1 INSTRUCTIONAL SUPPORT

1.1 Instructor

Instructor:  Beth Parker, Ph.D.
Office:   RICH 3503, ext. 53642
Email:   bparker@uoguelph.ca
Office hours:  TBA on Courselink or by appointment

2 LEARNING RESOURCES

2.1 Course Website

Course material, news, announcements, and grades will be regularly posted to the ENGG*6910 Courselink site. You are responsible for checking the site regularly.

2.2 Required Resources

Harrison et al. (1992) WRR 28:515-526
Cherry et al. (2014) The Bridge Article
Neuzil et al. (2013) Eos, Vol. 93, No. 30
2.3 Recommended Resources

Flow Systems
- Davis & DeWiest
- Eriksson, Gustafsson & Nilsson (1966)
- Hiscock (Freeze & Witherspoon summary, etc.)
- Schwartz & Zhang
- Hubbert (1940) flow system diagram
- Toth (1963) Classic paper
- Meyboom (1962) Prairie profiles classic overview paper

Geology of Aquitards
- AWWARF Report sections; Mudstone Book Chapt 5 (origins)
- Neuzil (1994) WRR 30:145-150

Presence of Fractures and Characteristics
- Grisak et al. (1970s) bulk fracture porosity
- McKay et al. (1993) ES&T; Ruland et al. (1991)
- Schwartz & Zhang pp. 146-152
- Freeze & Cherry pp.70-75
- Parker et al.(1994) Ground Water
- OHara et al.(2000) WRR
- Schwartz et al. (1982) WRR 18:535-545 Regina case study (PCBs)
- McIelwain et al. (1989); Wills et al. (1992) Smithville

Chemical profiles for aquitard integrity assessment
- Cherry (1987) Chapter 14 Canadian Aquatic Resources
- Cherry, Grisak & Clister (1973)
- Van der kamp & Maathuis (1985) Conference paper
- Johnson et al. (1989) ES&T
- Parker et al. (2004) JCH North Haven Aquitard

Remediation
- Mette Broholm papers

Head Profiles HGU’s
- AWWARF (2006) Chapter 3 Head Profiles
- CFB Borden Case (head, isotope and DNAPL tracers)
- Hart et al. (2007) Ground Water
**Additional Resources**

**Lecture Information:** All the lecture notes are posted on the web page (week #1-#5).

**Assignments:**

1) 2 Homework/assignments will be due 1 week after assignment is made.

2) Download the assigned readings on a weekly basis and prepare to participate in topic discussions.

3) Student-lead discussions on 3 papers per lecture topic – 1 student/article prepare formal overview and lead discussion - 20 mins X 3 students (1 to 2 article/student)

4) 3 page weekly summaries of literature identifying the key insights tied to lecture topic – 5 weeks/deliverables.
3 ASSESSMENT

3.1 Dates and Distribution

Weekly Reading summaries – 50%
Due 1st class the following week (Wed-25 May, Mon–30 May, Mon–6 Jun, Mon 13–Jun, Mon–20 June (Consortium + 1 day summary)

In-class Presentations: 20%
Final Project Report (Jun 20/21): 30%

3.2 Course Grading Policies

When You Cannot Meet a Course Requirement: When you find yourself unable to meet an in-course requirement because of illness or compassionate reasons, please advise the course in writing, with your name, id#, and e-mail contact. See the graduate calendar for information on regulations and procedures for Academic Consideration:
http://www.uoguelph.ca/registrar/calendars/graduate/current/genreg/sec_d0e1400.shtml

Accommodation of Religious Obligations: If you are unable to meet an in-course requirement due to religious obligations, please email the course instructor within two weeks of the start of the semester to make alternate arrangements. See the undergraduate calendar for information on regulations and procedures for Academic Accommodation of Religious Obligations:
http://www.uoguelph.ca/registrar/calendars/undergraduate/current/c08/c08-accomrelig.shtml

Passing grade: In accordance with the policies of the office of graduate studies, the minimum grade required to pass the course is 65%.
Late Submissions: Late submissions (without prior approval) will be penalized. For each day the assignment is late 10% will be deducted. If the file is submitted in an inaccessible format/file error 10% will be deducted and not given back because the assignment will be considered late.

