

# Lawrence C. Murdoch

## PERSONAL DATA

Professor  
Department of Environmental Engineering and Earth Sciences  
445 Brackett Hall  
Clemson University  
Clemson, SC 29634

## EDUCATION

Ph.D. University of Cincinnati, 1991, Geology  
M.S. University of Cincinnati, 1987, Environmental Science  
M.S. University of Cincinnati, 1983, Geology  
B.S. Penn State University, 1980, Geology

## PROFESSIONAL EXPERIENCE

Clemson University, 2008-present, Professor; 2002-2006, Associate Professor;  
1997-2002, Assistant Professor  
FRx Inc., 1994-present, President  
University of Cincinnati, Center for Geoenvironmental Science and Technology,  
1990-1996, Director of Research.  
University of Cincinnati, Center for Geoenvironmental Science and Technology,  
1986-1990, Geohydrology Group Leader.

## HONORS AND AWARDS

Best Student Paper Award to my Advisee, AGU Meeting, 2013  
Elected as Chair of CUAHSI Board of Directors, 2011  
Elected to Board of Directors, CUAHSI, 2007-2012  
Best Student Paper Award to my Advisee, AGU Meeting, 2012  
Best Student Paper Award to my Advisee, AGU Meeting, 2010  
Board of Trustees Award for Faculty Excellence, 2009  
Board of Trustees Award for Faculty Excellence, 2008  
Visiting Scientist, Geological Survey of Denmark, Copenhagen, Spring 2005  
Board of Trustees Award for Faculty Excellence, 2003  
Best Student Paper Award to my Advisee, AGU Meeting, 2002  
Board of Trustees Award for Faculty Excellence, 2001  
NSF CAREER Award, 1999, Hydraulic fractures at shallow depths  
Board of Trustees Award for Faculty Excellence, 1999

## PUBLICATIONS

### Book Chapters

- Murdoch, L.C. and others. Remediation of organic chemicals in the vadose zone, in *Vadose Zone, Science and Technology Solutions*. Chapter 7. pp 948-1247. R.Falta and B. Looney eds. Battelle Press, 2000.
- Murdoch, L.C., D. Wilson, K. Savage, W. Slack, and J. Uber. *Alternative Methods for Fluid Delivery and Recovery*. USEPA/625/R-94/003, 1995.
- Murdoch, L.C. Hydraulic and impulse fracturing for low permeability soils, Chapter in *Petroleum Contaminated Low Permeability Soil*, American Petroleum Institute Publication 4631, 1995.
- Beljin, M. and L.C. Murdoch. *Analytical solutions to the performance of interceptor trenches and drains*, 1995. International Ground Water Modeling Center, Golden, CO.

### Journal Publications

- Hua, L. Murdoch, L.C. and others. A Microwave Photonics Optical Fiber Method for Measuring Distributed Strain for Hydrologic Applications in the Vadose and Saturated Zones. *AGU Special Publication Distributed Acoustic Sensing in Borehole Geophysics*. OSTI ID: 2373043
- Roudini, S. L.C. Murdoch, Shojaei, M. and S. DeWolf. 2023. Proxy-based Bayesian inversion of strain tensor data measured during well tests. *Geomechanics for Energy and the Environment*, v36, Dec.  
<https://doi.org/10.1016/j.gete.2023.100506> OSTI ID:2371231
- Murdoch, L. C., DeWolf, S., Germanovich, L. N., Moysey, S., Hanna, A., Roudini, S., & Moak, R. (2023). Using the shallow strain tensor to characterize deep geologic reservoirs. *Water Resources Research*, 59, e2022WR032920.  
<https://doi.org/10.1029/2022WR032920> · OSTI ID: 1923717  
<https://doi.org/10.1364/OL.414699> OSTI 2373044
- Powell, B. A., Murdoch, L., Witmer, M., Kaplan, D., Santikari, V. (2022). Leaching and transport of technetium from reducing cementitious waste forms in field lysimeters. *Science of the Total Environment*, 841, 156596.
- Zhu, X. Liwei Hua, Jincheng Lei, Jianan Tang, Lawrence Murdoch, and Hai Xiao, "Microwave–photonic low-coherence interferometry for dark zone free distributed optical fiber sensing," *Opt. Lett.* 46, 1173-1176 (2021)
- Ferguson, B. O., Murdoch, L. C., Trumm, M., Liu, F., Rao, A. M., Powell, B. A. (2022). Mechanisms and kinetics of citrate-promoted dissolution of a uranyl phosphate mineral. *GEOCHIMICA ET COSMOCHIMICA ACTA*, 318, 247-262.
- Dawson, E., Murdoch, L. C. (2021). Damage detection in a laboratory-scale wellbore applying Time Reversal and Nonlinear Elastic Wave Spectroscopy (TR NEWS).

- NDT&E International*, 126. <https://doi.org/10.1016/j.ndteint.2021.102573> OSTI ID: 1868225
- Murdoch, L. C., Germanovich, L. N., Roudini, S., DeWolf, S. J., Hua, L., & Moak, R. W. (2021). A type-curve approach for evaluating aquifer properties by interpreting shallow strain measured during well tests. *Water Resources Research*, 57, e2021WR029613. <http://10.1029/2021WR029613> OSTI ID: 2373020
- Hua L., *et al.*, "Phase Demodulation by Frequency Chirping in Coherence Microwave Photonic Interferometry," in *IEEE Journal of Selected Topics in Quantum Electronics*, vol. 27, no. 2, pp. 1-9, March-April 2021, Art no. 7700109, doi: 10.1109/JSTQE.2020.2975575. OSTI ID: 2373045
- Li, C., Hassan, A., Palmai, M. *et al.* Experimental measurements and numerical simulations of the transport and retention of nanocrystal CdSe/ZnS quantum dots in saturated porous media: effects of pH, organic ligand, and natural organic matter. *Environ Sci Pollut Res* **28**, 8050–8073 (2021). <https://doi.org/10.1007/s11356-020-11097-0>
- Murdoch, L.C., S. DeWolf, L.N. Germanovich, S. Moysey, S. Kim, A. Hanna. 2020. Using in situ deformation to Monitor CO<sub>2</sub> storage. *International Journal of Greenhouse Gas Control*, v 93, <https://doi.org/10.1016/j.ijggc.2019.102853> OSTI ID: 2373022
- Yu, R. Lawrence C. Murdoch, Ronald W. Falta, Richard G. Andrachek, Amanda A. Pierce, Beth L. Parker, John A. Cherry, and David L. Freedman Chlorinated Ethene Degradation Rate Coefficients Simulated with Intact Sandstone Core Microcosms. *Environmental Science & Technology* **2020** 54 (24), 15829-15839. DOI: 10.1021/acs.est.0c05083
- Earnest, E. D. Boutt, L.C. Murdoch, W.P. Clement. 2019. Static and dynamic conceptual model of a complexly fractured crystalline rock aquifer. *Hydrological Processes*. June 2019. Doi 10.1002/hyp.13521.
- Santikari, V. and L.C. Murdoch. 2019. Accounting for spatiotemporal variations of curve number using variable initial abstraction and antecedent moisture. *Water Resources Management*. 2019. 33:641-656. Doi.org/10.1007/s11269-018-2124-0.
- Barajas-Rodriguez, F. J., Murdoch, L. C., Falta, R. W., and Freedman, D. L. 2019. Simulation of in situ biodegradation of 1,4-dioxane under metabolic and cometabolic conditions, *Journal of Contaminant Hydrology*. V. 223, June 2019. Doi.org/10.1016/j.jconhyd.2019.02.006. Santikari, V. and L.C. Murdoch. 2018. Including effects of watershed heterogeneity in the curve number method using variable initial abstraction. *Hydrol. Earth. Syst. Sci.* 22, 4725-4743. Sept. 2018. Doi.org/hess/22-4725-2018, 2018.
- Santikari, V.P., Lawrence C. Murdoch, 2019. Effects of construction-related land use change on streamflow and sediment yield, *Journal of Environmental Management*, Volume 252, 2019, 109605, ISSN 0301-4797, <https://doi.org/10.1016/j.jenvman.2019.109605>.

