Western University
Faculty of Engineering
Department of Civil and Environmental Engineering

CEE 9415 – Digital Water Infrastructures (with CEE 4416B)

COURSE OUTLINE 2025-2026

DESCRIPTION
Digital Water Infrastructure is a course designed to provide undergraduate and graduate students with a hands-on understanding of the technologies and methodologies driving the digital transformation of water infrastructure. It covers essential components of digital solutions, including smart instrumentation, data and metadata management, preprocessing techniques, and data-driven modeling. Through a hands-on project, students will engage with data-driven digital solutions such as soft sensors, predictive modeling, and advanced process control strategies to optimize system performance, enhance climate resilience, promote equity in water access and management, and support resource sustainability. Combining lectures, case studies, and practical exercises, the course equips learners with critical skills in environmental data handling, the development of data-driven solutions, and intelligent decision-making for next-generation water infrastructure.

ENROLLMENT RESTRICTIONS
Enrollment in this course is restricted to students in the Civil and Environmental Engineering department, as well as any student that has obtained special 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: Ahmed AlSayed
Email address: ahmed.alsayed@uwo.ca
Office: SEB 3041
Office hours: After Tutorials

COURSE FORMAT
In-person interactive lectures and tutorials. Lectures feature PowerPoint presentations, group-based activities, and student-led presentations. Tutorials are also conducted in person and combine guided instruction, hands-on assignments using Colab and Jupyter Notebooks, and interactive group activities to reinforce applied learning.

TOPICS

Topic #	Description	Learning Activities	Tentative timeline
1	**Introduction** (2 weeks)		
	<u>**Lesson 1**</u>: Digital Transformation of Water Infrastructure ▪ Navigating the definition of digital water ▪ Overview of water infrastructure ▪ Driving forces for digital transformation ▪ Setting the priorities of digital water	• PowerPoint lecture • Office hours • Tutorial – **Term project Introduction**	Week 1
	<u>**Lesson 2**</u>: The building blocks of digital water ▪ Introduction to different building blocks ▪ Guest Speaker(s): transformative digital solution and its building blocks in wastewater treatment systems ▪ *Student presentations* on transformative digital solutions in Digital Water	• Industrial Guest Speaker(s) • PowerPoint lecture • Flipped Classroom • Office hours • Tutorial – **Review on Basic Statistics** (Assignment 1)	Weeks 1-2
2	**"Garbage in, garbage out": Instrumentation and Data Management** (3 weeks)		
	<u>**Lesson 3**</u>: Instrumentation ▪ Instrumentation and its role in digital transformation ▪ *Student presentations* on Instrumentation in Digital Water ▪ Example: Sensors & Actuators in wastewater treatment plants ▪ Faults and their characteristics in wastewater sensors	• PowerPoint lecture • Flipped Classroom • Office hours • Tutorial – **Review on Regression** (Assignment 2)	Week 3
	<u>**Lesson 4**</u>: Metadata and its value in Digital Water ▪ Why meta-data? ▪ Types of data: terminology and Examples ▪ Metadata for a systematic description of signal data	• Industrial Guest Speaker(s) • PowerPoint lecture • Office hours • Tutorial – **Review on Classification** (Assignment 2)	Week 4
	<u>**Lesson 5**</u>: Fault Detection, Diagnosis, and Handling ▪ Introduction to Time-Series Modelling ▪ Faults: Terminology and Examples ▪ Fault-detection methods ▪ Fault-handling and recovery methods	• PowerPoint lecture • Office hours • Tutorial – **Time Series Modelling** (Assignment 3)	Week 4-5

3	"All models are wrong, but some are useful": Model development (3 weeks)		
	Lesson 6: Introduction to Data-driven & Hybrid Modelling ▪ Why Data-driven Modelling? ▪ Supervised, unsupervised, semi-supervised learning ▪ Variance-bias trade-off ▪ AI vs modelling ▪ Introduction to Hybrid Modelling	• PowerPoint lecture • In-class activity • Office hours • Tutorial – **Time Series Modelling** (Assignment 3)	Week 6
	Lesson 7: Data-Driven Modelling pipeline & practical considerations ▪ "Not everything is a nail": Define the problem ▪ Feature Selection & Engineering ▪ Model Cross Validation ▪ Hyperparameters Optimization ▪ Addressing Data Imbalance ▪ Performance metrics	• PowerPoint lecture • Office hours • Tutorial – **Term project working sessions**	Week 7
	Reading Week – No Class		
	Lesson 8: Examples of Data-Driven Modelling Application in Digital Water Infrastructure ▪ Examples include Soft-sensing, Fault-tolerant sensors, Digital alarms, Process Control and Optimization. ▪ Focus on Climate Resilience, Promoting Equity, and resource-efficiency ▪ Student-led presentations ▪ Industrial Guest Speaker(s)	• Student-led presentations • Industrial Guest Speaker(s) • Office hours • Tutorial – **Primary project presentation**	Week 9
4	**Process Control & Optimization** (3 weeks)		
	Lesson 9: Introduction to Process Control ▪ Driving forces and motivations ▪ Disturbances in wastewater treatment systems ▪ Basic control concepts ▪ The importance of dynamics ▪ Decision-support tools	• PowerPoint lecture • Office hours • Tutorial – **Term project working sessions**	Week 10
	Lesson 10: Selected topics on process control and optimization ▪ Optimization basics ▪ Model Predictive Control ▪ Fuzzy Logic based Control	• PowerPoint lecture • Office hours • Tutorial – **Final project Submission & presentation**	Weeks 11-12

REQUIRED TEXTBOOK
Prepared slides/study materials will be posted on OWL by course director covering the material on a weekly basis.

