GEOL 314
Engineering Geology
Spring 2022

Dr. Robert Mitchell
360-650-3591
rjmitch@wwu.edu
https://cse.wwu.edu/geology/rjmitch

Student support hours: M and W 1- 2:00 pm, or by arrangement.

Course Description

GEOL 314 focuses on the core activities of engineering geologists – site characterization and geologic hazard identification and mitigation. Through lectures, labs, and case study examination you will learn to couple your geologic expertise with the engineering properties of rock and unconsolidated materials in the characterization of geologic sites for civil work projects and the quantification of processes such as rock slides, soil-slope stability, settlement, and liquefaction.

Engineering geology is an applied geology discipline that involves the collection, analysis, and interpretation of geological data and information required for the safe development of civil works. Engineering geology also includes the assessment and mitigation of geologic hazards such earthquakes, landslides, flooding; the assessment of timber harvesting impacts; and groundwater remediation and resource evaluation. Engineering geologists are applied geoscientists with an awareness of engineering principles and practice—they are not engineers. In states that require professional licensing (e.g., Washington, Oregon, and California) these practitioners become Licensed Engineering Geologists (LEGs), not Professional Engineers (PEs) like geological engineers and geotechnical engineers

Course Structure

I will use a combination of (3 hours per week) and labs (2 hours per week). In the first half of the course I will discuss rock mechanics, and how to characterize the susceptibility of rock slopes sites to failure. You will learn how to assess rock-mass quality, perform kinematic analyses, and analyze rock-slope stability (sliding and topples). In the second half of the course I cover the mechanics of unconsolidated materials (soils) as applied to processes such consolidation/settlement, subsidence, liquefaction, compaction, and soil slope stability. I will also introduce common methods used in geotechnical engineering such as the Unified Soil Classification System and the American Society for Testing Materials (ASTM) standards (e.g., Atterberg limits and Proctor tests).

Reading Resources

There is not a required textbook for the course. Some recommended textbooks include:

Principles of Engineering Geology, Robert B. Johnson and Jerome V. De Graff, Wiley Press, 1988.

Geological Engineering, Luis I. González de Vallejo and Mercedes Ferrer, CRC Press, 2011

Geotechnical Engineering: Principles and Practice, Donald P. Coduto et al., 2nd Ed, Pearson, 2011.

Some online resources include:

Geotechnical Engineering Circular No. 5: Evaluation of Soil and Rock Properties, P.J. **Sabatini**, R.C. Bachus, P.W. Mayne, J.A. Schneider, T.E. Zettler. Report No. FHWA-IF-02-034.

Geotechnical Design Manual, Washington State Department of Transportation, Pub. No. M 46-03.10.

Engineering Geology Field Manual, U.S. Bureau of Reclamation.

Assessment of Learning

Pages 6-9 contain the learning outcomes in GEOL314. There are seven broad Core Concepts (CC) or big ideas, followed by more specific Learning Targets (LTs) and the Success Criteria (bulleted) that demonstrate mastery of the LTs.

Labs. There will be weekly two-hour labs that will include a mix of ArcGIS exercises, data analysis, and software applications using Rocscience. The lab topics are listed below. You will typically have one week to complete the labs. Labs turned in after class on the due date will be deducted 5%, and 10% for each day they are late. **I realize that life happens and that there are circumstances where it is difficult to get work done—especially with COVID. Under these circumstances I am flexible, so please see me before the project is due if you find yourself in a time management situation.**

Quizzes. Instead of a midterm exam, there will be four quizzes that will focus on the learning targets discussed prior to the quiz. The quizzes will be on Friday on Canvas and you will take them outside the class time.

Attendance: There will be important information presented in class and through breakout activities. It is important that you attend all meetings and actively participate.