- Choi, J-W, L. N. Germanovich, L.C. Murdoch, J.W. Castle, 2016, Pressure transients to characterize cavities dissolved for natural gas storage, *Journal of Natural Gas Science and Engineering*, v33, July 2016, Pages 611–623
- Hall, R. J., L. C. Murdoch, R. W. Falta, B. B. Looney, and B. D. Riha. Evaluation of liquid aerosol transport in porous media. *Journal of Contaminant Transport*. Volume 190, July 2016, Pages 15-28.
- Murdoch, L.C., S. Xie, R.W. Falta, and C. Ruprecht, 2015, Effects of increased upward flux of dissolved salts caused by CO<sub>2</sub> storage or other factors, *Journal of Hydrology*, Aug. 1 2015, DOI:10.1016/j.jhydrol.2015.05.022.
- Murdoch, L. C., C. E. Freeman, L. N. Germanovich, C. Thrash, and S. DeWolf, 2015, Using in situ vertical displacements to characterize changes in moisture load, *Water Resour. Res.*, 51, 5998–6016, doi:10.1002/2015WR017335.
- Chen, F., R. W. Falta, L. C. Murdoch. 2015. Numerical Analysis of Thermal Remediation in 3-D Field-Scale Fractured Geologic Media. *Ground Water*, Jul-Aug;53(4):572-87.
- Fan, Y., S. Richard, R. S. Bristol, S. E. Peters, S. E. Ingebritsen, N. Moosdorf, A. Packman, T. Gleeson, I. Zaslavsky, S. Peckham, L. Murdoch, M. Fienen, M. Cardiff, D. Tarboton, N. Jones, R. Hooper, J. Arrigo, D. Gochis, J. Olson and D. Wolock. 2014. DigitalCrust – a 4D data system of material properties for transforming research on crustal fluid flow. *Geofluids* (2015) 15, 372–379
- Hall, R. J., L. C. Murdoch, D. L. Freedman, B. B. Looney, and B. D. Riha. “Bench-Scale Evaluation of Aerosol Delivery for Biostimulation and Bioaugmentation in the Vadose Zone,” *Biodegradation*, <http://link.springer.com/article/10.1007/s10532-015-9718-5>, DOI 10.1007/s10532-015-9718-5 (2015).
- Ruprecht, C., R. Falta, L.C. Murdoch, S. Benson, R. Pini. 2014 Hysteretic Trapping and Relative Permeability of CO<sub>2</sub> in Sandstone at Reservoir Conditions. *International Journal of Greenhouse Gas Control*. In press
- Liu, X., L. C. Murdoch, R. W. Falta, T. Tan. 2014. Experimental characterization of CVOC removal from fractured clay during boiling. *International Journal of Heat and Mass Transfer* 70 (2014) 764–778.
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- Hisz, D.B. L.C. Murdoch. and L.N. Germanovich (2013). A Portable Borehole Extensometer and Tiltmeter for Characterizing Aquifers. *Water Resources Research*. vol. 49, 1–11, doi:10.1002/wrcr.20500.
- Slack, T. Z., L. C. Murdoch, L. N. Germanovich, and D. B. Hisz (2013), Reverse water-level change during interference slug tests in fractured rock, USA, *Water Resour. Res.*, 49, 1552–1567, doi:10.1002/wrcr.20095. published on-line 19 April 2013.
- Murdoch, L. C., and L. N. Germanovich (2012), Storage change in a flat-lying fracture during well tests, *Water Resour. Res.*, 48, W12528, doi:10.1029/2011WR011571.

- Chen, F., R.W. Falta, L.C. Murdoch. 2012. Numerical analysis of contaminant removal from fractured rock during boiling. *Journal of Contaminant Hydrology*. 134-135, 2012, p. 12-21.
- Burbey, T.J., D. Hisz, L. C. Murdoch, M. Zhang. 2011. Quantifying Fractured Crystalline-Rock Properties Using Well Tests, Earth Tides and Barometric Effects. *Journal of Hydrology*. : 28-NOV-2011 DOI information: 10.1016/j.jhydrol.2011.11.013
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- Chen, Fei, D.L. Freedman, R.W. Falta, L.C. Murdoch. 2011 Henry's Law constants of chlorinated solvents at elevated temperatures, *Chemosphere*, doi: 10.1016/j.chemosphere.edu.2011.10.004.
- Murdoch, L.C., L. Germanovich, H. Wang, T.C. Onstott, D. Elsworth, D. Boutt. 2011. Hydrogeology of DUSEL Homestake. *Hydrogeology Journal*. Published online, 11 Oct. 10.1007/s10040-011-0773-7  
<http://www.springerlink.com/content/p238qk4521235613/fulltext.html>
- Murdoch, L.C. 2011. Potential Groundwater Problems with Gas Production from Shale in Southwestern Pa. *Pittsburg Engineer. Quarterly Publication of the Engineers' Society of Western Pennsylvania*. Spring 2011, p. 14.
- Schweisinger, T., E. J. Svenson, and L. C. Murdoch. 2011. Hydromechanical Behavior During Constant-Rate Pumping Tests in Fractured Gneiss, *Hydrogeology Journal*, 19, 963-980.
- Chen, F., X. Liu, R.W. Falta, L.C. Murdoch. 2010. Experimental demonstration of contaminant removal from fractured rock by boiling. *Environ. Sci. Technol.* 44,6337-6442.
- Kennedy, C. D. Genereux, L.C. Murdoch. 2010. Comparison of Darcian flux calculations and seepage meter measurements in a sandy streambed in North Carolina, USA. *Water Resources Research*. V. 46, W09501, 2010.
- Onstott, T.C., E. van Heerden, L.C. Murdoch. 2010. Microbial life in the depths of the Earth. *BRGM Geosciences*. July, n. 11, 52-60.
- Germanovich, L. and L.C. Murdoch. 2010. Injection of solids to lift the ground. *Proceedings A of the Royal Society of London*, November 8, 2010 466:3225-3225.  
<http://rspa.royalsocietypublishing.org/content/early/2010/05/27/rspa.2010.0033.short?rss=1>
- Onstott, T. C., F. S. Colwell, T. L. Kieft, L. Murdoch, and T. J. Phelps. 2009. New Horizons for Deep Subsurface Microbiology. *Microbe*. Volume 4, Number 11, 2009. 499-505.
- Schweisinger, T., E. J. Svenson, and L. C. Murdoch. 2008. Introduction to hydromechanical well tests in fractured rock aquifers. *Ground Water*. v. 47 no. 1, 60-79.

