

Integrating WAVE Software into a Senior-Year Undergraduate Chemical Engineering Course

Ryan J. LaRue & David R. Latulippe | McMaster University (Hamilton, Canada)

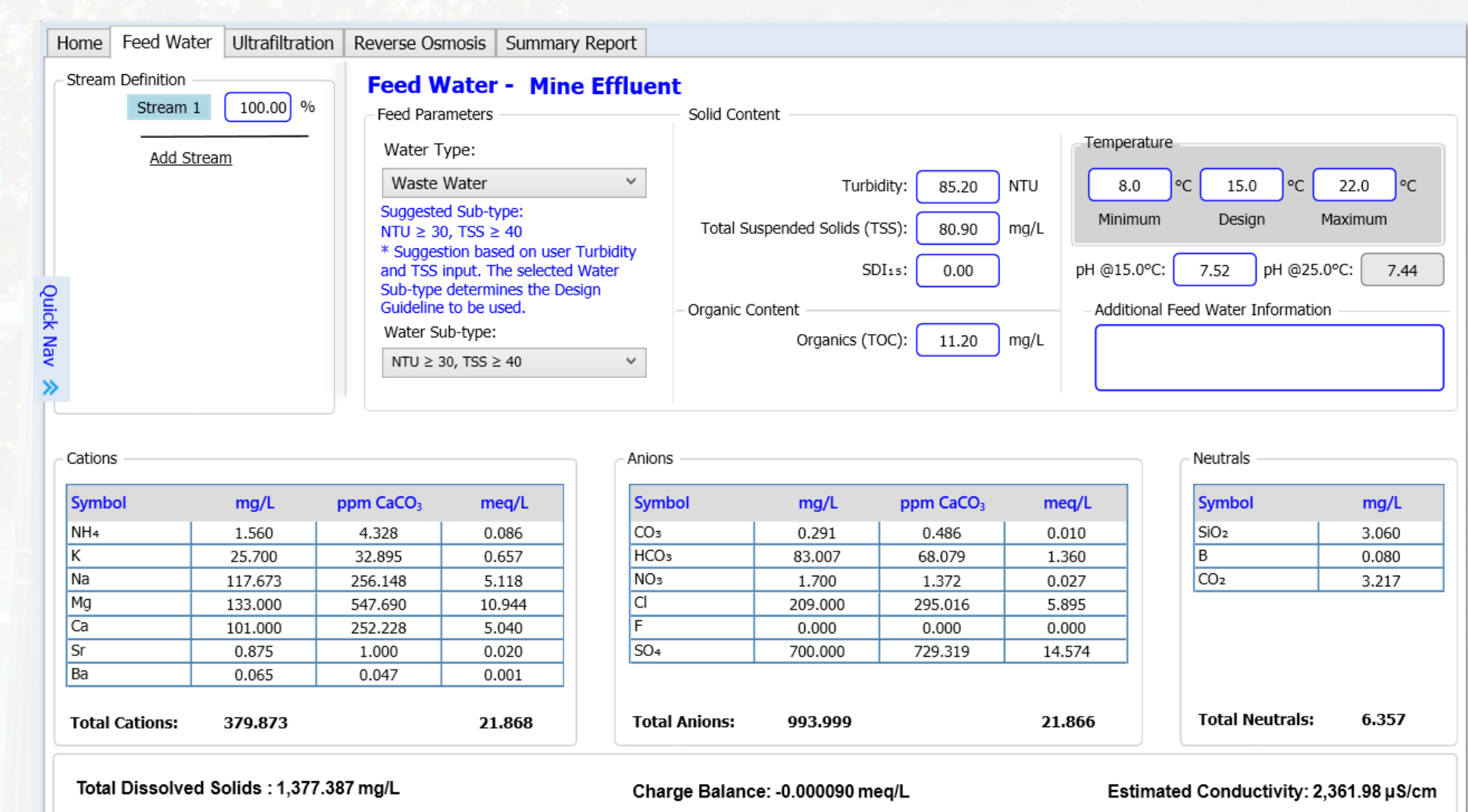


CONTACT US

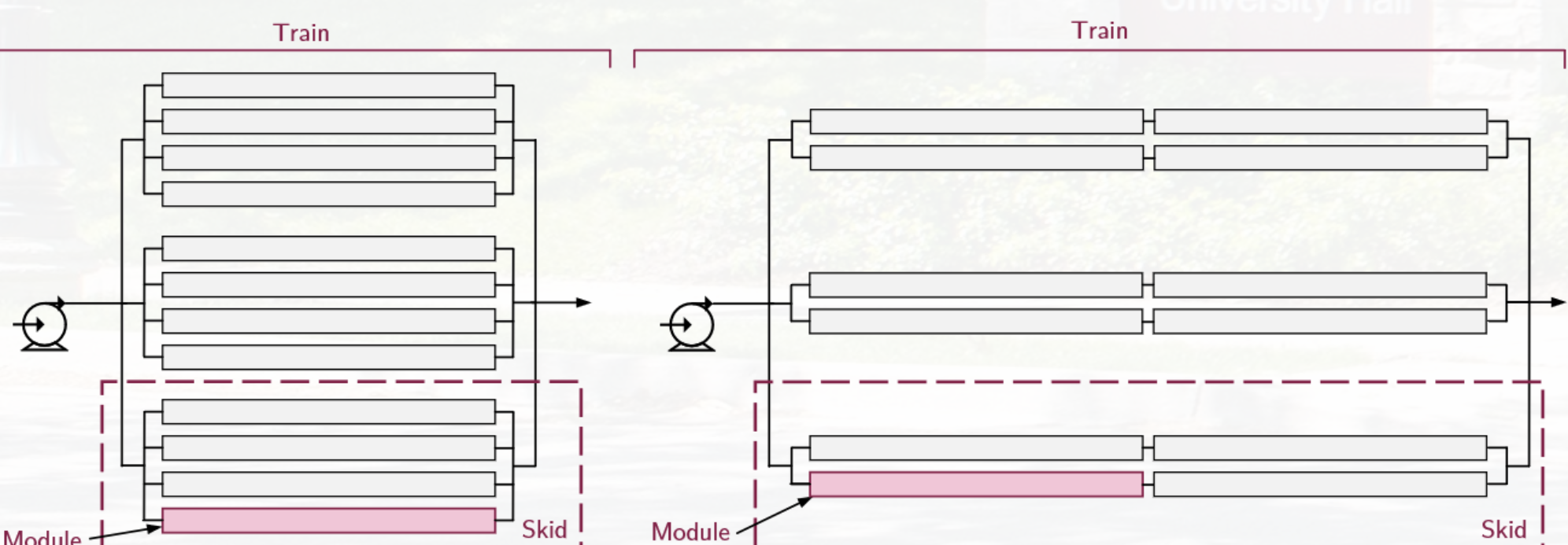
WAVE Courseware

Chapter 1 considers:
The need for membrane modelling software tools; what WAVE is and how it is used in actual applications; other available software

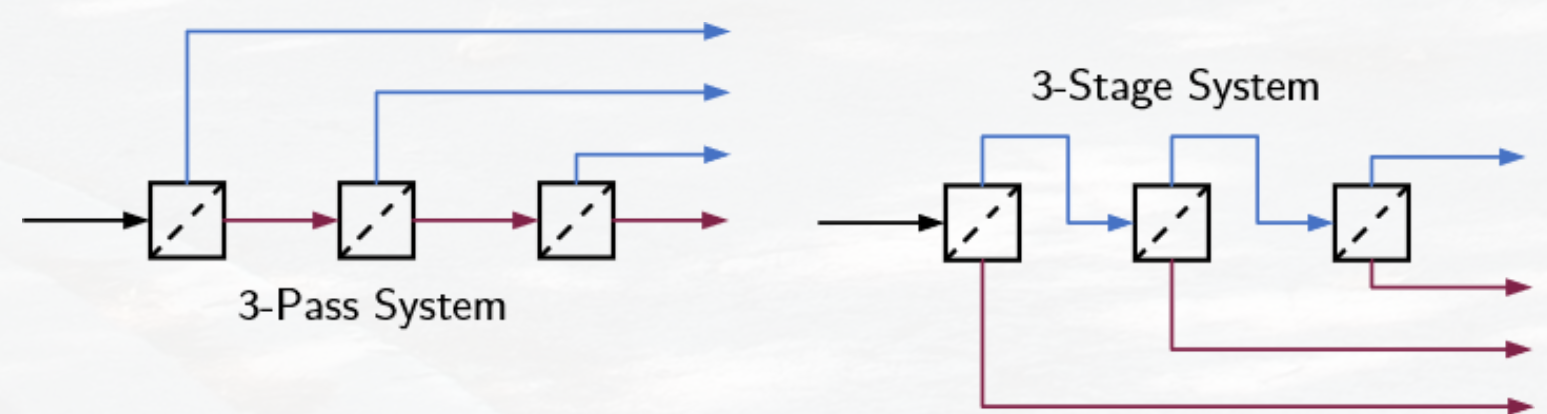
Chapter 2 considers:
Downloading and installing the software; key features of the interface; assigning water quality parameters; an example of a real-world problem to be solved using WAVE