Final exam. There will be a required, comprehensive final exam that will be administer on Canvas during the scheduled final exam time. Make-up exams will be given only in the case of official emergencies. An excused absence form from the office of Student Affairs is required. **Note: you must pass the final exam (≥ C-) to pass the course.**

Grading: The grading break down will be as follows:

Labs……….……50% (Every Friday 1-3 pm)
Quizzes…………30% (Friday morning on Canvas April 8 and 22, May 6 and 20)
Final Exam………20% (Thursday, June 9, 1:00 – 3:00 PM)

A grading scale will be as follows (a curve is possible but not certain):
100-93 = A, 92-90 = A-, 89-88 = B+, 87-83 = B, 82-80 = B-, 79-78 = C+, 77-73 = C, 72-70 = C-, 69-68 = D+, 67-63 = D, 62-60 = D-, 60 or below = F

Academic Success and Support Services: Please feel free to talk to me anytime about your performance in the course or possible ways you can improve.

I reserve the right to change the syllabus as required throughout the term to better meet the instructional needs of the class.

Please review the WWU Policies for Students (Links to an external site.)

Disability, equitable access, and accommodations: This course is intended for all WWU students, including those with visible or invisible disabilities. Students with disabilities will be provided equitable access to educational experiences and opportunities. If, at any point in the quarter, you find yourself not able to fully access the space, content, and experience of this course, please first contact the Disability Access Center (DAC) to discuss potential accommodations. Faculty and staff partner with the DAC in the implementation of accommodations. If you already have accommodations set up through the DAC, please be sure to send your Faculty Notification Letter to me, through the my DAC portal, and reach out so we can discuss how your approved accommodations apply to this course. If you need or are unsure if accommodations are appropriate for you, contact the DAC for more information, temporary assistance, or connections to other resources: Disability.wwu.edu or 360-650-3083.

Academic honesty is an important part of every course at WWU. You will find that cheating on digital projects is rather easy. However, turning in someone else's work will only ensure that you gain nothing from this class and that you have more difficulty later on in this or future classes. Cheating will also result in severe penalties. Please make sure you read the Academic Honesty Policy and Procedure in Appendix D (Links to an external site.) of the WWU Course Catalog for details.

Your **professional conduct** in this course is important. I facilitate my courses in a professional manner and have the same expectations of you. By professional, I mean having a respectful demeanor, arriving to Zoom sessions on time, no texting or internet surfing during meetings, communicating with courteous emails, producing neat organized and well written student works, and, maintaining academic honesty.

Classroom climate: I am committed to establishing and maintaining a classroom climate that is inclusive and respectful for all students and an environment free of discrimination and harassment. Federal and State laws, as well as WWU University policies, protect students, faculty and staff against discrimination. Learning includes being able to voice a variety of perspectives, and classroom discussion is encouraged. While students' expressed ideas may vary and/or be opposed to one another, it is important for all of us to listen and engage respectively with each other. In this class, I expect all students to make their best efforts to pronounce one another's names correctly, and to respect one another's personal pronouns. If you have questions or concerns related to these expectations, please speak with me. Please review WWU's Student Conduct Code.

Some EID information about me

My implicit biases influence how I perceive and interact with you, which are in-part based on the following:

I am a heterosexual white male over 60 years of age. I was born and raised in small 'white' town in northwestern Wisconsin by two parents and have five siblings. My parents grew up on farms in Wisconsin and raised me as a Catholic—I went to a Catholic school through the 8th grade. I am privileged to have had many outdoor experiences and adventures. I am a highly educated scientist/engineer and think analytically. I am a first-generation college student and worked and paid for my undergraduate education that I received at a state (public) university in Wisconsin. I have been married for 26 years to the same woman and have a daughter and son that are both in college. I am an introvert and use nature and exercise to maintain a positive, healthy mindset.

I am becoming more aware of how my implicit biases control my thinking and perceptions, primarily through equity, inclusion, and diversity (EID) training opportunities offered through the College of Sciences and Engineering (CSE). In addition to reading on my own, I have participated in four, half-day CSE Equity and Inclusion Forum Workshops in 2017 and recently participated in the Howard Hughes Medical Institute's—AEES Faculty Development Program—about 50 hours in 2020-21. I am also getting EID education as a board member of Wild Whatcom and from the Geology Department's URGE Pod.