- Svenson, E. T. Schweisinger, L.C. Murdoch, 2008, Field evaluation of the hydromechanical behavior of flat-lying fractures during slug tests. *Journal of Hydrology*, 359, v. 1-2. 30-45.
- Murdoch, L. C., J.R. Richardson, Q.Tan, S. C. Malin, and C. Fairbanks, 2007. Reply to the discussion by Au and Yeung on “Forms and sand transport in shallow hydraulic fractures in residual soil. *V. 44, n. 12.1476-1478.*  
<http://article.pubs.nrcnrc.gc.ca/RPAS/RPViewDoc?handler=HandleInitialGet&calyLang=eng&journal=cgj&volume=44&articleFile=t07-104.pdf>
- Schweisinger, T., L.C. Murdoch, C.O. Huey. 2007, Design of a removeable borehole extensometer. *Journal of Geotechnical Measurement. V 30 n. 3, p. 202-211.*
- Svenson, E. T. Schweisinger, L.C. Murdoch. 2007. Analysis of the hydromechanical response of a flat-lying fracture to a slug test. *Journal of Hydrology. 347, v. 1-2, 35– 47*
- Harrar, W., L.C. Murdoch, B. Nillson, K. Klint. 2007. Field characterization of vertical bromide transport in a fractured glacial till. *Hydrogeology Journal. 15: 1473– 1488.* <http://www.springerlink.com/content/283h02817k231n5j/fulltext.pdf>
- Murdoch, L.C., J. R. Richardson, Q. Tan, S.Malin, C. Fairbanks, 2006. Forms and sand transport in shallow hydraulic fractures in residual soil. *Canadian Geotechnical Journal, V. 43(10), Oct. 1061-1073.*
- Murdoch, L.C. and L. Germanovich. 2006. Analysis of a deformable fracture in a permeable material. *International Journal of Numerical and Analytical Methods in Geomechanics, 30:529-561.*
- Ross, C., Murdoch, L. C., Freedman, D. L. and Siegrist, R. L. 2005. Characteristics of potassium permanganate encapsulated in polymer. *ASCE J. Environ. Eng., v. 131. n. 5, 1203-1211..*
- Bradner, G. and L.C. Murdoch. 2005. Effects of skin and hydraulic fractures on the performance of an SVE well. *Journal of Contaminant Hydrology. v.77, issue 4, May, 271-297.*
- Kelly, S.E., and L.C. Murdoch, 2003. Well tests for determining the hydraulic conductivity of a stream bed. *Ground Water. v.41, n.4. p. 431-439.*
- Murdoch, L.C. and S.E. Kelly. 2003. Factors affecting the performance of conventional seepage meters. *Water Resources Research. v. 39. n. 6, 2-1.*
- Murdoch, L.C. and W.W. Slack. 2002. Forms of hydraulic fractures in shallow, fine-grained formations. *Journal of Geoenvironmental and Geotechnical Engineering. V. 128, no. 6, p. 479-487.*
- Murdoch, L.C. 2002. Mechanical analysis of an idealized hydraulic fracture at shallow depths. *Journal of Geoenvironmental and Geotechnical Engineering. v. 128, no. 6, p. 488-495.*

- Freedman, D.L., L.C. Murdoch, T. Karanfil, T.A. DeVol, A. Schank, and L. Drumm. Evaluation of reactive barrier materials for in situ treatment of TCE and Technicium-99. WEFTEC, October 13-17, Atlanta, GA, 2001
- Murdoch, L.C. and others. Remediation of organic chemicals in the vadose zone, in Vadose Zone, Science and Technology Solutions. Chapter 7. pp 948-1247. R.Falta and B. Looney eds. Battelle Press, 2000.
- Roulier, Mike, Mark Kemper, Souhail Al-Abed, Larry Murdoch, and Wendy Davis-Hoover. Feasibility of electrokinetic soil remediation in horizontal Lasagna cells, Journal of Hazardous Materials, B77, 161-176. 2000
- Murdoch, L.C., W.W. Slack, W.G. Harrar, R.L. Siegrist. Embedded sidewall samplers and sensors to monitor the subsurface. Ground Water, v.38, n. 5. p. 657-664, 2000
- Uber, J.G. and L.C. Murdoch. Evaluation of hopscotch method for transient groundwater flow. J. Hydraul. Eng., ASCE, v. 126, n. 8, August 2000, p. 615-626.
- Murdoch, L.C., W.W. Slack, W. Harrar, B. Nilsson, and R. Siegrist. Sidewall sensors for monitoring fractured clay till. Journal of Nordic Hydrology, 30, no. 4/5, 1999.
- Chen, J-L, Al-Abed, Bryndzia, and Murdoch, L.C. Effects of cation transport and partitioning during a field test of electroosmosis. Water Resources Research, v. 35, no. 2, pg. 3841-3851, Dec. 1999.
- Siegrist R.L., K. S. Lowe, L.C. Murdoch, T.L. Case, and D. A. Pickering. In situ oxidization by fracture emplaced reactive solids. Jour of Environ. Eng., v. 125, n. 5, 429-440. 1999.
- Chen, J-L. and Murdoch, L.C. In-situ electroosmosis between horizontal electrodes: a field test. J. Geotech. And Geoenviron. Eng., v. 125, no. 12, 1090-1100. 1999.
- Murdoch, L.C. and J-L. Chen. Effects of conductive fractures during in situ electroosmosis: Journal of Hazardous Materials, 55, 239-262, 1997.
- Chen, J-L. and Murdoch, L.C. In-situ electroosmosis between horizontal electrodes: a field test. J. Geotech. And Geoenviron. Eng., v. 125, no. 12, 1090-1100. 1999.
- Murdoch, L.C. Forms of hydraulic fractures created during a field test in fine-grained glacial drift, Quarterly Journal of Engineering Geology, 28, 23-35, 1995.
- Murdoch, L.C. and J. Franco. Analysis of constant head wells using instantaneous source functions, Water Resources Research v. 30, (1) 117-124, 1994.
- Murdoch, L.C. Transient analysis of an interceptor trench, Water Resources Research, 30(11), 3023-3032, 1994.
- Vesper, S. L.C. Murdoch, S. Hayes, and W. Davis-Hoover. Slow-release oxygen sources for bio-remediation in soils. Journal Hazardous Materials, 36, 265-274, 1994.
- Murdoch, L.C. Hydraulic fracturing of soil during laboratory experiments: methods and observations, Geotechnique, 43(2), 255-265, 1993.
- Murdoch, L.C. Hydraulic fracturing of soil during laboratory experiments: propagation, Geotechnique, 43(2), 266-276, 1993.

- Murdoch, L.C. Hydraulic fracturing of soil during laboratory experiments: theoretical analysis, *Geotechnique*, 43(2), 277-287, 1993.
- Du, Y., A. Aydin, and L.C. Murdoch. Incremental growth of a shallow hydraulic fracture at a waste remediation site, Oakbrook, Illinois from inversion of elevation changes. *Int. J. Rock Mech. Min. Sci.*, 30(7), 1273-1279, 1993.
- Wang, Stodt, Steirman and Murdoch. Mapping hydraulic fractures using a borehole-to-surface electrical resistivity method. *Geoexploration*. 28, 1991.