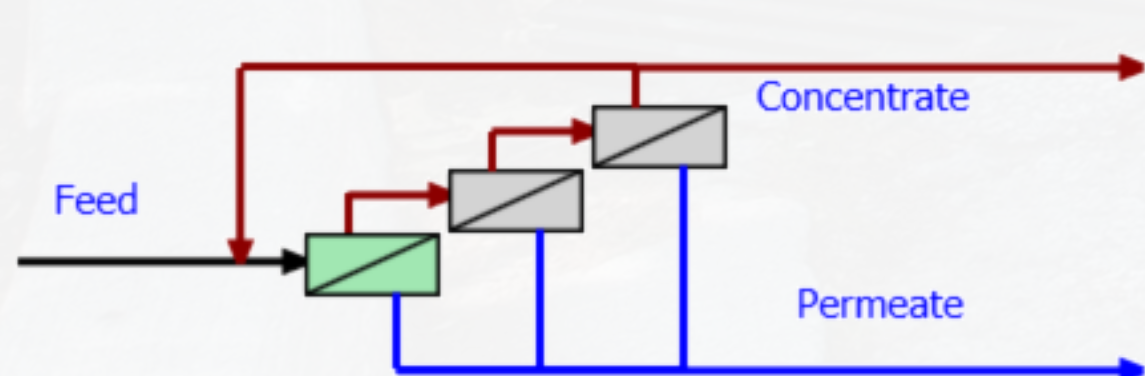
Chapter 3 considers:
Key UF terminology and concepts (e.g. elements, modules, skids, trains, etc.); modelling, analyzing, and optimizing UF processes; interpreting simulation results; handling UF design warnings



Chapter 4 considers:
Key RO concepts and terminology (e.g. stages, passes, etc.); using heuristics to design, model, and optimize RO systems; interpreting simulation results; handling RO system design warnings



Chapter 5 considers:
Assembling UF and RO processes in a single system; considering additional system design features (e.g. concentrate recycles, antiscalants, etc.); solving an integrated UF/RO real-world problem; further error-handling (e.g. ion solubility)



WAVE: Water Application Value Engine

- Free software package produced by DuPont (Dow) for the design and modelling of water treatment processes using their technologies
- Supports ultrafiltration (UF), reverse osmosis (RO), and ion exchange (IX) processes
- Enables the user to design and optimize membrane systems considering parameters such as membrane choice/area, recovery/flux, water quality, operating pressures, recycle streams, cleaning processes, chemical additives, cost, etc.



