Curriculum Vitae

MICHAEL JAMES FRIEDEL

michael.j.friedel@gmail.com
US Citizen

Residence
9 Taieri Crescent
Kelson, Lower Hutt
5010 New Zealand
+6421641900, 021641900
MichaelJFriedel (Skype)
www.michaeljfriedel.com
www.researchgate.net/profile/michael_friedel3

GNS Science
Hydrogeology Department
1 Fairway Drive
Lower Hutt, New Zealand
www.gns.cri.nz

University of Colorado
Mathematical & Statistical Sciences
Denver, Colorado, USA
www.ucdenver.edu/academics/colleges/CLAS/Departments/math/Pages/MathStats.aspx

EDUCATION

PhD, Water Resources Science (Computational Geoscience) **2002**
University of Minnesota – Global ranking # 69 Twin Cities, MN, USA
Dissertation: Simultaneous inverse estimation of coupled water, heat, and solute transport parameters with model validation and predictive analysis; Advisor: Prof. John L. Nieber

MS, Geological Engineering (Geomechanics) **1996**
University of Minnesota – Global ranking # 69 Twin Cities, MN, USA
Thesis (2 papers): (1) SWHT: Simultaneous Water and Heat Transfer; (2) Temporal imaging of mine-induced stress changes using seismic tomography; Advisor: Prof. Joseph Labuz

MS, Geosciences (Hydrogeology/Geophysics) **1986**
University of Wisconsin Milwaukee, WI, USA
Thesis: A numerical investigation of the amplitude of Rayleigh-wave ground motion

BS, Geosciences (Geology) **1983**
University of Wisconsin Milwaukee, WI, USA

Other

MBA (mini) **1996**
University of St. Thomas, USA Minneapolis, MN, USA

RESEARCH INTERESTS

My research activities focus on understanding the effects of natural and human pressures on earth systems. Toward that end, I use discovery science methods to arrive at transdisciplinary solutions for challenges in climate and land use, ecosystems, energy and minerals, natural hazards, seismology, tectonics, and water science. In particular, my discovery science approaches include numerical joint-inversion (novel constraints and solvers), artificial adaptive systems (evolutionary and machine-learning), and hybrid models (combination of the former two and geo/statistical models). In using these approaches, I rely on the design, collection, and integration of experimental laboratory and field data from multiple disciplines including climate, biogeochemistry, ecology, hydrology, geophysics, and remote sensing.

RESEARCH EXPERIENCE

Senior Scientist **2014 – present**
GNS Science, Hydrogeology Department **Lower Hutt, NZ**
I lead, coordinate and participate in transdisciplinary research and consulting team activities that characterize, monitor, and model the response of earth systems to natural and human pressures. My research involves development and application of computational models that incorporate numerical, machine-learning and evolutionary techniques for transdisciplinary solutions. My studies focus on hydrological interactions involving climate change, surface and groundwater, earthquakes, and sea-level rise; and ecological, geothermal and mineral-resource systems using borehole, ground, airborne, and remote hydrogeophysical measurements. In addition to project leadership, I mentor scientists and doctoral students. Some key research and international collaborations are listed below (see Research Achievements and Skills for details):

- Conditional uncertainty in rainfall-recharge estimates
- Development of evolutionary-gradient numerical inverse solver
- Development of genetic-artificial neural network joint-inverse solver
- Estimation and scaling of hydrostratigraphic units from hydrogeophysical data
- Estimation of water fluxes at earth-atmospheric boundary with remote sensing
- Evaluating role of large earthquakes on aquifer dynamics
- Hydrogeophysical modeling of heat and fluid flow in geothermal systems
- Improved crustal imaging with seismic-magnetotelluric data
- Imputation and clustering of sparse hydrogeophysical data
- Influence of climate, land-use, and land cover on flow, transport, and ecology
- Physical/biogeochemical interaction among groundwater, surface-water, and ecology
- Predicting aquatic species and metrics under climate change and urbanization
- Predicting groundwater recharge as function of stream flow and oxygen isotopes
- Real-time classifying of landscape soil and vegetation components using hyperspectral data
- Reduced order analysis of multi-scale geophysical and geoenvironmental systems
- Scaling and estimation of hydrogeophysical data and processes
- Sea-level rise effects on density dependent flow and coastal water supply
- Spatiotemporal downscaling of national climate station network
- Unconventional oil and gas prospecting with gravity, magnetics, and radiometrics
- Unconventional shale-gas prospecting with quantity, quality, maturation data
- Unsaturated-zone transport of water, gas, solutes in dual porous media
- International collaboration (active): Australia (Geoscience Australia), Brazil (Federal University of Natal; Empresa Brasileira de Pesquisa Agropecuária), China (Chinese Academy of Sciences; Sun Yat-sen University), Georgia (Tblisi State University), Italy (Semeion Institute; University of Florence), New Zealand (Regional councils, Ministry of Business, Innovation and Employment), Spain (Institute of Environmental Assessment and Water Research), USA (United States Geological Survey-Denver, University of Colorado-Denver).