Student Services: Western encourages students to seek assistance and support at the onset of an illness, difficulty, or crisis.

- Reasonable accommodation for persons with documented disabilities should be established within the first week of class and arranged through Disability Resources for Students: telephone: 650–3080; email: drs@wwu.edu; online: http://www.wwu.edu/depts/drs/
- In the case of a medical concern or question, please contact the Health Center: 650-3400 or https://studenthealth.wwu.edu/
- In the case of an emotional or psychological concern or question, please contact the Counseling Center: 650-3400 or https://counseling.wwu.edu/
- In the case of a health and safety concern, please contact the University Police: 650-3555 or http://www.wwu.edu/ps/
- In the case of a family or personal crisis or emergency, please contact the Office of Student Life https://wp.wwu.edu/officeofstudentlife/
- To seek confidential support related to sexual violence, please contact CASAS (650-3700), the Student Health Center, and/or the Counseling Center. To report sexual violence, please contact University Police, Bellingham Police, and/or the Title IX Coordinator in Western's Equal Opportunity Office (650-3307).

GEOL 314 - Engineering Geology Lab Topics

1. ArcGIS exercise: introduction to site characterization and geologic hazards in Whatcom County, WA.
2. I-90 Design Sector VI rock mass quality analysis using intact rock, core recovery, and rock quality designation (RQD) data.
3. I-90 Design Sector VI stereographic projection of discontinuity data using Rocscience Dips software.
4. I-90 Design Sector VI kinematic and equilibrium analysis using discontinuity data and slope face orientations and Rocscience Dips and RocPlane software.
5. Soil classification and the Unified Soil Classification System –determining the group symbol and group name of the course fraction resulting from sieve analyses.
6. Consolidation and Settlement – case study example using Rocscience Settle3 software.
7. Liquefaction – case study of liquefaction susceptibility at the Bellingham water using Rocscience Settle3 software.
8. ArcGIS exercise: using model builder in ArcGIS to examine infinite slope landslide susceptibility in the Smith Creek basin in the Lake Whatcom watershed.
9. Analysis of a deep-seated rotational landslide on coastal bluff on Whidbey Island using Rocscience Slide2 software.
10. Seismic Design Categories – use USGS web tools and DNR maps to examine the seismic design categories of site in Washington State.

GEOL 314 Learning Outcomes

Listed below are **seven** broad **Core Concepts (CC)** or big ideas covered in GEOL314, followed by more specific Learning Targets (LTs) and the Success Criteria (bulleted) that demonstrate mastery of the LTs.

CC1: Engineering geology is the study of how the engineering properties of Earth materials affect geologic processes and civil works.

LT1: The core values of the engineering geology discipline are to protect the health and welfare of people and property.

- I can describe why geologists are licensed in WA State and that Engineering Geology is a specialty license.
- I can describe the steps required to become a licensed engineering geologist in WA State.
- I can describe the types of geologic hazards that pose a risk to people and property in WA State.

LT2: The core activity of an engineering geologist is site characterization.

- I can describe the role of an engineering geologist in civil projects.
- I can describe the stages required for a site characterization
- I can describe ASTMs and why they are necessary.
- I can describe how engineering geology bridges a geology and geotechnical engineering.
- I can describe the conventions that geotechnical engineers use in data collection, analysis, and presentation and how they differ from a geologist.
- I can use ArcGIS to examine geology, soil, geologic hazard, and earthquake data to characterize a site.

CC2: Rocks have physical properties that determine their engineering strength.

LT1: How much strain a rock experiences depends on its material (elastic) properties and the magnitude of the applied stress under unconfined conditions.

- I can calculate the bulk properties of rocks and soils such as density, unit weights. void ratio (and porosity) and water contents.
- I can quantify the axial and transverse strain of a rock core subject to an unconfined axial stress.
- I can explain the units of stress and strain.
- I can describe the difference between tensile and compressive axial stress conditions.
- I can explain Hooke's Law as it applies to stress-strain relationships.
- I can explain why Young's elastic modulus (E) varies with rock types.
- I can explain why ASTMs are required to measure a rock's response to unconfined stresses.
- I can explain how to apply the Poisson's ratio (v) under axial unconfined stress-strain conditions.
- I can estimate the volume change of a rock core subject to an unconfined axial stress.
- I can explain the ultimate strength of a rock and why it is lower under tension than compression.

