting the location, design, construction, operation and maintenance of [engineering](http://en.wikipedia.org/wiki/Engineering) works are recognized and adequately provided for. [Engineering geologists](http://en.wikipedia.org/wiki/Engineering_geologists) investigate and provide geologic and geotechnical recommendations, analysis, and design associated with human development. The realm of the engineering geologist is essentially in the area of earth-structure interactions, or investigation of how the earth or earth processes impact human made structures and human activities.

Engineering geologic studies may be performed during the planning, environmental impact analysis, civil or structural engineering design, value engineering and construction phases of public and private works projects, and during post-construction and forensic phases of projects. Works completed by engineering geologists include; [geologic hazards](http://en.wikipedia.org/wiki/Geologic_hazards), [geotechnical](http://en.wikipedia.org/wiki/Geotechnical), material properties, [landslide](http://en.wikipedia.org/wiki/Landslide) and slope stability, [erosion](http://en.wikipedia.org/wiki/Erosion), [flooding](http://en.wikipedia.org/wiki/Flooding), [dewatering](http://en.wikipedia.org/wiki/Dewatering), and [seismic](http://en.wikipedia.org/wiki/Seismic) investigations, etc. Engineering geologic studies are performed by a [geologist](http://en.wikipedia.org/wiki/Geologist) or engineering geologist that is educated, trained and has obtained experience related to the recognition and interpretation of natural processes, the understanding of how these processes impact man-made structures (and vice versa), and knowledge of methods by which to mitigate for hazards resulting from adverse natural or man-made conditions. The principal objective of the engineering geologist is the protection of life and property against damage caused by geologic conditions.

Engineering geologic practice is also closely related to the practice of [geological engineering](http://en.wikipedia.org/wiki/Geological_engineering), [geotechnical engineering](http://en.wikipedia.org/wiki/Geotechnical_engineering), [soils engineering](http://en.wikipedia.org/wiki/Soils_engineering), [environmental geology](http://en.wikipedia.org/wiki/Environmental_geology) and [economic geology](http://en.wikipedia.org/wiki/Economic_geology). If there is a difference in the content of the disciplines described, it mainly lies in the training or experience of the practitioner.

## History

Although the science of [geology](http://en.wikipedia.org/wiki/Geology) has been around since the 18th century, at least in its modern form, the science and practice of engineering geology didn't begin as a recognized discipline until the late 19th and early 20th centuries. The first book entitled Engineering Geology was published in 1880 by William Penning. In the early 20th century Charles Berkey, an American trained geologist who was considered the first American [engineering geologist](http://en.wikipedia.org/wiki/Engineering_geologist), worked on a number of water supply projects for New York City, then later worked on the Hoover dam and a multitude of other engineering projects. The first American engineering geology text book was written in 1914 by Ries and Watson. In 1925, [Karl Terzaghi](http://en.wikipedia.org/wiki/Karl_Terzaghi), an Austrian trained engineer and geologist, published the first text in Soil Mechanics (in German). Terzaghi is known as the father of soil mechanics, but also had great interest in geology; Terzaghi considered soil mechanics to be a sub-discipline of engineering geology. In 1929, Terzaghi, along with Redlich and Kampe, published their own Engineering Geology text (also in German).

The need for geologist on engineering works gained world wide attention in 1928 with the failure of the St. Francis dam in California and the loss of 426 lives. More engineering failures which occurred the following years also prompted the requirement for engineering geologists to work on large engineering projects.

In 1951, one of the earliest definitions of the "[Engineering geologist](http://en.wikipedia.org/wiki/Engineering_geologist)" or "Professional Engineering Geologist" was provided by the Executive Committee of the Division on Engineering Geology of the Geological Society of America.