### **Reviewed Conference Publications**

- Laffaille, C., J. Parris, S. DeWolf, L. Germanovich, L. C. Murdoch. 2023. Feasibility of Measuring the Strain Tensor at Geothermal Reservoir Temperatures. *PROCEEDINGS, 49<sup>th</sup> Workshop on Geothermal Reservoir Engineering*. Stanford University, Stanford, California, February 12-14, 2024. SGP-TR-227
- Labrecque, D., J. Denison, L. Murdoch et al. 2016. Remote Imaging of Proppants in Hydraulic Fracture Networks Using Electromagnetic Methods: Results of Small-Scale Field Experiments Paper No. SPE-179170-MS. Society of Petroleum Engineers. SPE Hydraulic Fracturing Technology Conference, 9-11 February, The Woodlands, Texas, USA
- Douglass, B. W. Chamlee, T. Waterhouse, L.C. Murdoch, 2012. The Effect of Dam Removal on transport of Sediment in Twelve-Mile Creek, South Carolina. Fall 2012 Carolina Geological Society Meeting and Field Trip Guidebook, 6 p.
- Germanovich, L.N. L. C. Murdoch, Dmitry Garagash, Ze'ev Reches, Steve J Martel, Devon Gwaba, Derek Elsworth, Tullis C Onstott. 2011. Earthquake Rupture Experiment on the Homestake Fault. *Proceedings of 2011 NSF Engineering Research and Innovation Conference*, Atlanta, Georgia. 9 p.
- Wang, H., D. Fratta, M. MacLaughlin, L. Murdoch, (2011). "Fiber-Optic and Tilt Monitoring in the Deep Underground Science and Engineering Laboratory (DUSEL), Lead, SD," *NSF CMMI Research and Innovation Conference 2011*, Atlanta, Jan 4-7, 2011.
- H. F. Wang, J. R. Gage, D. Fratta, M. MacLaughlin, L.C. Murdoch, T. Tokunaga (2010), "Deep Underground Instrumentation and Monitoring," in *ISRM International Symposium 2010 and 6<sup>th</sup> Asian Rock Mechanics Symposium - Advances in Rock Engineering 23-27 October, 2010, New Delhi, India Proceedings*, ed. by K.G. Sharma, T. Ramamurthy, V. K. Kanglia, and A.C. Gupta, pp. KN46 - KN57.
- Burbey, T.J., and Murdoch, L.C., 2010, Using extensometer and earth tide data to characterize fractured crystalline-rock properties: in *Land Subsidence, Associated Hazards and the Role of Natural Resources Development*; Carreón-Freyre, D, Cerca, M., and Galloway D.L., eds.; IAHS Publication 339, p. 319-325.
- Murdoch, L.C., D.B. Hisz, J.F. Ebenhack, D.E. Fowler, C. R. Tiedeman, L. N. Germanovich. 2009. Analysis of Hydromechanical Well Tests in Fractured Sedimentary Rock at the NAWC Site, New Jersey. Asheville 2009, the 43rd US Rock Mechanics



Symposium and 4<sup>th</sup> U.S.-Canada Rock Mechanics Symposium, held in Asheville, NC  
June 28<sup>th</sup> – July 1, 2009, 8 p.

Schweisinger, T., E. Svenson, L.C. Murdoch. 2005. Transient changes in fracture aperture during hydraulic well tests in fractured gneiss. *Proceedings Georgia Water Resources Conference*, ed. K.J. Hatcher. April 25-27, 2005. University of Georgia. 4 pages.

Svenson, E. T. Schweisinger L.C. Murdoch. Air-slug, low-pressure straddle packer system to facilitate characterization of fractured bedrock. *Proceedings Georgia Water Resources Conference*, ed. K.J. Hatcher. April 25-27, 2005. University of Georgia.

Murdoch and Lakshmi. Prospectus of the Greater Santee River Basin as a hydrologic observatory. Presented at the *CUAHSI Hydrologic Observatory Meeting*, Ogden, Utah. Aug. 2004, 10 pages.

Slack, W.W. and L. C. Murdoch. Passive ISCO with permanganate installed by hydraulic fracturing techniques. *Fourth International Battelle Conference on the Remediation of Chlorinated and Recalcitrant Compounds*, Monterey, California. 24-27 May, 2004.

Castle, J.W. , D.A. Bruce, S.E. Brame, D.Brooks, R.W. Falta, L.C. Murdoch. 2004. Design and Feasibility of Creating Gas-Storage Caverns by Using Acid to Dissolve Carbonate Rock Formations -- *Society of Petroleum Engineers (SPE) Paper Number 91436*.

Murdoch, L.C., T. Schweisinger, E. Svenson, L.Germanovich , 2004. Measuring and analyzing transient changes in fracture aperture during hydraulic well tests: preliminary results. *Dynamics of Fluids in Fractured Rock. Witherspoon Conference*, Feb. 10-14, 2004.

Freedman, D.L., L.C. Murdoch. T. Karanfil, T.A. DeVol, A. Schank, and L. Drumm. Evaluation of reactive barrier materials for in situ treatment of TCE and Technicium-99. *WEFTEC*, October 13-17, Atlanta, GA, 2001

Slack, W.W., Lawrence C. Murdoch, and Dave Butler, Recovering Free Product from Clay Using Hydraulic Fractures. *in Proceedings of Battelle Second International Conference on Remediation of Chlorinated and Recalcitrant Compounds*, Monterey, CA. May, 2000.

Slack, W.W. and Lawrence C. Murdoch, Hydraulic Fractures to Improve In Situ Remediation, *in Proceedings of Battelle Second International Conference on Remediation of Chlorinated and Recalcitrant Compounds*, Monterey, CA. May 2000.

Davis-Hoover, W. J., L. T. Bryndzia, M. H. Roulrier, L. C. Murdoch, M. Kemper, P. Cluxton, S. Al-Abed., W. W. Slack, and S. J. Vesper. 1999. *In Situ Bioremediation utilizing Horizontal LASAGNA<sup>tm</sup>* . In Leeson, A. and Alleman, B. C. (Ed.) *Engineered Approaches for In situ Bioremediation of Chlorinated Solvent Contamination - 5(2)*, Battelle Press, Columbus, OH. pp 263-267.

Siegrist, R.L., K.S. Lowe, L.C. Murdoch, and A.M. Struse. In situ chemical treatment using hydraulic fracturing to emplace Fe methal and KMnO4 reactive solids. *Proceedings of the Conference on Abiotic In Situ Technologies for Groundwater Remediation*. Aug. 31-Sept 2, 1999, Dallas, Texas.

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- Murdoch, L.C., W. Slack, R. Siegrist, S. Vesper, T. Meiggs, Hydraulic fracturing advances. *Civil Engineering*, May 1997, 10A-12A.
- Murdoch, L.C., W. Slack, R. Siegrist, S. Vesper, T. Meiggs, Advanced hydraulic fracturing methods to create in situ reactive barriers. *Proceedings of the International Containment Technology Conference and Exhibition*, Feb. 9-12, 1997, St. Petersburg, FL
- Chen, J.-L., and Murdoch, L. Field demonstration of in situ electroosmosis between horizontal electrodes. *Proceedings ASCE 1997 Annual Convention*, Minneapolis, Minn, Jan. 1997.
- Wolf, A. And L.C. Murdoch. A field test of air flow to a hydraulic fracture, *NGWA Outdoor Action Conference*, Las Vegas, NV, May 1993.
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- Murdoch, L.C. and L. Germanovich. 2008. Can hydraulic fractures save the coastal cities of the world? *17<sup>th</sup> Clemson Hydrogeology Symposium*. 3 April, 2008.
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- Atterbery, J. S. Brames, J.Castle, R. Falta, L. Murdoch. Integration of GIS mapping and regional geology of carbonate formations in the Appalachian Basin. *GSA SE Regional Meeting*, 2005
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- Tan, Q., J.R. Richardson, and L.C. Murdoch. 2003. Forms and analysis of hydraulic fractures at shallow depths. AGU Fall Meeting. *13<sup>th</sup> Clemson Hydrogeology Symposium*, 2004
- Hall. R., L.C. Murdoch, and R. Falta. Effects of sand-filled hydraulic fractures during air sparging. *2003 AGU Fall Meeting*.
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- Bradner, G. and L.C. Murdoch, Effects of shallow induced fractures on the performance of soil vapor extraction wells. *10<sup>th</sup> Clemson Hydrogeology Symposium*, 2002
- Richardson, J., Shawn Malin, Qingfeng Tan, and Larry Murdoch. Characteristics and Design of Hydraulic Fractures in Saprolite, *10<sup>th</sup> Clemson Hydrogeology Symposium*, 2002
- Schweisinger, T.C. and L.C. Murdoch. . Measuring changes in fracture aperture during injection to estimate characteristics of fractured rock near a well. *AGU Fall Meeting*. 2002
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- Bradner, G. and L.C. Murdoch.. Effects of sand-filled fractures on the performance of SVE wells. *AGU Fall Meeting*. 2001

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- Souders A., S.A. Kelly and L.C. Murdoch. An in-situ method for determining the hydraulic conductivity of a stream bed. *AGU meeting, Dec. 2000.*
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## **Patents**

Murdoch, L.C., L. N. Germanovich, W.W. Slack. Storing solid carbon-bearing particles in geologic formations. Patent Application, 17/590.351 filed 1 Feb. 2022.