Chemical Engineering Separations Course (ChemEng 4M03)

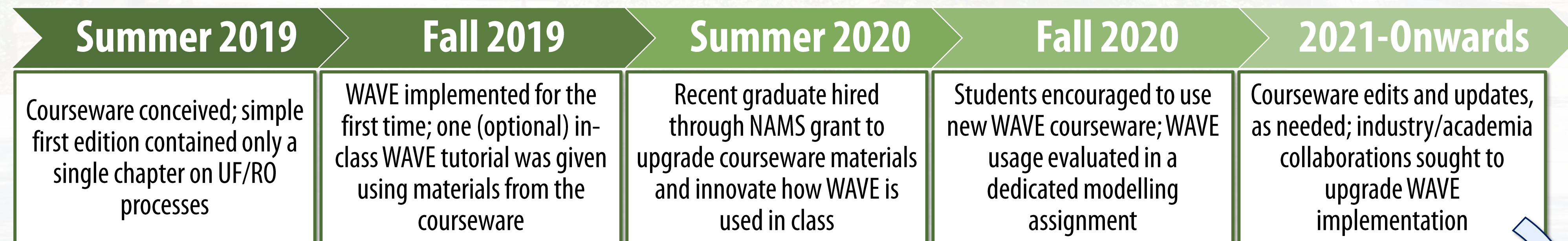
- Senior-year elective course (enrolment ~ 60 students) which teaches students separations science concepts
- Course topics include membranes, settling, centrifugation, adsorption, liquid-liquid extraction, etc.
- Motivation in incorporate WAVE: offer students the opportunity to use industry tools
- Satisfies Canadian Engineering Accreditation Board (CEAB) indicator for the "ability to use modern/state-of-the-art tools"; similar requirements are prescribed by the Accreditation Board for Engineering & Technology (ABET) in the USA

WAVE Courseware

- A series of five self-guided tutorials (free PDF or purchasable hard copy) to teach students to use WAVE
- Written to introduce the software and to demonstrate modelling of UF and RO processes with increasing levels of complexity
- Teaches supplemental concepts of membrane system design/operation not covered in lectures
- Includes relevant examples and student problems

Tutorials, Assignments & Course Projects

- One two-hour class per semester allocated to a hands-on introductory WAVE tutorial (2019-)
- One of six assignments per semester allocated towards asking students to model/optimize an UF/RO system using WAVE (2020-)
- Where feasible, students were encouraged to use WAVE in their course project on evaluating separation technologies in a real-world application (2020-)