## The Practice

One of the most important roles of the [engineering geologist](http://en.wikipedia.org/wiki/Engineering_geologist) is the interpretation of [landforms](http://en.wikipedia.org/wiki/Landforms) and earth processes to identify potential geologic and related man-made hazards that may impact civil structures and human development. Nearly all engineering geologists are initially trained and educated in [geology](http://en.wikipedia.org/wiki/Geology), primarily during their undergraduate education. This background in geology provides the engineering geologist with an understanding of how the earth works, which is crucial in mitigating for earth related hazards. Most engineering geologists also have graduate degrees where they have gained specialized education and training in [soil mechanics](http://en.wikipedia.org/wiki/Soil_mechanics), [rock mechanics](http://en.wikipedia.org/wiki/Rock_mechanics), [geotechnics](http://en.wikipedia.org/wiki/Geotechnics), [groundwater](http://en.wikipedia.org/wiki/Groundwater), [hydrology](http://en.wikipedia.org/wiki/Hydrology), and civil design. These two aspects of the engineering geologists' education provides them with a unique ability to understand and mitigate for hazards associated with earth-structure interactions.

## Scope of Studies

Engineering geologic studies may be performed:

* for residential, commercial and industrial developments;
* for governmental and [military](http://en.wikipedia.org/wiki/Military) installations;
* for public works such as a [power plant](http://en.wikipedia.org/wiki/Power_plant), [wind turbine](http://en.wikipedia.org/wiki/Wind_turbine), [transmission line](http://en.wikipedia.org/wiki/Transmission_line), [sewage treatment](http://en.wikipedia.org/wiki/Sewage_treatment) plant, [water treatment](http://en.wikipedia.org/wiki/Water_treatment) plant, [pipeline](http://en.wikipedia.org/wiki/Pipeline_transport) ([aqueduct](http://en.wikipedia.org/wiki/Aqueduct), [sewer](http://en.wikipedia.org/wiki/Sanitary_sewer), [outfall](http://en.wikipedia.org/wiki/Outfall)), [tunnel](http://en.wikipedia.org/wiki/Tunnel), [trenchless](http://en.wikipedia.org/wiki/Trenchless) construction, [canal](http://en.wikipedia.org/wiki/Canal), [dam](http://en.wikipedia.org/wiki/Dam), [reservoir](http://en.wikipedia.org/wiki/Reservoir_%28water%29), building, [railroad](http://en.wikipedia.org/wiki/Railroad), [transit](http://en.wikipedia.org/wiki/Mass_transit), [highway](http://en.wikipedia.org/wiki/Highway), [bridge](http://en.wikipedia.org/wiki/Bridge), [seismic retrofit](http://en.wikipedia.org/wiki/Seismic_retrofit), [airport](http://en.wikipedia.org/wiki/Airport) and park;
* for [mine](http://en.wikipedia.org/wiki/Mining) and [quarry](http://en.wikipedia.org/wiki/Quarry) excavations, [mine tailing dam](http://en.wikipedia.org/w/index.php?title=Mine_tailing_dam&action=edit&redlink=1), [mine reclamation](http://en.wikipedia.org/wiki/Mine_reclamation) and mine [tunneling](http://en.wikipedia.org/wiki/Tunnel);
* for [wetland](http://en.wikipedia.org/wiki/Wetland) and [habitat restoration](http://en.wikipedia.org/wiki/Habitat_restoration) programs;
* for [coastal](http://en.wikipedia.org/wiki/Coastal) engineering, [sand replenishment](http://en.wikipedia.org/wiki/Sand_replenishment), bluff or [sea cliff](http://en.wikipedia.org/wiki/Sea_cliff) stability, [harbor](http://en.wikipedia.org/wiki/Harbor), [pier](http://en.wikipedia.org/wiki/Pier) and waterfront development;
* for offshore [outfall](http://en.wikipedia.org/wiki/Outfall), [drilling platform](http://en.wikipedia.org/wiki/Drilling_platform) and [sub-sea pipeline](http://en.wikipedia.org/w/index.php?title=Sub-sea_pipeline&action=edit&redlink=1), sub-sea cable; and
* for other types of facilities.