Germanovich, L.N., Murdoch, L.C., Robinowitz, M.J., 2018, Emergency method and system for in-situ disposal and containment of nuclear material at nuclear power facility, US Patent No. 10115489.



Germanovich, L.N., Murdoch, L.C., Robinowitz, M.J., 2015, Abyssal sequestration of nuclear waste and other types of hazardous waste, US Patent No. 9190181.

Murdoch, L.C., T. Schweisinger, C.O. Huey. *A device to measure axial displacement in a borehole*. Patent #7347003, Issued 25 March 2008

Castle, J.W., D.A. Bruce, R.W. Falta, and L.C. Murdoch, *United States Provisional Patent for Storage Cavities in Carbonate Rock*, 7156579 B2, Jan. 2, 2007.

Molz, F. , L. Murdoch. C. Dinwiddie, J. Castle. *Small Drill-Hole, Gas Mini-permeameter Probe*, Patent #H2052H. Dec. 2002.

Seigrist, R. and L.C. Murdoch. *Oxidative particle grouts for in situ ground water treatment* US Patent. 6102621 issued August 15, 2000.

Hunt, S.C. , T.O. Meiggs, L.C. Murdoch, W.W. Slack. *Method and system for bioremediation of contaminated soil using inoculated support spheres*. Patent 5,733,067 issued 31 March 1998

### **Ideas Commercialized**

Founded FRx Inc., a company that provides services to the environmental community. FRx specializes in hydraulic fracturing and other processes that developed as part of my research program.

### **Published Research Reports**

Murdoch, Lawrence C.; Scott DeWolf, Liwei Hua, Leonid N Germanovich, Hai Xiao, Xuran Zhu, Wu Yongji, Jing Guo, Robert Moak, Riley Blais, Soheil Roudini, Olivia Costantino, Grant Plunkett, Austin Smith-Jones. (2023) Robust In-Situ Strain Measurements to Monitor CO<sub>2</sub> Storage. Final Report for US DOE Project De-FE0028292. 692 p. <https://doi.org/10.2172/1997547>

Murdoch, L.C, Scott DeWolf, Leonid Germanovich, Alex Hanna, Robert Moak and Stephen Moysey. (2019). Characterizing and Interpreting the In Situ Strain Tensor During CO<sub>2</sub> Injection. Final Report for US DOE Project DE-FE 0023313, 252 p. <https://doi.org/10.2172/1529100>

Murdoch, L.C., L.N. Germanovich, S.Moysey, A. Hanna, S. Kim, S. Dewolf, J. Ebenhack, G. Skawski. 2015. Proof-of-Feasibility of Using Wellbore Deformation as a Diagnostic Tool to Improve CO<sub>2</sub> Sequestration. Final Report for Project DE FE0004542. U.S. Department of Energy. 276 p. <https://doi.org/10.2172/1240376>

McPherson, B. et al. 2002. EARTHLAB. A Subterranean Laboratory and Observatory to Study Microbial Life, Fluid Flow, and Rock Deformation <http://www.earthlab.org/>.

Falta, R.W., L.C. Murdoch, and G.K. Chambers, Review of Current Technology for Acid Dissolution and Hydraulic Fracturing (Task 5), *Technical Report prepared for US DOE*, February 28, 2004

Seigrist, R. L., K.S. Lowe, L.C. Murdoch, W.W. Slack, T.C. Houk. X-231A demonstration of in situ remediation of DNAPL compounds in low permeability media by soil fracturing with thermally enhanced mass recovery and reactive barrier destruction. *DOE document ORNL/TM-13534*, March 1998.

Murdoch, L.C. G. Losonsky, P. Cluxton, B. Patterson, I. Klich, B. Braswell. The feasibility of hydraulically fracturing soil to improve remedial actions. *NTIS Report PB91-181818*, 1991.

Murdoch, L.C., G. Holzhausen, and J-C. Roegiers. *Innovative delivery and recovery systems: hydraulic fracturing*, EPA 68-03-3379, 207 p., 1987.

### **Presentations**

Three Faces of Fracturing. Virginia Tech. 27 March 2015

Protecting Coastal Cities from Catastrophic Flooding. University of Minnesota, Warren Lecture, Oct 22 2010

Can Hydraulic Fractures Save the Coastal Cities of the World? Invited talk at *University of Wisconsin*, March, 2008.

Hydromechanical well tests in fractured rock. Invited talk at *University of Wisconsin*, March, 2008.

Fracture Processes Laboratory for DUSEL at Homestake. *DUSEL Homestake planning workshop*, 3-4, Nov. 2007.

Can Hydraulic Fractures Save the Coastal Cities of the World? Invited Keynote Address. *7<sup>th</sup> Annual Meeting of the Hydraulic Fracturing Club*, Atlanta, Georgia, 22-26 May, 2007.

Geoscience plan for the Henderson Deep Underground Science and Engineering Laboratory (DUSEL) proposal. *Presentation to National Science Foundation review panel*, May, 2007. 19 April 2007

Are T and S Constant During Well Tests in Fractured Crystalline Rock? *16<sup>th</sup> Clemson Hydrogeology Symposium*. 17 April, 2007.

Multiphysics: A New Tool for Analyzing Processes in Hydrogeology. *15<sup>th</sup> Clemson Hydrogeology Symposium*, 30 March, 2006.

Predicting long-term well performance using short-term hydraulic tests. *14<sup>th</sup> Clemson Hydrogeology Symposium*.

Using changes in fracture aperture during the interpretation of hydraulic well tests. *AGU Fall Meeting*. 2003.