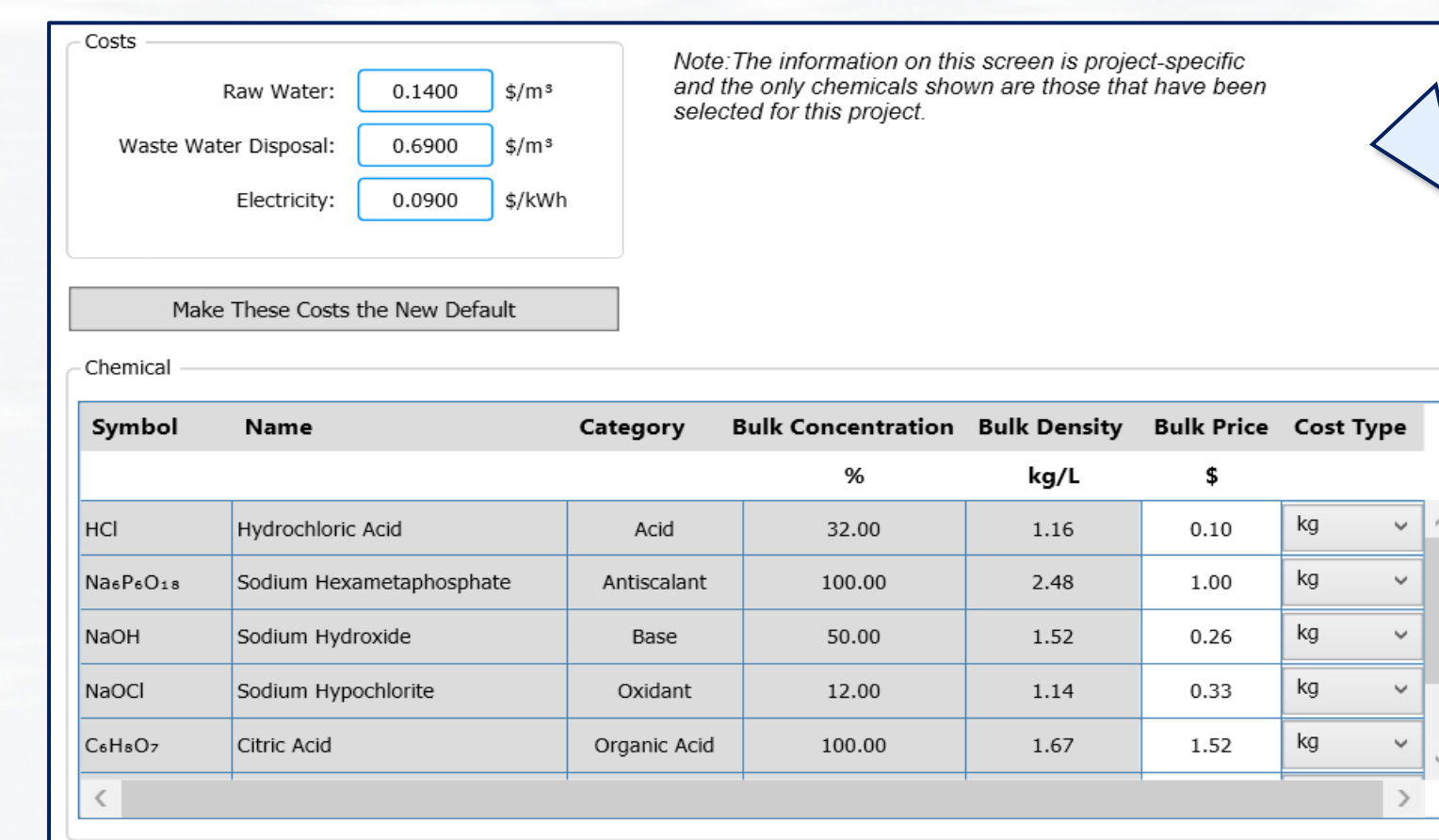


Next Steps

- The addition of a chapter outlining the usage of WAVE's process costing feature (shown on the right)
- The addition of a chapter involving the simulation and optimization of IX processes in WAVE
- Continuous formulation of new assignment problems for students from real-world case studies (e.g. dairy, oil-and-gas industries, etc.)

If you are interested in collaborating on this initiative, feel free to reach out to us via email:

Ryan: laruerj@mcmaster.ca David: latulid@mcmaster.ca



Acknowledgements



We would like to thank the following individuals/organizations: NAMS for the Education Initiative Fellowship to David Latulippe (2020), Isabella Monaco for her work on advancing the courseware, Jeff Cobbledick, Caleb Funk, Garth Parker, and Jack Gilron for their input and advice, as well as Ana Arežina for sharing examples of student work.