## Geohazards and adverse geo-conditions

Typical [geologic hazards](http://en.wikipedia.org/wiki/Geologic_hazards) or other adverse conditions evaluated and mitigated by an [engineering geologist](http://en.wikipedia.org/wiki/Engineering_geologist) include:

* [fault rupture](http://en.wikipedia.org/wiki/Earthquake#Shaking_and_ground_rupture) on seismically active [faults](http://en.wikipedia.org/wiki/Fault_%28geology%29) ;
* [seismic](http://en.wikipedia.org/wiki/Seismic) and [earthquake](http://en.wikipedia.org/wiki/Earthquake) hazards (ground shaking, [liquefaction](http://en.wikipedia.org/wiki/Liquefaction), [lurching](http://en.wikipedia.org/w/index.php?title=Lurching&action=edit&redlink=1), [lateral spreading](http://en.wikipedia.org/w/index.php?title=Lateral_spreading&action=edit&redlink=1), [tsunami](http://en.wikipedia.org/wiki/Tsunami) and [seiche](http://en.wikipedia.org/wiki/Seiche) events);
* [landslide](http://en.wikipedia.org/wiki/Landslide), [mudflow](http://en.wikipedia.org/wiki/Mudflow), [rockfall](http://en.wikipedia.org/wiki/Rockfall), [debris flow](http://en.wikipedia.org/wiki/Debris_flow), and [avalanche](http://en.wikipedia.org/wiki/Avalanche) hazards ;
* [unstable slopes](http://en.wikipedia.org/w/index.php?title=Unstable_slopes&action=edit&redlink=1) and [slope stability](http://en.wikipedia.org/wiki/Slope_stability);
* [erosion](http://en.wikipedia.org/wiki/Erosion);
* [slaking](http://en.wikipedia.org/wiki/Slaking_%28geology%29) and [heave](http://en.wikipedia.org/wiki/Heave) of geologic formations;
* ground [subsidence](http://en.wikipedia.org/wiki/Subsidence) (such as due to [ground water](http://en.wikipedia.org/wiki/Ground_water) withdrawal, [sinkhole](http://en.wikipedia.org/wiki/Sinkhole) collapse, [cave](http://en.wikipedia.org/wiki/Cave) collapse, decomposition of organic soils, and [tectonic](http://en.wikipedia.org/wiki/Tectonic) movement);
* [volcanic](http://en.wikipedia.org/wiki/Volcanic) hazards ([volcanic eruptions](http://en.wikipedia.org/wiki/Volcanic_eruption), [hot springs](http://en.wikipedia.org/wiki/Hot_springs), [pyroclastic flows](http://en.wikipedia.org/wiki/Pyroclastic_flows), [debris flow](http://en.wikipedia.org/wiki/Debris_flow), [debris avalanche](http://en.wikipedia.org/wiki/Debris_avalanche), [gas emissions](http://en.wikipedia.org/w/index.php?title=Gas_emissions&action=edit&redlink=1), volcanic [earthquakes](http://en.wikipedia.org/wiki/Earthquakes));
* [non-rippable](http://en.wikipedia.org/w/index.php?title=Non-rippable&action=edit&redlink=1) or [marginally rippable](http://en.wikipedia.org/w/index.php?title=Marginally_rippable&action=edit&redlink=1) rock requiring heavy ripping or [blasting](http://en.wikipedia.org/wiki/Rock_blasting);
* weak and collapsible soils, foundation bearing failures;
* shallow ground water/seepage; and
* other types of geologic constraints.

An engineering geologist or [geophysicist](http://en.wikipedia.org/wiki/Geophysicist) may be called upon to evaluate the [excavatability](http://en.wikipedia.org/wiki/Excavatability) (i.e. [rippability](http://en.wikipedia.org/wiki/Rippability)) of earth (rock) materials to assess the need for pre-[blasting](http://en.wikipedia.org/wiki/Rock_blasting) during earthwork construction, as well as associated impacts due to [vibration](http://en.wikipedia.org/wiki/Oscillation) during blasting on projects.