LT2: Lithostatic stresses beneath the Earth's surface depend on variations in rock density.

- I can calculate the lithostatic stress in a layered system of Earth deposits.
- I can explain the role of the Bulk modulus (k) under an elastic confining stress-strain relationship.
- I can estimate the change in volume of a rock under confining stress conditions.
- I can explain why a granitic batholith expands upon exposure at the Earth's surface.
- I can couple lithostatic and unconfined stress-strain concepts using a room and pillar mine design.
- I can explain the concept of 'factor of safety' and how it relates to an engineering design.

LT3: Rock failures are commonly associated with failure due to imposed shear stresses.

- I can explain the role of the shear modulus (θ) under an elastic shear stress-strain relationship.
- I can explain why the plane with the maximum shear stress is at 45^{o} to the maximum principal stress.
- I can apply relations to estimate an elastic modulus in terms of other elastic moduli.
- I can apply relations to estimate seismic wave velocities using rock densities and elastic moduli.

CC3: Rock slope stability is function of rock strength and structural discontinuity orientations.

LT1: Rock-mass quality refers to the ability of a rock mass to perform certain design requirements for civil works.

- I can list the factors that are used to assess the Rock-Mass Rating of a rock outcrop (ASTM-D5878).
- I can assess the rock-quality designation (RQD) of rock cores from a field site.
- I can interpret uniaxial compressive strength data from rock cores at a field site.

LT2: A kinematic analysis considers the geometric potential for movement in a slope.

- I can plot the dip and dip direction of discontinuity measurements in Rocscience Dips software and identify mean orientation poles in a stereographic projection.
- I can explain the necessary conditions for planar failure in a stereographic kinematic analysis.
- I can explain a daylight envelope on a stereographic projection in Rocscience Dips.
- I can explain the necessary conditions for flexural toppling failure in a stereographic kinematic analysis.
- I can use Rocscience Dips software to perform a kinematic analysis for planar and flexural toppling conditions.

LT3: A limit-equilibrium stability analysis compares the forces resisting failure to those forces causing failure, i.e., the factor of safety (FS).

- I explain the difference between mechanical friction and cohesion strength of a rock slope.
- I can explain how the internal angle of friction relates to the coefficient of friction.
- I can explain the internal and external driving forces of a planar rock slope.
- I can explain how the rock slope angle influences forces on a rock slope.
- I can calculate the FS of a planar rock slope using forces or stresses.
- I can explain how rock bolts strengthen a planar rock slope.
- I can explain how pseudo-static earthquake forces decrease the stability of a rock slope.
- I can apply a moment analysis to assess the direct toppling risk of a rock block.
- I can use Rocscience RocPlane software to a perform a limited equilibrium (kinetic) analysis under deterministic, probabilistic and earthquake and bolt conditions for planar sliding.

CC4: Soils are unconsolidated materials that are classified differently by engineers.

LT1: Soils are unconsolidated deposits derived from the weathering of parent material.

- I can describe how a soil scientist and geologist define a soil.
- I can describe how a geotechnical engineer and engineering geologist describe a soil.
- I can summarize the most recent glacial history in the Puget Sound region.
- I can describe the key glacial deposits associated with the last glaciation and how glacial deposits formed.
- I can describe the Holocene fluvial deposits that form soils in the Puget Sound region.

LT2: Coarse soils are classified by their distribution of grain sizes.

- I can explain the difference between a sorting system and graded system for describing the grain-size distribution of a soil.
- I can plot a grain-size distribution curve based on the results of a sieve analysis (ASTM D6913).
- I can apply the USDA textural diagram to classify a soil.
- I can calculate the Uniformity Coefficient (C_u) and Coefficient of curvature (C_c) from a grain-size distribution plot.
- I can apply the Unified Soil Classification System (USCS) flow diagram to identify a group symbol and group name of a soil (ASTM 2847).