- Characteristics and mechanics of hydraulic fractures in soils. *Invited seminar, Georgia Tech*, 23 April, 2003.
- Scientists and Engineers in the Schools, NSF-Sponsored program to promote interactions between active scientists and students in middle school. *Presentation to Pickens County Middle School*, May 2001.
- Hydraulic well tests to characterize fractured rock, invited talk at *Enigmas of Ground Water in Crystalline Rocks—Problems and Solutions*. Sponsored by Association of Engineering Geologists, Feb. 16, 2001. Raleigh, N.C.
- Effect of recharge on a shallow pumping well. *Clemson Hydrogeology Symposium*, 2000
- Environmental applications for hydraulic fractures. *Savannah River Site Groundwater Invited Technology Update Meeting*, Nov. 1999.
- Mechanics and applications for hydraulic fractures. *Invited lecture. University of Tennessee Department of Geology*, Sept. 1999.
- Transient Water Budgets from Stream Hydrographs. *7<sup>th</sup> Annual Clemson Hydrogeology Symposium*, April, 1999.
- Opportunities for sidewall sampling and hydraulic fracturing at Savannah River Site. *SRS Technical Panel Meeting*, 17 Dec. 1998.
- Environmental Applications for Hydraulic Fractures, (with a field demonstration) *Association of Engineering Geologists Banquet*, Nov. 6, 1998.
- Feasibility of creating reactive barriers using fracturing or related injection techniques. *Review panel for the remediation of the East Fork of the Upper Poplar Creek Watershed. Oak Ridge National Laboratory*, Sept. 1998.
- Hot-fluid injection into hydraulic fractures in fine-grained formations. *DOE Workshop and Program Review*. Aug. 1998
- Sidewall sensors for monitoring fractured clay till. *Mass Transport in Fractured Aquifers and Aquitards Conference*. Copenhagen, DK. May 14-16, 1998.
- Arrays of sidewall sensors to monitor subsurface conditions. *4<sup>th</sup> International Symposium on Environmental Geotechnology*, Boston, Mass. Aug. 9-13, 1998.
- Sidewall sensors to monitor subsurface conditions. *6<sup>th</sup> Annual Clemson Hydrogeology Symposium*, April, 1998.
- Subsurface injection of solid oxidants, *Workshop on Subsurface Applications for Chemical Oxidants*, WEFTEC Annual Meeting, Chicago, Oct. 1997
- Recent Advances in Environmental Applications for Hydraulic Fractures, *Danish ATV Technical Conference on Soil Remediation*, Jutland, Denmark, March 11-12, 1997
- Environmental Applications for Hydraulic Fractures, *5<sup>th</sup> Annual Clemson Hydrogeology Symposium*, April, 1997.
- Applications for Hydraulic Fractures, *South Carolina Geological Association, Southeast Chapter, Monthly Meeting*, Aiken, SC, July, 1997

- Environmental Applications for Hydraulic Fractures, *Association of Engineering Geologists Banquet*, Jan. 1996
- Use of Hydraulic Fractures to Facilitate Remediation of Fine-Grained Soils Contaminated with DNAPL, *Workshop on remediation of fine-grained soils contaminated with DNAPL. Sponsored by DOE and American Petroleum Institute*, 1993 and 1994.
- Use of Hydraulic Fractures to Facilitate Remediation of Fine-Grained Soils Contaminated with Petroleum Hydrocarbons, *Workshop on remediation of fine-grained soils contaminated with petroleum hydrocarbons, sponsored by API*, 1993.
- State-of-the-art of hydraulic fracturing research for remediation, *Solvents in Groundwater Research Consortium meeting*, University of Waterloo, Canada, Sept. 1994.
- Environmental applications of horizontal barrier technologies, *Society American Military Engineers meeting*, August, 1994.
- New methods for enhancing recovery of contaminants *Society American Military Engineers Meeting*, April, 1994.
- Innovative methods of enhancing recovery of contaminated groundwater, Short course on groundwater field methods, Ohio University, Athens, OH, July, 1992.
- In situ delivery and recovery of liquids to facilitate corrective actions, *USEPA Seminar on RCRA Corrective Action Stabilization Technologies*:
- 13 Nov. 1991 Boston, MA
  - 14 Nov. 1991 Chicago, IL
  - 10 Dec. 1991 San Francisco, CA
  - 7 Jan. 1992 Kansas City, MO
  - 11 Feb. 1992 Denver, CO
  - 12 Feb. 1992 Seattle, WA
  - 18 March 1992 Philadelphia, PA
  - 19 March 1992 New York, NY
  - 2 April 1992 Atlanta, GA
- Mechanics of hydraulic fractures in soil, *Invited talk, Purdue University*, Feb. 1990.
- Hydraulic fracturing to improve remediation, *Invited talk IBM Environmental Seminar*, Jan. 1989.
- Convener**
- Murdoch, L.C. and others. Session H21B. Fractures, Fracture Networks, and Fractured Media. 2011 Fall AGU Meeting.
- 3rd Workshop on a Community Hydrologic Modeling Platform., J. Famiglietti, Murdoch, L.C., V. Lakshmi, R. Hooper . March 12 – 15, 2011. University of California at Irvine.

- Germanovich, L. and L.C. Murdoch. 2010. Workshop on Current Frontiers in Faulting Research. Westin Hotel, San Francisco. Approximately 20 attendees. 12 Dec. 2010.
- Murdoch, L.C. 2010. Workshop on Planning Experiments at DUSEL. Westin Hotel, San Francisco. Approximately 40 attendees. 12 Dec. 2010.
- Murdoch, L C , D Elsworth, T C Onstott, W M Roggenthen Rocks, Fractures, Fluids, and Life: Insights From Subsurface Observatories II AGU Special Session 2010.
- Murdoch, L C , D Elsworth, T C Onstott, W M Roggenthen Rocks, Fractures, Fluids, and Life: Insights From Subsurface Observatories I AGU Special Session 2009.
- 2nd Workshop on a Community Hydrologic Modeling Platform. Murdoch, L.C., J. Famiglietti, V. Lakshmi, R. Hooper . March 31 – April 1, 2009. University of Memphis
- Community models for hydrologic and environmental research. Murdoch, L.C., J. Famiglietti, V. Lakshmi, R. Hooper, 2008. Special Session at 2008 CUAHSI Biennial Meeting.
- Impacts of Effective Sea Level Rise on Coastal Areas: Advances in Understanding, Assessment, and Mitigation Posters. Germanovich, L.N. and L.C. Murdoch. 2008. AGU Fall Meeting.
- New Approaches to Models for the Hydrologic Community. Murdoch, L.C., J. Famiglietti, V. Lakshmi, R. Hooper, 2008. Special Session, Computational Methods in Water Resources Conference, July, San Francisco.
- Scoping Workshop on a Community Hydrologic Modeling Platform. Murdoch, L.C., J. Famiglietti, V. Lakshmi, R. Hooper, 2008, March 27 –March 29, 2008, Washington, DC
- Interactions Between Fluids and Fractures. *Special Session at 2007 Fall AGU Meeting*, co-convended with Leonid Germanovich
- Interactions Between Fluids and Fractures. *Special Session at 2003 Fall AGU Meeting*, co-convended with Leonid Germanovich
- Recent Advances in Well Testing. *Special Session at 2001 Fall AGU Meeting*, co-convended with Jim Butler.
- Interactions Between Fluids and Fractures. *Special Session at 2007 Fall AGU Meeting*, co-convended with Leonid Germanovich
- New Approaches to Models for the Hydrologic Community. *Planned for Computational Methods in Water Resources Conference*, July 2008. co-conveners: Venkat Lakshmi, Jay Famiglietti

#### **SPONSORED RESEARCH**

*I have been PI or co-PI on approximately 40 projects over the last 30 years. I have been the PI on more than \$10M, and co-PI on more than \$8M in sponsored research. Individual projects are listed below.*