Assignments

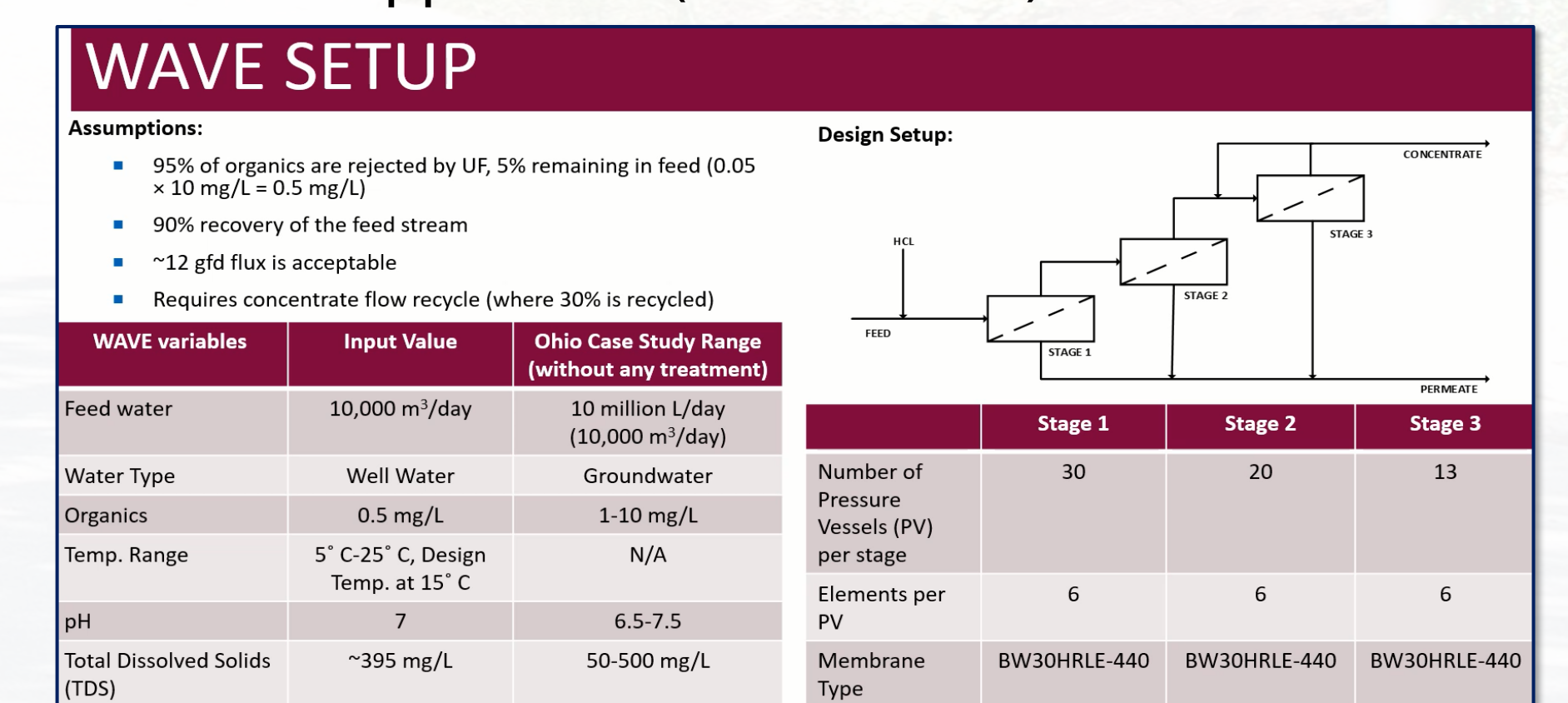
Assignment #5 (2020) was given which solely evaluated students on their usage of WAVE to optimize a UF/RO system:

- Task:** Do the example (treatment of mining wastewater) outlined in Ch. #5 of the courseware. Then, make any suitable improvements to design/operation of that system.
- Deliverable:** Describe the system which was designed and simulated. Justify design decisions (e.g. element choice, number of stages/passes, etc.) that were made in terms of the feasibility of the system, capital and operating costs, the yield of water, the quality of the separation, as well as other factors deemed important using engineering judgement.

Course Project

In groups of 3/4, students were given a choice of one of five custom-written case studies involving a separation problem from a real-world industry:

- A: Separation of H₂ gas** **B: Li capture in battery recycling**
- C: Cement dust abatement** **D: Therapeutic protein purification**
- E: Removal of PFAS from drinking water**
- Groups were asked to propose a separation technology that could be used in that application, then evaluate it on its merits (e.g. effectiveness, capital and operating costs, etc.)
- Groups which pitched a membrane-based process were encouraged to use WAVE to perform a techno-economic assessment on the technology
- One group pitched the use of RO membranes for PFAS removal (Case Study E) and effectively used WAVE to assess costs in this application (shown below)



Student Feedback

Student feedback regarding WAVE has been largely positive:

- "The wave software is pretty cool, I would've liked to work with it more but the semester was so busy that I think 1 tutorial and 1 assignment was all we could really do with it with the remaining time in the semester."
- "WAVE was an interesting addition and again kept tutorials/assignments varied and interesting..."
- "I liked the exposure to Wave but it seemed really rushed. I wish it was covered in more depth. We barely talked about CIP and backwashing membranes. At the end of the day Wave is a programme and if you put garbage in you will expect garbage out and that's what I feel that I am doing. I wish the WAVE tutorials were more fully integrated through the course."