LT3: Fine-grained soils contain silt and clay-sized particles.

- I can explain why clay minerals have a negative charge.
- I can explain why montmorillonite (or smectite) has a high cation exchange capacity.
- I can explain why a clay mineral deposit can swell upon becoming saturated with water.
- I can explain why glaciomarine clays are highly sensitive and can be classified as quick clays.
- I can perform laboratory tests to determine Atterberg limit values for a fine-grained soil.
- I can use a placticity chart and a USCS flow diagram to identify a group symbol and group name of a fined-grained soil.

CC5: Soils adjust in response to external stresses from civil projects.

LT1: Index parameters can be used to predict soil geotechnical properties.

- I can calculate the dry, moist, saturated and average particle density of a soil sample.
- I can calculate the porosity and void ratio of a soil sample.
- I can calculate the water content (*wc*) of a soil sample.

LT2: Compaction of near-surface soils minimizes settlement and increases a soils bearing capacity.

- I can explain the difference between a cohesive and non-cohesive soil.
- I can explain why cohesive soils compact more efficiently than non-cohesive soils.
- I can explain why near surface soils are compacted in construction projects.
- I can explain how the water content of soil influences the degree of compaction.
- I can describe how to conduct a Proctor test and interpret a plot resulting from Proctor tests.

LT3: Saturated soils consolidate in response to an external stress.

- I can explain what quantifies a buoyancy force.
- I can explain how the buoyancy force relates to the 'effective stress' of saturated sediment.
- I can apply formulas to determine the magnitude of induced stresses in the soils from structures and fills
- I can explain why clay rich soils consolidate more than sands and silts.
- I can describe the stages of the consolidation process.
- I can describe the relationship between soil consolidation and ground-surface settlement.
- I can describe how the compression index of a soil is estimated.
- I can describe what determines the magnitude of soil consolidation.
- I can describe what determines the magnitude of the hydraulic conductivity of a soil and how it relates to the rate of consolidation of a soil.
- I can use Rocscience Settle3 to assess the magnitude and rate of soil settlement in response to an external load.
- I can describe how soil consolidation on a local scale relates to subsidence on a regional scale.
- I can explain how the hydraulic gradient in the direction of flow relates to a seepage force acting on porous media and explain how quicksand forms.
- I can explain the process of liquefaction and what types of soils are most susceptible to liquefaction due to ground shaking from earthquakes.
- I can apply Rocscience Settle3 to assess the liquefaction susceptibility at a site.

CC6: The shear strength of soil resists the movement of soils on slopes.

LT1: The shear strength of soils is determined by mechanical and molecular factors.

- I can describe the mechanical attributes of soils and how they relate to the internal angle of friction.
- I can explain how the magnitude of the normal force of a soil on a slope influences the magnitude of the soil shear strength.
- I can explain how van der Waals forces offer cohesive strength (drained cohesion) to cohesive soils.

- I can explain how capillary forces create tension in soils and create capillary cohesion strength to non-cohesive soils.
- I can expression the shear strength of a soil in terms of a Mohr-Coulomb failure plot.
- I can describe the field techniques (SPT, CPT) that are used to estimate the shear strength of soils.
- I can describe lab techniques (split mold, direct shear, and triaxial) that are use to estimate the shear strength of soils.
- I can describe how triaxial tests results are used with Mohr diagrams to estimate the Mohr-Coulomb failure criteria.
- I can access regional literature to find average shear strength values for common Puget Sound region glacial and fluvial unconsolidated deposits.

LT2: Shallow infinite slope failures are translational slides that occur in thin soils on steep slopes.

- I can describe the conditions under which infinite slope failures occur.
- I can list the assumptions associated with the infinite slope factor of safety equation.
- I can describe the difference between a debris flow and an infinite slope failure.
- I can describe how vegetation roots increase the strength to soils (root cohesion).
- I can describe how water in soils decreases the soil shear strength and increase the shear stress.
- I can describe how vegetation interception and transpiration decreases the soil-water content.
- I can apply a deterministic form of the infinite slope equation in ArcGIS to create a slope failure susceptibly map given spatial, soil and vegetation characteristics of a hillslope.

