

Western University  
Faculty of Engineering  
*Department of Civil and Environmental Engineering*

**CEE 9870 – Groundwater Flow and Contaminant Transport**

**COURSE OUTLINE – Winter 2025**

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**DESCRIPTION**

This course is an advanced course in groundwater flow and subsurface contamination. The general objectives are for the student to develop and understanding of:

- Groundwater and its role in the hydrologic cycle
- Water movement in geological formations
- Analytical solutions for flow problems
- Subsurface characterization and the need of accurate conceptual site models
- Contamination of subsurface water and sources of pollution
- Numerical solutions to groundwater flow and mass transport equations
- Current and future issues facing groundwater management

This course also strives to improve communication skills through (i) open interactions in class, (ii) written assignments and project, and (iii) oral presentation on a key topic in the course (e.g., groundwater resource management, approaches for aquifer evaluation, contaminant remediation).

**ENROLLMENT RESTRICTIONS**

Enrollment in this course is restricted to graduate students with bachelor's degree in Civil Engineering, as well as any student that has obtained permission to enroll in this course from the course instructor, as well as the Graduate Chair (or equivalent) from the student's home program.

**INSTRUCTOR CONTACT INFORMATION**

- Course instructor: Dr. Christopher Power
- Email address: [cpower24@uwo.ca](mailto:cpower24@uwo.ca)
- Lecture hours: 3 hours per week
- Tutorial hours: 1 hour per week
- Administrative Support: SEB-3118, or email: [ceeresearchgrad@uwo.ca](mailto:ceeresearchgrad@uwo.ca) (research graduate students) or [ceeprofessionalgrad@uwo.ca](mailto:ceeprofessionalgrad@uwo.ca) (MEng students)

**COURSE FORMAT**

The course will be delivered in-person.

**TOPICS**

<b>Topic #</b>	<b>Description</b>	<b>Learning Activities</b>	<b>Tentative timeline</b>
<b>1</b>	<b>Groundwater and the Hydrologic Cycle</b>		
	Lesson 1: Introduction	<ul style="list-style-type: none"> <li>• Lectures</li> <li>• Additional reading material</li> </ul>	Week 1
	Lesson 2: The Hydrologic Cycle	<ul style="list-style-type: none"> <li>• Lectures</li> <li>• Additional reading material</li> </ul>	Week 1
	Lesson 3: Water Balance	<ul style="list-style-type: none"> <li>• Lectures</li> <li>• Additional reading material</li> </ul>	Week 1
<b>2</b>	<b>The Near Surface Environment</b>		
	Lesson 1: Role of Geology	<ul style="list-style-type: none"> <li>• Lectures</li> <li>• Additional reading material</li> </ul>	Week 2
	Lesson 2: Matter and Energy	<ul style="list-style-type: none"> <li>• Lectures</li> <li>• Additional reading material</li> </ul>	Week 2
	Lesson 3: Physical Properties	<ul style="list-style-type: none"> <li>• Lectures</li> <li>• Additional reading material</li> <li>• Assignment</li> </ul>	Week 2
	Lesson 4: Energy and Hydraulic Head	<ul style="list-style-type: none"> <li>• Lectures</li> <li>• Additional reading material</li> <li>• Assignment</li> </ul>	Week 2
<b>3</b>	<b>Darcy's Law and Hydraulic Conductivity</b>		
	Darcy's Law	<ul style="list-style-type: none"> <li>• Lectures</li> <li>• Additional reading material</li> <li>• Assignment</li> </ul>	Week 3
	Hydraulic Conductivity	<ul style="list-style-type: none"> <li>• Lectures</li> <li>• Additional reading material</li> <li>• Assignment</li> </ul>	Week 3
	Measuring Hydraulic Conductivity	<ul style="list-style-type: none"> <li>• Lectures</li> <li>• Additional reading material</li> <li>• Assignment</li> </ul>	Week 4
<b>4</b>	<b>Aquifer Characteristics</b>		
	Aquifers	<ul style="list-style-type: none"> <li>• Lectures</li> <li>• Additional reading material</li> <li>• Assignment</li> </ul>	Week 4
	Water Table/ Potentiometric Surface	<ul style="list-style-type: none"> <li>• Lectures</li> <li>• Additional reading material</li> <li>• Assignment</li> </ul>	Week 4