OPTIONAL COURSE READINGS
Grievson, O., Holloway, T., Johnson, B. (Eds.), 2022. A Strategic Digital Transformation for the Water Industry. IWA Publishing. https://doi.org/10.2166/9781789063400
(Free online version, to buy print book is 75.00 USD)
Villez, K., Aguado, D., Alferes, J., Plana, Q., Ruano, M., Samuelsson O. (Eds.), 2024. Metadata Collection and Organization in Wastewater Treatment and Wastewater Resource Recovery Systems. IWA Publishing. https://doi.org/10.2166/9781789061154
(Free online version, to buy print book is 156.00 USD)
Araghinejad, S., 2014. Data-Driven Modeling: Using MATLAB® in Water Resources and Environmental Engineering, Water Science and Technology Library. Springer Netherlands, Dordrecht. https://doi.org/10.1007/978-94-007-7506-0
(Free online version, to buy print book is 64.99 USD)
Olsson, G., Ingildsen, P., 2023. Process control. https://doi.org/10.2166/9781789060362_0667
(Free online version, to buy print book is 125.00 USD)

ASSESSMENTS

Assessment Type	Material Covered	Weight
General Participation in class	Participation in lectures and tutorials	5%
Student-led activities	Weeks 2,3, and 6	10%
In Class Presentation	Presenting an existing Digital Water Solution in Week 9	10%
Mini Review (1)	Systematic or Critical review of the state-of-the-art in one of the water infrastructure fields	20%
Project Preliminary presentation	Tutorial Week 9 – identify the problem and the need for digital solution	10%
Final project documentation of code and dataset	Tutorial Week 12	10%
Final project report	Tutorial Week 12	20%
Final project presentation	Tutorial Weeks 11-12	15%

- Instructions and specific timeline for Project deliverables will be discussed in Tutorial Week1 and will be posted to OWL website.
- Groups and their project topic to be finalized by Week 3.
- Topics and details about the In-Class presentations and Student-let activities will be provided at least one week prior to delivery.

Activities in which collaboration is permitted:
- Students are encouraged to work on final project, In Class Presentations, Student-led presentations & discussions, Mini Review in groups (groups number to be determined)

Activities in which students must work alone (collaboration is not permitted):
- Assignments 1-3: students are encouraged to discuss ideas, but assignments must be submitted individually

SPECIFIC LEARNING OUTCOMES

Degree Level Expectation	Weight	Assessment Tools	Outcomes
Depth and breadth of knowledge	25%	• Project • Mini Review • In-Class Presentation	• Understanding of advanced concepts and theories • Awareness of important current problems in the field of study • Understanding of computational and/or empirical methodologies to solve related problems
Research & scholarship	15%	• Mini Review	• Ability to conduct critical evaluation of current advancements in the field of specialization • Ability to conduct coherent and thorough analyses of complex problems using established techniques/principles and judgment
Application of knowledge	30%	• Project • In-Class Presentation	• Ability to apply knowledge in a rational way to analyze a particular problem • Ability to use coherent approach to design a particular engineering system using existing design tools
Professional capacity / autonomy	5%	• Project • In-Class presentation	• Awareness of academic integrity • Ability to implement established procedures and practices in the coursework • Defends own ideas and conclusions • Integrates reflection into his/her learning process
Communication skills	15%	• Student-led activities • In-Class Presentation	• Ability to communicate (oral and/or written) ideas, issues, results and conclusions clearly and effectively
Awareness of limits of knowledge	10%	• Project • In-Class Presentation	• Awareness of the need of assumptions in complex scientific analyses and their consequences • Understanding of the difference between theoretical and empirical approaches • Ability to acknowledge analytical limitation due to complexity of practical problems

STATEMENT ON THE USE OF GENERATIVE ARTIFICIAL INTELLIGENCE (AI)

Large language models (LLMs) such as ChatGPT, Gemini, Copilot, Deepseek, etc are permitted but must be acknowledged, and any code from LLMs must be verified that they perform as intended. Any sequential outputs (text, code, etc.) taken from LLMs, or images taken from generative models (e.g. stable diffusion, GANs, etc) must be explicitly indicated as such.

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

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 https://www.uwo.ca/health/.

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 https://www.uwo.ca/health/psych/index.html 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/gbsv/support/get-help.html. To connect with a case manager or set up an appointment, please contact 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

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.