ESM 226: Groundwater Management
Scott Jasechko

“Examines the principles and tools for groundwater management and stewardship of groundwater resources in the US and includes examples drawn from global groundwater management challenges.”

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Office Hours: By appointment
Office: Bren Hall 4404

Course Text and Relevant Readings: Readings posted online

Grading:

<table>
<thead>
<tr>
<th>Item</th>
<th>Percent of course grade</th>
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<tr>
<td>Quiz</td>
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<tr>
<td>Problem set 1</td>
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<td>Problem set 2</td>
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<td>Term project oral presentation</td>
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Course Objectives:

1. Develop proficiencies in core qualitative and quantitative principles of groundwater storage, flow, recharge, discharge, quality, management and legal frameworks [Classes #1 through #6; evaluation via Problem set 1 and Quiz]

2. Develop ability to quantify and evaluate groundwater management challenges arising from groundwater overuse and pollution including those identified by California’s Sustainable Groundwater Management Act (SGMA):

   (2a) Develop abilities to quantify spatiotemporal trends in groundwater levels and identify key processes driving groundwater level fluctuations and trends over time [Classes #8-11 and Problem set 2]

   (2b) Learn to quantify groundwater storage and its relevance to stakeholders in a groundwater basin [Class #10 and Problem set 3]
(2c) Develop knowledge of common groundwater pollutants and techniques available
to evaluate contaminant sources and processes governing their abundance [Classes #5
and #12 and Problem set 4]

(2d) Understand factors impacting aquifer storage and evaluate techniques applied to
identify land subsidence induced by groundwater pumping [Class #14 and Problem
set 5]

(2e) Understand theory and principles governing seawater intrusion and engineering
and management interventions available to ameliorate seawater intrusion
vulnerability [Class #13]

(2f) Develop skills to evaluate where rivers gain and lose water, and understand how
pumping from wells can impact streamflow [Class #16 and Problem set 6]

3. Review, synthesize and present groundwater quality and quantity research and couple
results to potential management strategies [Oral Presentations during Classes #17 and
#18; Term project final report]

4. Review and discuss interconnections between environmental justice and groundwater
[Many classes will begin with an active learning exercise devoted to environmental
justice and groundwater, drawing from a series of readings to be posted to GauchoSpace
ahead of class e.g., https://link.springer.com/chapter/10.1007/978-3-319-23576-9_10]

Course Overview and Connections to Course Objectives:

➢ Classes #1 through #6 introduce core principles of groundwater science, including
introductions to groundwater storage, flow, replenishment, discharge, quality,
management and legal frameworks [Direct link to course objective 1 – objective outcome
evaluated via Problem set 1 and Quiz]

➢ Classes #8 through #16 couple lectures on the six key aspects of California’s Sustainable
Groundwater Management Act (the six “undesirable results”) to problem sets
highlighting one or more ways these aspects can be evaluated. Lectures will take place on
Mondays; guidance and support for problem sets will usually take place on Wednesdays.
Critically, each student will complete a problem set for a different groundwater basin
(i.e., region) identified by the Sustainable Groundwater Management Act; results of each
problem set will be synthesized into the student’s final project. [Direct link to course
objectives 2a, 2b, 2c, 2d, 2e and 2f – objective outcome evaluated via Problem sets 2, 3,
4, 5, and 6]