5	<b>Groundwater Flow</b>		
	Lesson 1: General Flow Equations	<ul style="list-style-type: none"> <li>• Lectures</li> <li>• Additional reading material</li> <li>• Assignment</li> </ul>	Week 5
	Lesson 2: Solving Flow Equations	<ul style="list-style-type: none"> <li>• Lectures</li> <li>• Additional reading material</li> <li>• Assignment</li> </ul>	Week 5
6	<b>Groundwater Flow to Wells</b>		
	Lesson 1: Steady-State Flow to a Well	<ul style="list-style-type: none"> <li>• Lectures</li> <li>• Additional reading material</li> <li>• Assignment</li> </ul>	Week 6
	Lesson 2: Transient Well Hydraulics	<ul style="list-style-type: none"> <li>• Lectures</li> <li>• Additional reading material</li> <li>• Assignment</li> </ul>	Week 6-7
7	<b>Contaminant Transport</b>		
	Lesson 1: Sources of Contamination	<ul style="list-style-type: none"> <li>• Lectures</li> <li>• Additional reading material</li> <li>• Assignment</li> </ul>	Week 7
	Lesson 2: Transport Phenomena	<ul style="list-style-type: none"> <li>• Lectures</li> <li>• Additional reading material</li> <li>• Assignment</li> </ul>	Week 7-8
8	<b>Contaminant Transport Modeling</b>		
	Lesson 1: The Modeling Process	<ul style="list-style-type: none"> <li>• Lectures</li> <li>• Additional reading material</li> <li>• Assignment</li> </ul>	Week 8
	Lesson 2: Modeling Groundwater Flow and Contaminant Transport	<ul style="list-style-type: none"> <li>• Lectures</li> <li>• Additional reading material</li> <li>• Assignment</li> </ul>	Week 9
9	<b>Contaminant Remediation</b>		
	Lesson 1: Mapping Contamination	<ul style="list-style-type: none"> <li>• Lectures</li> <li>• Additional reading material</li> </ul>	Week 10
	Lesson 2: Remediation Approaches	<ul style="list-style-type: none"> <li>• Lectures</li> <li>• Additional reading material</li> </ul>	Week 10

\*Note there will be no lectures during reading week (February 17-21, 2025)

**SPECIFIC LEARNING OUTCOMES**

<b>Degree Level Expectation</b>	<b>Weight</b>	<b>Assessment Tools</b>	<b>Outcomes</b>
<b>Depth and breadth of knowledge</b>	35%	<ul style="list-style-type: none"> <li>• Assignments</li> <li>• Project</li> <li>• Examinations</li> </ul>	<ul style="list-style-type: none"> <li>• Understanding of advanced concepts and theories</li> <li>• Awareness of important current problems in the field of study</li> <li>• Understanding of computational and/or empirical methodologies to solve related problems</li> </ul>
<b>Research &amp; scholarship</b>	10%	<ul style="list-style-type: none"> <li>• Project</li> </ul>	<ul style="list-style-type: none"> <li>• Ability to conduct critical evaluation of current advancements in the field of specialization</li> <li>• Ability to conduct coherent and thorough analyses of complex problems using established techniques/principles and judgment</li> </ul>
<b>Application of knowledge</b>	35%	<ul style="list-style-type: none"> <li>• Assignments</li> <li>• Project</li> <li>• Examinations</li> </ul>	<ul style="list-style-type: none"> <li>• Ability to apply knowledge in a rational way to analyze a particular problem</li> <li>• Ability to use coherent approach to design a particular engineering system using existing design tools</li> </ul>
<b>Professional capacity / autonomy</b>	5%	<ul style="list-style-type: none"> <li>• Project</li> </ul>	<ul style="list-style-type: none"> <li>• Awareness of academic integrity</li> <li>• Ability to implement established procedures and practices in the coursework</li> <li>• Defends own ideas and conclusions</li> <li>• Integrates reflection into his/her learning process</li> </ul>
<b>Communication skills</b>	10%	<ul style="list-style-type: none"> <li>• Project</li> </ul>	<ul style="list-style-type: none"> <li>• Ability to communicate (oral and/or written) ideas, issues, results and conclusions clearly and effectively</li> </ul>
<b>Awareness of limits of knowledge</b>	5%	<ul style="list-style-type: none"> <li>• Project</li> </ul>	<ul style="list-style-type: none"> <li>• Awareness of the need of assumptions in complex scientific analyses and their consequences</li> <li>• Understanding of the difference between theoretical and empirical approaches</li> <li>• Ability to acknowledge analytical limitation due to complexity of practical problems</li> </ul>