1. Characterizing strain tensor response to permeability changes. Subcontract to: Center for Understanding Subsurface Signals and Permeability (CUSSP), Pacific Northwest National Laboratory. Department of Energy, \$957,471. 2023-2027
2. A Strain Sensing Array to Characterize Deformation at the FORGE Site. DOE \$3,964,306 (PI). 2022-2025
3. Characterizing high temperature borehole heat exchangers for energy storage. DoD. \$2.2M co-PI. 2023-2028.
4. Fukushima Daiichi Water Treatment Study, Bechtel Corp. co-PI \$115,000
5. Autonomous Monitoring of Wellbore Integrity Applying Time Reverse Nonlinear Elastic Wave Spectroscopy (TR NEWS) and Fiber Optic Sensing and Communication. DOE. Co-PI \$450,000
6. Radionuclide Waste Disposal: Development of Multi-scale Experimental and Modeling Capabilities, DOE EPSCoR, 5,525,000. co-PI, 20-14-2019.
7. Robust In-Situ Strain Measurements to Monitor CO<sub>2</sub> Storage. DOE P.I. \$1775437. 2016-2022
8. Characterizing and interpreting the in situ strain tensor during CO<sub>2</sub> injection. DOE FE0023313, P.I. \$1,560,316. 2014-2017
9. Aerosol Delivery for Vadose Zone Remediation—ARRA. SCUREF, PI, \$35k.
10. Development of a Fracture Processes Facility at DUSEL Homestake. NSF, co-PI. \$10,000.
11. Fiber-Optic Strain Monitoring of Rock Masses in Large, Underground Facilities. NSF. \$129k co-PI.
12. Proof-of-Feasibility of Using Well Bore Deformation as a Diagnostic Tool to Improve CO<sub>2</sub> Sequestration, \$450,000. DOE. PI.
13. Effects of Hydrologic Processes on In Situ Stress Transient, NSF. PI, 2010-2015, \$250k
14. Understanding and Managing Risks Posed by Brines Containing Dissolved Carbon Dioxide; USEPA. \$900k, 2010-2014, co-PI with Ron Falta.
15. Ecohydrology of Deep Crystalline Rocks at DUSEL Homestake, NSF, subcontract from University of Mass. 2009-2011 \$12k
16. Characterization of Fractured Rock Aquifers Using Hydromechanical Well Tests, 2007-2011, NSF Award, Principal Investigator, \$278,213
17. Proof of Concept of a Hydrologic Multiphysics Model. \$48,000. 2009-2011 NSF, Principle Investigator.
18. Deep Underground Science and Engineering Laboratory Coordination, \$50,000 2008-2011 NSF, co-PI.

19. Contaminant Mass Transfer During Boiling in Fractured Geologic Media, 2008-2011, SERDP, co-PI with Ron Falta. \$541,000 (\$270,00)
20. ERTS Edible Oils for Enhanced VOC Degradation, \$32,000, 2008-2009, SCUREF, Principal Investigator.
21. ERTS Edible Oils for Enhanced VOC Degradation, \$36,000, 2007-2008, SCUREF, Principal Investigator.
22. Soil Fractures and Edible Oils for Enhanced VOC Degradation, \$34,000, 2006-2007, SCUREF, Principal Investigator.
23. ERTS Hydraulic Fracturing Collaboration, \$34,000, 2005-2006, SCUREF, Principal Investigator
24. Fracture Dissolution of Carbonate Rock: An Innovative Approach for Gas Storage. DOE. \$647,194 (\$161,798). co-PI with Jim Castle, Ron Falta, David Bruce. 2003-2006.
25. Characterization of hydraulically active sheet fractures. NSF Award, Principal Investigator, July, 2000-June, 2005. (\$225,000).
26. Hydraulic fractures at shallow depths, NSF CAREER Award, Principal Investigator, June 1999-June 2004. (\$220,000).
27. Evaluation of reaction kinetics and design data for a zero-valent iron reactive wall. (\$50,000). PI. FRx Inc. 2000.
28. Development and evaluation of micro-encapsulated permanganate for slow release applications during remediation. Principal Investigator. DOE through FRx Inc. (\$50,000). 1999-2000.
29. Evaluation of steam stripping and hot air injection into fine-grained soils containing hydraulic fractures, API/DOE, Co-Principal Investigator, Oct. 1995-1997, (\$200,000).
30. Electrokinetic remediation of soil using innovative subsurface techniques, USEPA, Principal Investigator, 1994-1997, (\$900,000).
31. Evaluation of an in situ horizontal grout barrier, DOE, Principal Investigator, 1994-1995 (\$180,000).
32. Alternative methods for delivery or recovery, Handbook Preparation, USEPA, Principal Investigator, 1994, (\$74,000).
33. Innovative delivery and recovery systems, USEPA, Principal Investigator, 1993 (\$361,240), 1992 (\$121,200), 1991 (\$91,500), 1990 (\$140,500).
34. Hydraulic fracturing field demonstration , USEPA, Principal Investigator, 1992 (\$283,000), 1991 (\$202,000), 1990 (\$100,000).
35. Development of methods to hydraulically fracture soil, USEPA, Principal Investigator, 1989 (\$188,088), 1988 (\$108,000), 1987 (\$47,000)

36. Interceptor trenches for recovery of hazardous waste site leachates; *USEPA*, Principal Investigator, 1993 (\$40,000), 1992 (\$66,975), 1991 (\$67,600), 1990 (\$82,300)
37. A survey of innovative delivery and recovery systems and techniques for hazardous waste remediation, *USEPA*, Principal Investigator, (1988), \$40,000.
38. A demonstration of hydraulic fracturing to facilitate remediation in Illinois, *Illinois Department of Energy and Natural Resources-Hazardous Waste Research and Information Center*, Principal Investigator,(1990-1992), \$50,000.
39. Acoustic methods for enhancing well performance and remediation, *USEPA*, Co-Principal Investigator, 1989, \$40,000 (\$20,000).
40. Uniformity of in situ soil mixing, *USEPA*, Co- principal investigator, \$40,000 (\$10,000).
41. Feasibility of using solar energy and optical fibers to heat subsurface soils, *USEPA*, Co-principal Investigator, 1989, \$30,000 (\$10,000).

#### **OTHER SPONSORED ACTIVITY**

Graduate Student Internship, *Bunnell Lammons environmental consultants*, 2004, \$18,000.

Creation of Clemson Hydrogeology Well Field. *Clemson Teaching Innovation Grant*, \$20,000. March 2000.

A new method for sampling groundwater, *Clemson University Research Grant*, 1998, \$2977.

Testing sidewall sensors in Denmark, Travel Funds, *Geological Survey of Denmark*, 1997, \$5000.

University of Cincinnati summer research fellowship, 1984, 1983, 1982, 1981

Sigma Xi Grant-in-Aid of Research, 1982, 1981

#### **GRADUATE STUDENTS**

##### **PhD Graduates**

Vijay Santikari (PhD), 2016. Evaluating effects of construction-related land use change on streamflow and water quality

Richard Hall (PhD), 2012 Aerosol transport through unsaturated soil

Xiaoling Liu (PhD), 2012 Effects of heating and boiling during remediation

Todd Schweisinger, 2007 (Ph.D. in Mechanical Engineering) Measurement and analysis of hydromechanical effects in fractured rock. Clemson University.

Jiann-Long Chen, 1998 (Ph.D. in Civil Engineering) In Situ Electroosmosis Using Hydraulic Fractures Filled with Conductive Material, University of Cincinnati.