## Soil and Rock Mechanics

Main articles: [Soil mechanics](http://en.wikipedia.org/wiki/Soil_mechanics) and [Rock mechanics](http://en.wikipedia.org/wiki/Rock_mechanics)

[Soil mechanics](http://en.wikipedia.org/wiki/Soil_mechanics) is a discipline that applies principles of engineering mechanics, e.g. kinematics, dynamics, fluid mechanics, and mechanics of material, to predict the mechanical behavior of soils. [Rock mechanics](http://en.wikipedia.org/wiki/Rock_mechanics) is the theoretical and applied science of the mechanical behaviour of rock and rock masses; it is that branch of mechanics concerned with the response of rock and rock masses to the force fields of their physical environment. The fundamental processes are all related to the behaviour of porous media. Together, soil and rock mechanics are the basis for solving many engineering geologic problems.

## Methods and reporting

The methods used by [engineering geologists](http://en.wikipedia.org/wiki/Engineering_geologist) in their studies include

* [geologic field mapping](http://en.wikipedia.org/wiki/Geologic_map) of geologic structures, geologic formations, soil units and hazards;
* the review of geologic literature, geologic maps, geotechnical reports, engineering plans, environmental reports, stereoscopic [aerial photographs](http://en.wikipedia.org/wiki/Aerial_photograph), remote sensing data, [Global Positioning System](http://en.wikipedia.org/wiki/Global_Positioning_System) (GPS) data, topographic maps and [satellite](http://en.wikipedia.org/wiki/Satellite) imagery;
* the excavation, sampling and logging of earth/rock materials in drilled borings, backhoe test pits and trenches, fault trenching, and bulldozer pits;
* [geophysical](http://en.wikipedia.org/wiki/Geophysical) surveys (such as [seismic refraction](http://en.wikipedia.org/wiki/Seismic_refraction) traverses, [resistivity](http://en.wikipedia.org/wiki/Resistivity) surveys, [ground penetrating radar](http://en.wikipedia.org/wiki/Ground_penetrating_radar) (GPR) surveys, [magnetometer](http://en.wikipedia.org/wiki/Magnetometer) surveys, [electromagnetic](http://en.wikipedia.org/wiki/Electromagnetism) surveys, high-resolution sub-bottom profiling, and other geophysical methods);
* [deformation monitoring](http://en.wikipedia.org/wiki/Deformation_Monitoring) as the systematic measurement and tracking of the alteration in the shape or dimensions of an object as a result of the application of stress to it manually or with an [automatic deformation monitoring system](http://en.wikipedia.org/wiki/Automatic_Deformation_Monitoring_System); and
* other methods.

The field work is typically culminated in analysis of the data and the preparation of an engineering geologic report, geotechnical report, fault hazard or seismic hazard report, geophysical report, [ground water](http://en.wikipedia.org/wiki/Ground_water) resource report or [hydrogeologic](http://en.wikipedia.org/wiki/Hydrogeology) report. The engineering geologic report is often prepared in conjunction with a geotechnical report, but commonly provide geotechnical analysis and design recommendations independent of a geotechnical report. An engineering geologic report describes the objectives, methodology, references cited, tests performed, findings and recommendations for development. Engineering geologists also provide geologic data on topograpic maps, aerial photographs, geologic maps, [Geographic Information System](http://en.wikipedia.org/wiki/Geographic_information_system) (GIS) maps, or other map bases.

## See also

* [Earthquake engineering](http://en.wikipedia.org/wiki/Earthquake_engineering)
* [Geoprofessions](http://en.wikipedia.org/wiki/Geoprofessions)
* [Geotechnics](http://en.wikipedia.org/wiki/Geotechnics)
* [Geotechnical engineering](http://en.wikipedia.org/wiki/Geotechnical_engineering)
* [Geotechnical investigation](http://en.wikipedia.org/wiki/Geotechnical_investigation)
* [Important publications in engineering geology](http://en.wikipedia.org/wiki/List_of_publications_in_geology#Engineering_geology)
* [Mining engineering](http://en.wikipedia.org/wiki/Mining_engineering)
* [Petroleum engineering](http://en.wikipedia.org/wiki/Petroleum_engineering)
* [Hydrogeology](http://en.wikipedia.org/wiki/Hydrogeology)

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