**ASSESSMENTS**

<b>Assessment Type</b>	<b>Material Covered</b>	<b>Tentative Due Date</b>	<b>Weight</b>
Participation in Class Activities	In-person and posted questions on OWL site (Forums)	Ongoing	5%
Homework Assignments (three)	Topic 2, 3, 4 Topic 5, 6 Topic 7, 8	February 7, 2025 March 7, 2025 April 4, 2025	18%
Midterm Exam	Topic 1, 2, 3, 4	February 25, 2025	20%
Project	Topic to be decided later	March 31, 2025	17%
Final Exam	All topics	April 8, 2025	40%

\*The presented dates are an approximate guide for students and may be subject to change

*Note:*

(a) **Students must pass the final examination to pass this course.** Students who fail the final examination will be assigned the aggregate mark, as determined above, or 48%, whichever is less.

(b) **Students must turn in their assignments and achieve a passing grade in this component, to pass this course.** Students who do not satisfy this requirement will be assigned 48% or the aggregate mark, whichever is less.

(c) **Students who have failed this course previously must repeat all components of the course.** No special permissions will be granted enabling a student to retain assignment or test marks from previous years. Previously completed assignments and laboratories cannot be resubmitted.

**1. Participation**

As part of the course mark breakdown, 5% will be allocated to student participation in class. Participation is an important component of this course and will be assessed by attendance and interaction in the lectures and/or the forums on OWL.

**2. Assignments**

Three assignments will be scheduled during the term. Assignments are to be done individually. Each assignment will be posted on the OWL course website on specified weeks. You should review the assignment before the tutorial and may only ask for assistance on a question you have attempted.

*Late Assignments:* Late assignments will be accepted for 3 days following their due date. 10% per day will be deducted for late assignments. An assignment will not be accepted after 3 days. Extensions are to be negotiated with the course instructor. If no assignment is received for a student, the mark assigned is zero for that assignment. The maximum number of missed assignments for each student will be one; if more than one assignment is missed then a student may be barred from writing the final exam.

*Plagiarism on Assignments:* Each person must hand in an assignment that contains only their own work. If an assignment is deemed to be similar to another assignment, this will be taken as a case

of plagiarism. In such circumstances, both individuals (e.g., the person providing the answer and the person copying it) will both receive a mark of zero on the entire assignment. For a first offense, both individuals will receive a personal warning and the infraction will be recorded. For a second offense, further action will be taken.

### **3. Midterm and Final Examinations**

One midterm examination (2 hours) will be held during the lecture/tutorial period on Tuesday, February 25, 2025. The final examination (3 hours) will be held on Tuesday, April 8, 2025. The examinations will be **CLOSED BOOK** and a sheet will be provided containing necessary equations. No programmable calculators or other external sources of information, including books, notes or crib sheets, are permitted. A list of acceptable calculators for closed book exams will be posted on the bulletin board across from the Department of Civil and Environmental Engineering Office: please be sure your calculator is on it!

### **4. Project**

Students will conduct a project on a specialized topic relevant to the course. They will present their findings through an annotated bibliography, summary sheet and oral presentation to the class

#### **Activities in which collaboration is permitted:**

- Participation using course OWL site “Forums”: Weekly forums will be posted on the course site OWL. Each week students are expected to interact with the course content and with each other by posting questions/responding to existing questions on OWL “Forums”. Minimum expectation regarding this participation activity is at least one posting per week. Group discussion using “Forums” regarding course material and topics covered in lectures is permitted.
- Assignments: students are encouraged to ask their questions or provide hints to solve given problems using the forums on OWL, or in tutorials. Students are not allowed to copy assignments, which will be considered plagiarism.
- Project: Students will be divided into groups (2-3 members per group). Collaboration between **only** group members is permitted. A single annotated bibliography and summary sheet is required from each group, along with a group presentation.