4 AIMS, OBJECTIVES & GRADUATE ATTRIBUTES

4.1 Calendar Description

This course concerns groundwater flow systems and the role of aquitards in these systems with and without pumping for water supply. The hydrology and hydrochemistry of most aquifers are governed by aquitard influences and yet the literature concerning the role of aquitards in groundwater systems is relatively sparse and not well-integrated. Representative geologic domains will be examined using multiple types of evidence to discern flow system characteristics and present various conceptual models from field-based research studies. Topics of interest include: flow pattern characteristics, groundwater age and residence time, discerning advection versus diffusion dominated domains, aquitard integrity for aquifer protection and implications of flow system delineation and aquitard characteristics concerning selection, design concepts and monitoring of waste disposal sites (e.g. siting and designing solid (municipal) and hazardous (industrial) waste landfills, deep radioactive waste repositories, carbon sequestration, petroleum storage, etc.) in the context of shallow, intermediate and deep flow systems. The
course is comprised of lectures, class discussions, and student projects and presentations based on literature reviews and/or applications of mathematical models to evaluate concepts and explore relevant aquitard topics to the profession.

4.2 Course Aims

The objective of this course is to provide a sound understanding of the role of aquitards in groundwater flow systems and their role in land disposal/entombment of wastes and natural resource extraction. The main goals of this course are to:

1) Examine representative geologic domains using multiple types of field, lab and modeling data to provide evidence of flow system characteristics and quantified process-based site conceptual models
2) Analyze various hydrogeologic system conditions from field-based research studies including shallow freshwater zone and deep brackish zones
3) Discuss hydrology and hydrochemistry and relation to governing aquitard influences

4.3 Learning Objectives

At the successful completion of this course, the student will have demonstrated the ability to:

1. Understand groundwater flow systems and the role of aquitards in these systems.
2. Understand aquitard integrity and characteristics concerning design concepts and monitoring of waste disposal sites, hazardous waste landfills and deep radioactive waste repositories.
3. Critically review technical literature related to Groundwater resource protection and waste management
4. Understand environmental threats from deep sedimentary rock aquitards targeted for unconventional oil and gas extraction, coal and mining

4.4 Instructor’s Role and Responsibility to Students

The instructor’s role is to develop and deliver course material in ways that facilitate learning for a variety of students. Selected lecture notes will be made available to students on Courselink/D2L but these are not intended to be stand-alone course notes. During lectures, the instructor will expand and explain the content of notes and provide example problems that supplement posted notes. Scheduled classes will be the principal venue to provide information and feedback for tests and project.

4.5 Students’ Learning Responsibilities

Students are expected to take advantage of the learning opportunities provided during lectures. Students, especially those having difficulty with the course content, should also make use of other resources recommended by the instructor. Students who do (or may) fall behind due to illness, work, or extra-curricular activities are advised to keep the instructor informed. This will allow the instructor to recommend extra resources in a timely manner and/or provide consideration if appropriate.

E-mail Communication: As per university regulations, all students are required to check their uoguelph.ca e-mail account regularly: e-mail is the official route of communication between the University and its students.
Recording of Materials: Presentations which are made in relation to course work—including lectures—cannot be recorded in any electronic media without the permission of the presenter, whether the instructor, a classmate or guest lecturer.

4.6 Relationships with other Courses

Previous Courses: None
Follow-on Courses: None

5 Teaching and Learning Activities

5.1 Timetable

Richards # 3527: 9:00 am – 12:00 noon, 3 days a week; Mondays, Wednesdays and Thursdays

5.2 Course Topics and Schedule

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<thead>
<tr>
<th>Week #</th>
<th>Dates</th>
<th>Lecture Topic</th>
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<tbody>
<tr>
<td>1</td>
<td>May 16 - 19</td>
<td>Aquitards in Regional Groundwater Flow System context</td>
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<td>Geologic Origins of Non-indurated Aquitards- Aquifer Systems and Relevance to Hydrogeologic Properties</td>
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<td>2</td>
<td>May 23 - 26</td>
<td>Characterization of Clayey Aquitards: Approaches and Methods</td>
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<td>Diffusion- controlled Aquitards: natural solutes. (eg major ions , isotopes)</td>
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<td>Groundwater Velocity, Age and Residence Time: contrasts between porous and fractured media</td>
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<td>3</td>
<td>May 30 - June 2</td>
<td>Geologic Origin and Characteristics of Bedrock Aquitards Characterization Methods for Bedrock Aquitards Role &amp; Use of Aquitards in (deep) Waste Disposal and unconventional gas extraction</td>
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<td>4</td>
<td>June 6 - 9</td>
<td>Hydraulic characterization methods</td>
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<td>- Single &amp; multi well tests</td>
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<td>- Steady state and transients</td>
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<td>- Hydraulic head profiles</td>
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<td>June 13-17</td>
<td>No classes - University Consortium</td>
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<td>5</td>
<td>June 20 - 23</td>
<td>Role of Aquitards In Contaminant Transport and Fate:</td>
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<td>- Aquitard Integrity &amp; Groundwater Resource Protection (assessing current conditions versus predicting future impacts)</td>
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<td>- Vulnerability Assessment</td>
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<td>- Aquitards in Contaminated Site Remediation</td>
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<td>- Effects of Mass Storage and Release from Low Permeability (Aquitard) Zones</td>
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5.3 Other Important Dates