**MS Graduates as of 2015**

- Colby Thrash, 2015 Effects of hydrologic processes on subsurface displacements,
- Shuangshuang Xie, 2014, Evaluation of effects of basin pressurization on interactions between groundwater and surface water,
- Johnathan Ebenhack, 2013, Hydromechanical effects during dewatering at the Homestake Mine
- Seth Shantz, 2023, Contaminant fate and transport at the Statesville Superfund Site,
- David Hisz, 2013 Multicomponent deformation of aquifers during well tests.
- Clay Freeman, 2012 Estimating Water Flux and Storage Using Displacement Measurements in Saprolite at Depth.
- Glenn Skawski, 2012 Hydromechanical Well Testing Using a 3D Optical Fiber Extensometer
- Curtis Gebhard, 2010, Master's Thesis, Clemson University Evaluation of interaction between ground water and surface water.
- Trever Slack, 2010, Master's Thesis, Clemson University Hydromechanical effects during high pressure injection
- David Hisz, 2010. Master's Thesis, Clemson University Factors affecting the long-term performance of wells in the Piedmont
- Jong-Won Choi 2011 (PhD at Georgia Tech) co-advisor. Geomechanics of subsurface sand production and gas storage.
- Todd Schweisinger, 2008, PhD, Clemson University. Hydromechanical well tests in fractured rock.
- Rob Workman, 2007, Non-thesis Masters degree, Clemson University
- Erik Svenson, 2006. Master's Thesis, Clemson University. Methods for measuring and analyzing transient head and aperture changes during air-slug tests in fractured bedrock.
- Allison Craig. 2006. Master's Thesis, Clemson University. Evaluation of spatial and temporal variation of groundwater discharge to streams. Clemson University.
- James Foley, 2006. Master's Thesis, An analysis of cavern stability and hydraulic fractures in relation to natural gas storage in limestone formations. Clemson University.
- Shaun Malin. 2005. Analysis of pressure responses during hydraulic fracturing to estimate in situ stress in partially saturated soil. Master's Thesis, Clemson University.
- Richard Hall. 2005. The effects of sand-filled hydraulic fractures on air sparging. Master's Thesis, Clemson University.

- James Henley. 2004 The Hopscotch Method for analyzing transient groundwater problems. Master's Thesis, Clemson University. Won Outstanding Student Paper in Hydrology Award at 2001 AGU Meeting.
- Richardson, Jim. 2003. Forms of hydraulic fractures created at shallow depths in Piedmont Soils. Master's Thesis, Clemson University.
- Tan, Qingfeng. 2003 Two-dimensional hydraulic fracture simulations using Franc2D. Master's Thesis, Clemson University.
- Bradner, Graham. 2002. Effects of shallow induced fractures on the performance of soil vapor extraction wells. Master's Thesis, Clemson University.
- Ross, Chapman. 2002. The characteristics of potassium permanganate encapsulated in polymer. Master's Thesis, Clemson University.
- Passinos, Vasi. 2001. Effects of Idealized Lateral Heterogeneities on the Performance of a Well. Master's Thesis, Clemson University.
- Kelly, Susan 2001 Methods for Determining the Hydraulic Conductivity of Streambeds, Master's Thesis, Clemson University.
- Dunlap, J. 1999. Hydraulic Conductivity of Mixtures of Soil and Cement, Master's Thesis, Civil and Environmental Engineering, University of Cincinnati,
- Hart, P. 1997. Dewatering and Soil Vapor Extraction Using Hydraulic Fractures, Civil and Environmental Engineering, University of Cincinnati.
- Wolf, A., 1994. Air flow to a Hydraulic Fracture in Silty Clay, Civil and Environmental Engineering, University of Cincinnati.

### **Undergraduate Research Advising**

- Trayle Kulshan, Agricultural Engineering, 1998
- Trevor Benton, Geological Sciences, 2000, Trevor received two cash awards for a presentation he made describing his research project at the South Carolina Academy of Sciences
- Joey Koon, Geological Sciences, 2000
- Kate Souders, Geological Sciences, 2000. Kate presented her research as a poster session at AGU
- Ramie Walters, Geological Sciences, 2001.
- Ryan Elmore, Geological Sciences, 2004-2005
- Megan Duncan, Phung Pham, Katie Stone, Cole Marchin, Geological Sciences, 2005-2006
- Dan Brown, Geological Sciences; Holly Burwinkle, Math. 2007-2008
- Zach Dixon, Math. 2011

### **TEACHING**

#### **Courses taught**

Geol 850, Site Assessment and Remediation, Spring'97

Geol 408/608, Applied Hydrogeology, Fall'97, F'98, F'99, F'00-F'07,F'09-F-12  
Geol 415/615, Method of Analysing Geological Processes  
Spring'97, Fall'98, F'99, F'00-F'07,F'09-F-12  
Geol 816, Aquifer Systems, Spring'99, S'01, S'03, S'05, S'07,S'09,S'12  
Geol 475/675, Hydrogeology Field Camp First Summer Session'97, S1'98, S1'99,  
S1'00, S1'01, S1'02, S1'03, S1'04, S1'06  
Geol 818, Hydrology and Mechanics of Fractured Media, S'00, S'02, S'04, S'06,  
S'08,S'10,S'11  
EES 817 Applied Process Simulation S'13

### **New Course Development**

Geol 850, Site Assessment and Remediation, 1997  
Geol 415/615, Methods of Analyzing Geological Processes, 1998  
Geol 816, Aquifer Systems, 1999  
Geol 818, Hydrology and Mechanics of Fractured Media, 2000  
Geol 475/875 Hydrogeology Field Camp, 1999  
EEES 817 Applied Process Simulation, 2013

### **CONSULTING**

- Synterra, 2014-present. Developed and reviewed groundwater flow and transport models.
- Kurion Corp. 2013. Developed simulation involving transport and sorption.
- Lord Corp. 2013. Evaluated opportunities for innovative applications of displacement sensors.
- El Paso Natural Gas, 2007, Reviewed characterization and remediation activities at Superfund site and provided recommendations for improvement.
- Massenburg Construction, 2006, Provided advice about dewatering during excavation in coastal areas.
- Nexsen-Pruet, 2006. Provided expert testimony concerning a horizontal boring in a coastal area.
- FRx Inc. 1998-present. Provide advice on the design and application of innovation remediation systems.
- Linemaster Switch Corporation, Woodstock, Conn., 1994-1997. Developed method for accelerating remediation of Superfund site.

### **UNIVERSITY AND PUBLIC SERVICE**

#### **Professional:**

- Elected Chair of the Board of Directors of CUAHSI. Three year term of chair-elect, chair, past chair, 2010-2012

- Invited member of the DUSEL Experimental Design Committee, 2007-; responsible for coordinating experiments from Geosciences community in a \$250M MREFC proposal to NSF.
- Elected to CUAHSI Board of Directors, 2007-2010
- Chair of Geoscience Committee for a Deep Underground Science and Engineering Lab at the Henderson Mine, Colorado, 2007
- Invited to NSF Review Panel, Spring 2007
- Invited to AGU Technical Program Committee, Ground Water, 2005-present
- Invited contributor to EarthLab, 2002-2003

**Advisor:** Geology Club (1999-2006)

**Committees**

University: Member, Library Committee, (1997-)  
College: Member, Curriculum Committee, (1998-2001)  
Department: Recording Secretary, (1997-1999)  
Graduate Assessment (1999-present)  
Faculty Search Committee, Chair 2004  
Faculty Search Committee, Member 2005, 2006

**Coordinator:** Departmental Alumni Newsletter

**Associate Editor:** Hydrogeology Journal: 2010-2016  
Water Resources Research: 2015-present

**Reviewer:** Proposals for NSF, NSERC (Canadian NSF), Wisconsin Natural Resources, Erwin Schroedinger Fellowship Program, Petroleum Research Fund.

Papers for Water Resources Research, Advances in Water Resources, J of Hydrology, Ground Water, Engineering Geology, Limnology and Oceanography, Int. J. of Rock Mechanics, Engineering Fracture Mechanics, J. of Applied Mechanics, Ground Water Remediation Technologies Analysis Center, among others.

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