LT3: Deep-seated or rotational slides occur in thick unconsolidated deposits.

- I can describe why deep-seated landslides have curved failure surfaces and rotational movement.
- I can apply a moment analysis to estimate a FS of failure for a rotational slide.
- I can apply a moment analysis and the pseudo-static method to assess the effect of earthquake forces on the stability of a rotational slide.
- I can apply a method of slices technique to assess the FS of a rotational slide.
- I can apply Rocscience Slide2 software (method of slices) to examine the most probable failure surface in a geologic cross section.
- I can apply Rocscience software to examine the sensitivity of a probable failure surface to soil mechanical properties, slope angle, and water content.

CC7: Earthquakes cause ground shaking that can damage buildings.

LT1: Earthquake hazard maps are used to illustrate the risk and magnitude of earthquake ground shaking.

- I can explain the concept of peak ground acceleration (PGA).
- I can explain the factors that go into the development of a probability of exceedance PGA map.
- I can describe the three different sources for earthquakes in the Puget Sound region.
- I can USGS web sites to examine crustal faults in the Puget Sound region.
- I can describe key city lifelines that could get damaged by earthquake ground shaking.

LT2: The Seismic Design Category for a site is used to mitigate the response of a building to earthquake ground shaking.

- I can use shear wave velocities to determine the soil Site Class for the upper 100-feet of soil.
- I can explain why higher Site Class letters produce more ground shaking.
- I can view soil Site Class maps for Washington State in ArcGIS.
- I can explain how spectral acceleration relates to a building height.
- I can explain how design spectral short period (S_{DS}) and long period (S_{D1}) response acceleration data relate to building shaking.
- I can use the SEAOC/OSHPD Seismic Design Maps Tool to determine the Seismic Design Category for a site.

Geology 314 – Engineering geology provides information for the following Geology degree program outcomes:

	B.A. Geology	B.S. Geology	B.S. Geophysics	GUR
Program Outcomes	*2. Earth's surface is affected by dynamic processes on a range of timescales.* *7. Graduates have developed their observational, analytical and quantitative skills (field, lab, computer, and classroom)*	*2. Earth's surface is affected by dynamic processes on a range of timescales.* *7. Graduates have developed their observational, analytical and quantitative skills (field, lab, computer, and classroom)* *10. Graduates (alone or in teams) will be able to present geological information clearly*	*2. Earth's surface is affected by dynamic processes on a range of timescales.* *7. Graduates have developed their observational, analytical and quantitative skills (field, lab, computer, and classroom)* *10. Graduates (alone or in teams) will be able to present geological information clearly*	*1. Analyze and communicate ideas effectively in oral, written, and visual forms.* *3. Use quantitative and scientific reasoning to frame and solve problems.*

Geology Department Program Student Learning Outcomes

Geology BA Degree

Cognitive outcomes: Our students will have a deep understanding of the following foundational geologic principles:

1. Earth has a history of biological and physical change over billions of years.
2. Earth's surface is affected by dynamic processes on a range of timescales.
3. Earth's composition varies and these compositions provide the raw materials for the rock cycle.
4. Earth's interior is dynamic and drives plate tectonics.
5. Earth scientists use repeatable observations and testable ideas to understand and explain our planet.
6. Geology and society are fundamentally inter-related.

Skills: Our students will have critical skills required by professional geologists. Graduates:

7. Have developed their observational, analytical and quantitative skills.

Geology BS Degree (all of the above plus)

Skills:

8. Can create maps and understand what they tell us about the Earth.
9. Will be able to apply physics, chemistry, and mathematics concepts to the study of Earth.
10. Will be able (alone or in teams) to present geological information clearly.

Geophysics BS Degree (all of the above plus)

Skills:

11. Will be able to demonstrate general proficiency with concepts and quantitative problems involving Newtonian mechanics, energy, and momentum.