HWRS 561B Physical Hydrogeology II
Spring 2026

Catalog Description

This course is the second part of Physical Hydrogeology, which focuses on the physical concepts underlying water flow and solute transport in variably saturated porous media. We will approach these concepts from a fundamental perspective of multiphase flow and transport in porous media to help students develop a strong physical intuition. Building up on the intuitive understanding, we will then formulate mathematical models and discuss physical behaviors of the various solutions of variably saturated flow and transport. New cutting-edge topics on the fate and transport of emerging contaminants (e.g., PFAS) in the subsurface will also be introduced.

Course Prerequisites or Co-requisites

HWRS 561a Physical Hydrogeology I

Must be enrolled in the MS Hydrogeology program

Required co-registration in HWRS 599 Section 001 (Recitation), HWRS 562b Chemical Hydrogeology II, HWRS 563b Hydrogeologic Measurement Methods II, HWRS 564b Hydrogeologic Analysis Tools & Methods II, and HWRS 565b Communications in Hydrogeology II

Required Textbooks/Materials

None

Reference Readings (Optional)

References will be provided as needed through D2L. You will not need to purchase these references.

Course Objectives

Students will

1. understand the physical concepts and pore-scale controls underlying water flow and solute transport in variably saturated media
2. learn the assumptions behind macroscopic governing equations for flow and transport in variably saturated media.
3. analyze hydrogeologic problems under a wide range of conditions to gain physical intuition.
4. use analytical and numerical methods for solving flow and transport equations in variably saturated media.
5. understand concepts and tools used to analyze contaminant transport in the vadose zone.

Expected Learning Outcomes

Students will be able to

1. Characterize saturation-dependent soil hydraulic properties, both qualitatively and quantitatively, and develop an understanding of the relationship of those properties with pore scale air and water distributions.
2. Develop appropriate physical and mathematical representations of water flow and solute transport through fully and partially water saturated porous media at multiple scales in 1D, 2D, and 3D.

3. Synthesize and contextualize knowledge of data collection methods, quantitative models of flow and solute transport, and fundamental conceptual understanding for the purposes of supporting water resources decision-making.

Course Format and Teaching Methods

The course will consist of a mixture of lectures, in-class discussion and exercises.

Planned Field Trips

While this class has no field trips, there may be field trips in the other courses in the MS Hydrogeology program. The timing of all field trips are coordinated with students' schedules and the instructors of the other courses in the MS Hydrogeology program. This allows us to accommodate the field experience and not have it impact your participation in this course.

Schedule of Topics & Activities

The course will be organized around month long projects that give a learning context for all five co-convened classes. It follows the theory-data-prediction structure, including case-based theory and project-based methodology practice. Take Spring 2026 as an example, the scheduled activities are follows.

1	1/12/2026	**Re-orientation**	
Module 1: Solute transport in saturated media			
2	1/19/2026	Conservative solute transport (pore-scale controls, macroscopic formulation, governing equations, BCs, 1D Taylor-Aris dispersion)	HW 1: Solute transport in saturated media (concepts)
3	1/26/2026	Conservative solute transport (analytical and numerical solutions - python implementation)	
4	2/2/2026	Reactive solute transport (analytical/numerical solutions with retardation, kinetic/equilibrium adsorption). Focus more on the impact of retardation and adsorption on solute transport (less on the mechanisms of retardation and adsorption, which will be covered in chemical hydro).	HW 2: Solute transport in saturated media (theory and solutions)
Module 2: Pore-scale controls and macroscopic description of variably saturated flow			
5	2/9/2026	Pore scale air-water distribution (capillary tubes)	HW 3: Pore-scale controls
6	2/16/2026	Macroscopic descriptions of air/water distribution: theta(psi), K(theta), upscaling networks of capillary tubes	HW 4: Macroscopic description
7	2/23/2026	Two-phase flow. Richards' assumptions; Richards' equation.	HW 5: Richards' assumptions and Richards' equation Due date of Project 4: 2/22/2026
Module 3: Steady-state and transient variably saturated flow			
8	3/2/2026	Steady-state 1D unsaturated flow.	
9	3/9/2026	**No class: Spring break**	
10	3/16/2026	Steady state unsaturated flow in multiple dimensions and with heterogeneities	HW 6: Steady-state unsaturated flow
	3/18/2026	Mid-term exam	
11	3/23/2026	Transient 1D unsaturated flow. Simplified models (Green-Ampt, Philip's models). Analytical solutions.	HW 7: Transient unsaturated flow I
12	3/30/2026	Transient 1D unsaturated flow. Numerical solutions of Richards equation.	Due date of Project 5: 3/29/2026
13	4/6/2026	Unsaturated flow in multidimensions. Solute transport with unsaturated flow.	HW 8: Transient unsaturated flow II
Module 4: Risk assessment of contaminant transport in the vadose zone and groundwater			