**Drop Date:** The last date to drop one-semester courses, without academic penalty, is June 9. Two-semester courses must be dropped by the last day of the add period in the second semester. Refer to the Graduate Calendar for the schedule of dates:
http://www.uoguelph.ca/registrar/calendars/graduate/current/sched/sched-dates-f10.shtml

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6 LAB SAFETY

Safety is critically important to the School and is the responsibility of all members of the School: faculty, staff and students. As a student in a lab course you are responsible for taking all reasonable safety precautions and following the lab safety rules specific to the lab you are working in. In addition, you are responsible for reporting all safety issues to the laboratory supervisor, GTA or faculty responsible.

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7 ACADEMIC MISCONDUCT

The University of Guelph is committed to upholding the highest standards of academic integrity and it is the responsibility of all members of the University community faculty, staff, and students to be aware of what constitutes academic misconduct and to do as much as possible to prevent academic offences from occurring. University of Guelph students have the responsibility of abiding by the University’s policy on academic misconduct regardless of their location of study; faculty, staff and students have the responsibility of supporting an environment that discourages misconduct. Students need to remain aware that instructors have access to and the right to use electronic and other means of detection.

Please note: Whether or not a student intended to commit academic misconduct is not relevant for a finding of guilt. Hurried or careless submission of assignments does not excuse students from responsibility for verifying the academic integrity of their work before submitting it. Students who are in any doubt as to whether an action on their part could be construed as an academic offence should consult with a faculty member.

7.1 Resources

The Academic Misconduct Policy is detailed in the Undergraduate Calendar:
http://www.uoguelph.ca/registrar/calendars/undergraduate/current/c08/c08-amisconduct.shtml

A tutorial on Academic Misconduct produced by the Learning Commons can be found at:
http://www.academicintegrity.uoguelph.ca/

Please also review the section on Academic Misconduct in your Engineering Program Guide.

The School of Engineering has adopted a Code of Ethics that can be found at:
http://www.uoguelph.ca/engineering/undergrad-counselling-ethics

8 ACCESSIBILITY

The University of Guelph is committed to creating a barrier-free environment. Providing services for students is a shared responsibility among students, faculty and administrators. This relationship is based on respect of individual rights, the dignity of the individual and the University community's shared commitment to an open and supportive learning environment. Students requiring service or accommodation, whether due to an identified, ongoing disability for a short-term disability should contact the Centre for Students with Disabilities as soon as possible.

For more information, contact CSD at 519-824-4120 ext. 56208 or email csd@uoguelph.ca or see the website: http://www.uoguelph.ca/csd/

9 RECORDING OF MATERIALS

Presentations which are made in relation to course work—including lectures—cannot be recorded or copied without the permission of the presenter, whether the instructor, classmate or guest lecturer. Material recorded with permission is restricted to use for that course unless further permission is granted.

10 RESOURCES

The Academic Calendars are the source of information about the University of Guelph’s procedures, policies and regulations which apply to undergraduate, graduate and diploma programs:
http://www.uoguelph.ca/registrar/calendars/index.cfm?index

The Graduate Calendar is the source of information about the University of Guelph’s procedures, policies and regulations which apply to graduate programs:
http://www.uoguelph.ca/registrar/calendars/graduate/current/

A tutorial on Academic Misconduct produced by the Learning Commons can be found at:
http://www.academicintegrity.uoguelph.ca/

The School of Engineering has adopted a Code of Ethics that can be found at:
http://www.uoguelph.ca/engineering/undergrad-counselling-ethics