➢ Term project presentations—where each student provides a synthesis of results from
Problem sets 1-6 for their unique groundwater basin—take place during classes #17 and
#18 [Direct link to course objective 3 – objective outcome evaluated via Oral
presentation and Final report]
<table>
<thead>
<tr>
<th>Date</th>
<th>Lecture</th>
<th>Specifics</th>
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<tbody>
<tr>
<td>(Class #1)</td>
<td>Groundwater hydrology 1</td>
<td><strong>Topics</strong>: relevance of groundwater to provision of drinking water, industry and irrigation, and streamflow generation; global (and US-wide) overview of groundwater withdrawals; overview of role of groundwater in global change processes; definitions of key terms (e.g., groundwater, wells, groundwater management, recharge, gaining/losing streams); porosity (primary and secondary)</td>
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<tr>
<td>(Class #2)</td>
<td>Groundwater hydrology 2</td>
<td><strong>Topics</strong>: permeability; hydraulic conductivity; definitions of aquifer, aquitard, aquiclude; heterogeneity and anisotropy; confined conditions; water tables; types of aquifer systems; sources of water to wells;</td>
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<td>(Class #3)</td>
<td>Groundwater hydrology 3</td>
<td><strong>Topics</strong>: storativity; specific yield; residence times; estimating groundwater flow rates; (ground)watersheds; hydraulic heads and gradients (horizontal and vertical); flow nets; discharge</td>
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<td>(Class #4)</td>
<td>Recharge, Discharge</td>
<td><strong>Topics</strong>: quantifying ‘groundwater’ contributions to streamflow; diffuse recharge, focused recharge, water table fluctuation method, tracer hydrology methods; detecting groundwater discharges, managed aquifer recharge</td>
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<td>(Class #5)</td>
<td>Groundwater quality</td>
<td><strong>Topics</strong>: Conservative versus non-conservative solutes, Solubility, Major and minor ions, Solute sources, Advection, Dispersion, Common groundwater contaminants (hydrocarbons, arsenic, salinity, nitrate, fluoride) and controls on their mobility, retardation, reaction, point and non-point sources, geogenic sources</td>
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<tr>
<td>(Class #6)</td>
<td>Pumping and Management</td>
<td><strong>Topics</strong>: Well hydraulics, Cone of depression, Radius of influence, Spatial scales, Legal principles, SGMA, GSPs, GSAs,</td>
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<tr>
<td>(Class #7)</td>
<td>Quiz</td>
<td><strong>Quiz — Problem set (1 of 6)</strong>: Select and introduce SGMA basin</td>
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<td>(Class #8)</td>
<td>Groundwater levels</td>
<td><strong>Topics</strong>: Groundwater depletion, techniques to evaluate groundwater levels (e.g., GRACE, piezometric records)</td>
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<td>(Class #9)</td>
<td>Groundwater levels</td>
<td><strong>Problem set (2 of 6)</strong>: “Chronic lowering of groundwater levels...” [SGMA “undesirable result” 1 of 6] piezometric time-series analyses</td>
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<td>(Class #10)</td>
<td>Groundwater storage</td>
<td><strong>Topics</strong>: SGMA’s “minimum threshold” value, managed aquifer recharge</td>
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<td>(Class #11)</td>
<td>Groundwater storage</td>
<td><strong>Problem set (3 of 6)</strong> &quot;Significant and unreasonable reduction of groundwater storage” [SGMA &quot;undesirable result&quot; 2 of 6] - stored groundwater and its spatiotemporal distribution, wells at risk of running dry</td>
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<td>(Class #12)</td>
<td>Groundwater quality</td>
<td><strong>Problem set (4 of 6)</strong>: &quot;Significant and unreasonable degraded water quality, including the migration of contaminant plumes that impair water supplies&quot; [SGMA &quot;undesirable result” 4 of 6]</td>
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<td>(Class #13)</td>
<td>Seawater intrusion</td>
<td><strong>Topics</strong>: Prevalence, Theory, Treatment and engineering ‘solutions’</td>
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<td>(Class #14)</td>
<td>Land subsidence</td>
<td><strong>Topics</strong>: land subsidence; <strong>Problem set (5 of 6)</strong>: &quot;Significant and unreasonable land subsidence that substantially interferes with surface land uses” [SGMA “undesirable result” 5 of 6]</td>
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<td>(Class #15)</td>
<td>Streamflow depletion</td>
<td><strong>Topics</strong>: Capture, groundwater dependent ecosystems, losing and gaining reaches</td>
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<tr>
<td>(Class #16)</td>
<td>Streamflow depletion</td>
<td><strong>Problem set (6 of 6)</strong>: &quot;Depletions of interconnected surface water..” [SGMA &quot;undesirable result” 6 of 6]</td>
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<tr>
<td>(Class #17)</td>
<td>Presentations day (part 1 of 2)</td>
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<tr>
<td>(Class #18)</td>
<td>Presentations day (part 2 of 2)</td>
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