14	4/20/2026	Risk assessment - Transport of pesticides/nutrients in the vadose zone. [Transient infiltration]	
15	4/30/2026	Risk assessment - Transport of emerging contaminants (e.g., PFAS, micro/nano plastics, ...) in the vadose zone. [Transient infiltration]	HW 9: Risk assessment of contaminant transport Due date of Project 6: 5/6/2026
15	5/8/2026	Final exam	

Course Assessments and Grading Breakdown

You will be assessed on the basis of weekly assignments. You will also be assessed based on how you apply the understanding gained in this class to the projects. Finally, you will receive completion credit for completing weekly self-assessments.

HW Assignments are assigned every Monday, and they are due the following week, Thursday by 10 pm. These assignments will consist of a few short answer and/or calculation questions. Each assignment will be given a time budget. This will give students an indication of the level of effort expected for each assignment. Students will report the time spent on the project. If individual students are spending more time than the average, the instructor will meet with them to identify and solve any issues. If many students are spending more than the assigned time, then the assignments will be modified for the remainder of the term and for subsequent years. It is expected that students will spend no more than 1.5 hours per week on these class assignments. The assignments will consist of a report of methods applied in the class that week, a summary of data collected, and limited data analysis to answer no more than three specific questions.

Exams – These will test of your understanding of elements of the course and your ability to apply that knowledge. This may include calculations, analysis, synthesis, and written elements.

Projects – Physical Hydrogeology Component - assigned monthly. These projects are designed to synthesize the content/skills you are learning in all 5 courses that month to address a hydrogeologic problem/task. This means that the projects in their entirety are not specific to any one course and require you to pull knowledge from them all to address a hydrogeologic problem. However, you will be graded and assessed on the knowledge/skills needed from physical hydrogeology to address this problem.

The grade you receive for the physical hydrogeologic skills/content portion of the projects will be used to calculate your total course grade in Physical Hydrogeology II for the semester.

"**Class participation** it is expected that all students in the program will participate fully in all aspects of the course. This includes showing up in class, being present and engaged in discussion, answering and asking questions during class, and contributing to the culture of learning of the program. If a student is not meeting expectations, they will be notified by the instructor, given guidance on how to increase their participation, and given a chance to improve. Thereafter, if student continues to fall below meeting the expectations for participation, their class participation points will be reduced."

Class participation will be earned by participating in designated class discussions. If a student is not meeting expectations, they will be notified by the instructor, given guidance on how to increase their participation, and given a chance to improve. Thereafter, if student continues to fall below meeting the expectations for participation, their class participation points will be reduced.

The percentage distribution of your grade will be as follows.

HW Assignments	(9)	: 27%
Projects – physical hydrogeology component	(3)	: 15%
Mid-term exam		: 25%
Final exam		: 28%
Participation		: 5%

University policy regarding grades and grading systems is available at this link.

Final Examination or Project

The final examination course will happen during the scheduled final exam time for the university. For Spring 2026, this date will be somewhere between 5/8/2026-5/14/2026. It has yet to be scheduled by the university.

Grading Scale

Your final grade will be informed via D2L. Letter grades are determined using the following scale:

A: >= 90.0%

B: >= 80 - 89%

C: >= 70 – 79 %

D: >= 60 to 69 %

E: below 59 %

University policy regarding grades and grading systems is available at https://catalog.arizona.edu/policy/courses-credit/grading/grading-system.

Latework Policy

No late work will be accepted for a grade, but students will receive feedback on all submitted work. Each student will be allowed to drop the one lowest grade from their Weekly Course Assignments for this class. Students may not opt to drop any of their Project Element grades related to this class.

Incomplete (I) or Withdrawal (W):

Requests for incomplete (I) or withdrawal (W) must be made in accordance with University policies, which are available at this link associated with the registrar.

University of Arizona Course Policies

All University of Arizona course and syllabi policies, as well as other helpful information and resources, can be found at this link.

If you are in need of basic needs care, here is another helpful link, in addition to what you can find at the policy link above.

Subject to Change Statement

Information contained in the course syllabus, other than the grade and absence policy, may be subject to change with advance notice, as deemed appropriate by the instructor.