#### **Activities in which students must work alone (collaboration is not permitted):**

- Midterm Exam
- Final Exam

### **COURSE MATERIAL**

Prepared class notes will be made available through the course website on OWL at <http://owl.uwo.ca/>, along with other useful reference material and data for assignments. Lecture notes and any posted demonstration videos are copyrighted to the instructor and legally protected. Do not post these videos and lecture notes on any other website or online forums. The recording of the live/synchronous lectures of the course without the permission from the course instructor is prohibited. The illegal posting and sharing of the copyrighted course content could be subjected to legal actions.

## **REQUIRED TEXTBOOK**

No textbook is required.

## **OPTIONAL COURSE READINGS**

The following list contains suggested supplementary references:

- Fitts, C.R. 2002. Groundwater Science. WAcademic Press, London, UK
- Pinder, G.F. and Celia, M.A. 2006. Subsurface Hydrology. Wiley-Interscience, New York
- Domenico, P.A. and Schwartz, F.W. 1998 Physical and Chemical Hydrogeology. 2<sup>nd</sup> Edition. Wiley and Sons, New York.
- Fetter, C.W. 2001. Applied Hydrogeology. 4<sup>th</sup> Edition. Merrill Publishing Co.

## **COMPUTING**

One of the assignments will involve computer modeling of groundwater flow and contaminant transport using the commercial program Processing Modflow for Windows (PMWIN 11). PMWIN is a pre-processor for MODFLOW and MT3DMS and a full version of this program is freely available in Engineering computer labs.

## **UNITS**

SI units will be used in lectures and examinations.

## **STATEMENT ON THE USE OF GENERATIVE ARTIFICIAL INTELLIGENCE (AI)**

The use of AI in the preparation of the project and assignments must be acknowledged in the submission. Please refer to the published [Provisional Guidance for the Use of Generative AI in Graduate Studies](#) at Western University.

## **iCLICKER CLOUD**

*Classroom Polling:* We will be using iClicker Cloud, a cloud-based student response software, in class this semester. This will help me understand what you know, give everyone a chance to participate in class, and provide more interaction on concepts and example questions. We will also use this software to keep track of attendance. At the start of every class you will register your attendance; only after you do this will you be able to answer any poll questions posted. You are required to bring a device connected to the university Wi-Fi to participate in iClicker Cloud during class, including a smartphone, tablet, laptop or iClicker remote. You will need to create an iClicker Reef Student account to participate in class.

*Creating Your iClicker Reef Student Account:* Go to [iclicker.com/students](https://iclicker.com/students) or download the iClicker Reef Student app for your Apple or Android device to sign up for a Reef account. You should use your university email address and your University ID (e.g., “cpower24” for student [cpower24@uwo.ca](mailto:cpower24@uwo.ca)) in the Student ID field. You can edit your email address, password, or student ID from your account profile. Do not create and use more than one Reef account as you will only receive credit from a single account. You do not need to purchase anything – iClicker Cloud is fully supported by Western and is free to all its students. Make sure you choose Western University Ontario when signing up.

*Add This Course to Your Reef Account:* Search with the following information to find this course and add it to your Reef account:

Institution: Western University Ontario

Course: CEE 9870 W25 GWFlow\_ContTransport

## **USE OF ENGLISH**

In accordance with Senate and Faculty Policy, students may be penalized up to 10% of the marks on all assignments, tests, and examinations for the improper use of English. Additionally, poorly written work, with the exception of the final examination, may be returned without grading. If resubmission of the work is permitted, it may be graded with marks deducted for poor English and/or late submission.

## **CHEATING, PLAGIARISM/ACADEMIC OFFENCES**

Academic integrity is an essential component of learning activities. Students must have a clear understanding of the course activities in which they are expected to work alone (and what working alone implies) and the activities in which they can collaborate or seek help; see information above and ask instructor for clarification if needed. Any unauthorized forms of help-seeking or collaboration will be considered an academic offense. University policy states that cheating is an academic offence. If you are caught cheating, there will be no second warning. Students must write their essays and assignments in their own words. Whenever students take an idea or a passage of text from another author, they must acknowledge their debt both by using quotation marks where appropriate and by proper referencing such as footnotes or citations. Plagiarism is a major academic offence. Academic offences are taken seriously and attended by academic penalties which may include expulsion from the program. Students are directed to read the appropriate policy, specifically, the definition of what constitutes a Scholastic Offence at the following website: [https://www.uwo.ca/univsec/pdf/academic\\_policies/appeals/scholastic\\_discipline\\_grad.pdf](https://www.uwo.ca/univsec/pdf/academic_policies/appeals/scholastic_discipline_grad.pdf)

All required papers may be subject to submission for textual similarity review to the commercial plagiarism-detection software under license to the University for the detection of plagiarism. All papers submitted for such checking will be included as source documents in the reference database for the purpose of detecting plagiarism of papers subsequently submitted to the system. Use of the service is subject to the licensing agreement, currently between The University of Western Ontario and Turnitin.com (<http://www.turnitin.com>).

## **CONDUCT**

Students are expected to follow proper etiquette to maintain an appropriate and respectful academic environment. Any student who, in the opinion of the instructor, is not appropriately participating in course activities and/or is not following the rules and responsibilities associated with the course activities, will be reported to the Associate Dean (Graduate) (after due warning has been given). On the recommendation of the Department concerned, and with the permission of the Associate Dean (Graduate), the student could be debarred from completing the assessment activities in the course as appropriate.

## **HEALTH/WELLNESS SERVICES**

As part of a successful graduate student experience at Western, we encourage students to make their health and wellness a priority. Western provides several health and wellness related services to help you achieve optimum health and engage in healthy living while pursuing your graduate degree. Information regarding health- and wellness-related services available to students may be found at <http://www.health.uwo.ca/>.



Students seeking help regarding mental health concerns are advised to speak to someone they feel comfortable confiding in, such as their faculty supervisor, their program director (graduate chair), or other relevant administrators in their unit. Faculty of Engineering has a Student Wellness Counsellor. Information on how to schedule an appointment with the counsellor is available at: <https://www.eng.uwo.ca/undergraduate/academic-support-and-accommodations/Student-Wellness-Counselling.html>

Students who are in emotional/mental distress should refer to Mental Health@Western: <http://www.uwo.ca/uwocom/mentalhealth/> for a complete list of options about how to obtain help.

### **STATEMENT ON GENDER-BASED AND SEXUAL VIOLENCE**

Western is committed to reducing incidents of gender-based and sexual violence (GBSV) and providing compassionate support to anyone who is going through or has gone through these traumatic events. If you are experiencing or have experienced GBSV (either recently or in the past), you will find information about support services for survivors, including emergency contacts at the following website: [https://www.uwo.ca/health/student\\_support/survivor\\_support/get-help.html](https://www.uwo.ca/health/student_support/survivor_support/get-help.html). To connect with a case manager or set up an appointment, please contact [support@uwo.ca](mailto:support@uwo.ca).

### **SICKNESS**

Students should immediately consult with the Instructor (for a particular course) or Associate Chair (Graduate) (for a range of courses) if they have problems that could affect their performance. The student should seek advice from the Instructor or Associate Chair (Graduate) regarding how best to deal with the problem. Failure to notify the Instructor or the Associate Chair (Graduate) immediately (or as soon as possible thereafter) will have a negative effect on any appeal. Obtaining appropriate documentation (e.g., a note from the doctor) is valuable when asking for accommodation due to illness.

Students who are not able to meet certain academic responsibilities due to medical, compassionate or other legitimate reason(s), could request for academic consideration. The Graduate Academic Accommodation Policy and Procedure details are available at: <https://www.eng.uwo.ca/graduate/current-students/academic-support-and-accommodations/index.html>

### **ACCESSIBLE EDUCATION WESTERN (AEW)**

Western is committed to achieving barrier-free accessibility for all its members, including graduate students. As part of this commitment, Western provides a variety of services devoted to promoting, advocating, and accommodating persons with disabilities in their respective graduate program. Graduate students with disabilities (for example, chronic illnesses, mental health conditions, mobility impairments) are strongly encouraged to register with Accessible Education Western (AEW): [http://academicsupport.uwo.ca/accessible\\_education/index.html](http://academicsupport.uwo.ca/accessible_education/index.html)

AEW is a confidential service designed to support graduate and undergraduate students through their academic program. With the appropriate documentation, the student will work with both AEW and their graduate programs (normally their Graduate Chair and/or Course instructor) to ensure that appropriate academic accommodations to program requirements are arranged. These accommodations include individual counselling, alternative formatted literature, accessible campus transportation, learning strategy instruction, writing exams and assistive technology instruction.