Research Geophysicist, GS-1313-14/9 **2005 – 2014**
U.S. Geological Survey, Crustal Imaging and Minerals Teams **Denver, CO, USA**
I led, coordinated, and participated in international transdisciplinary research and consulting team activities that characterized, monitored, and modeled the response of earth systems to natural and human pressures. I designed studies, collected hydrogeophysical measurements (borehole, ground, airborne and remote); and developed and applied new modeling software (combined numerical, statistical, machine-learning and evolutionary techniques) for transdisciplinary solutions in climate and land use, ecosystems,

energy and minerals, natural hazards, seismology, tectonics, and water science. In addition to project leadership, I mentored visiting USGS scientists, doctoral candidates and post-doctoral fellows at universities in the USA and abroad. Some key research and international collaborations are listed below (see Research Achievements and Skills for details):

- Aquatic-mining ecosystem connectivity and response
- Biodegradation or organic compounds in porous media
- Climate-change effects and socio-economics of United States
- Climate-change effects on groundwater recharge
- Climate and hydrology in formation of acid-rock drainage
- Connectivity mapping among groundwater system variables
- Coupled watershed processes under climate change
- Detection and discrimination of unexploded ordnance
- Differentiating background and mine-related acidity and metals
- Downscaling and spatiotemporal modeling of climate data
- Dual permeability and reactive transport model development
- Economic feasibility of mining undiscovered mineral deposits
- Effect of climate-change impacts on coastal environments
- Efficacy of reactive barriers to mitigate mine-waste problems
- Flood-warning system for Haitian government
- Forecast change in ecological integrity for metropolitan Chicago, USA
- Forecasting post-fire debris and flood response in western USA
- Groundwater modeling of the Bishkek region, Kyrgyz republic
- Hillslope weathering and shallow ground-water quality
- Hydrogeologic properties from magnetic resonance data
- Hydrogeologic map of Mauritania, Africa
- Imaging and quantifying uncertainty in lithospheric boundaries
- Infiltration and drainage in arid intermountain valleys
- Joint prediction of well yield in northeastern Brazil
- Joint inversion of seismic and magnetotelluric data for crustal imaging
- Joint estimation of extreme rainfall in ungauged basins
- Landscape discrimination using remote sensing data and artificial adaptive systems
- Metal mine-waste speciation and toxicity effects on aquatic receptors
- Mineral-resource effects on aquatic ecosystems
- Multiphase fluid flow and transport
- Multivariate geostatistical modeling of spatially-limited data
- Post-fire debris-flow volumes and their uncertainty
- Reactive transport in geothermal systems
- Modeling hydrologic and geomorphic hazards across post-fire landscapes
- Modeling reactive chemistry in Aries River basin tailings
- Near real-time airborne electromagnetic 3D imaging of surficial aquifers
- Optimization of stochastic reservoir operations
- Persistence of El Niño-Southern Oscillation over 2,000 years
- Predicting coastal hydro-meteorological hazards
- Predicting background and mine-related acidity and metals
- Probable flooding in ungaged basins
- Quantifying streamflow uncertainty in ungaged basins
- Quantifying uncertainty in joint seismic crustal imaging

- Radar imaging of contaminant spill
- Reconstruction of global temperature change and solar activity
- Reconstructing conditional trends in climate change at regional and global scales
- Remote location of improvised explosive devices
- Sediment transport in mining-affected Aries River basin
- Scaling of ground-water recharge measurements
- Spatial continuity from spatially-limited data for numerical inverse problems
- Statistical reliability of geophysical instruments to unexploded ordnance
- Stresses on water-quality in existing and proposed mining watersheds
- Stochastic assessment of undiscovered mineral resources
- Tailings and waste dump inventory and risk prioritization for Romania
- Uncertainty in joint-inverse depth estimates of Moho
- Uncertainty in airborne estimates of gold mineralization
- Uncertainty in multi-component reactive groundwater systems
- Variably-saturated dual permeability gas, flow and transport modeling
- Vertical drainage and groundwater flow in arid intermountain valleys
- Water-quality response across hydrothermal alteration-mining gradient
- International collaboration: Brazil (University of Campinas; University of Brasilia; Empresa Brasileira de Pesquisa Agropecuária, Geological Survey of Brazil), Finland (University of Kuopio, Geological Survey of Finland), Georgia (Tblisi State University), Haiti (Geological Survey of Haiti), Italy (Semeion Institute), Kyrgystan (Research Institute of Irrigation, Hydrogeology and Water Economy), Mauritania (Ministre du Petrole, de L' Energie et des mines), Romania (Romanian National Agency for Mineral Resources), USA (Univ of Colorado-Denver).

Research Hydrologist, GS-1315-13 **2001-2004**
U.S. Geological Survey, Colorado Water Science Center **Denver, CO, USA**
I led, coordinated and participated on research team activities that characterized, monitored, and modeled the occurrence, distribution, and transport of water quality in surface and groundwater basins of Colorado. I designed studies, collected data, and developed and applied modeling techniques and software for predicting flow and transport in response to agricultural, wildfire, and reservoir stresses. I mentored the project chief and visiting USGS scientists. Some key research activities are listed below (see Research Achievements and Skills for details):

- Agricultural land-use study in South Platte River basin
- Calibration and predictive analysis of vadose zone models
- Enhanced remediation of toluene biodegradation in vadose zone
- Hydrologic risk assessment and flood protection for coastal basins
- Post-wildfire assistance to US Federal Emergency Management Agency
- Post-wildfire flood potential in Willow and Mitchell Creek watersheds
- Preferential flow and transport in the High Plains aquifer
- Probable effects of proposed reservoir on river quantity and quality
- Satellite resolution and effects on wildfire-induced flood models
- Water and solute transport in variably-saturated dual porous soils
- Stratified sample design for water quality studies
- Stochastic optimization of reservoir operations for water-quality benefits

Supervisory Hydrologist, GS-1315-13 **1997 – 2001**
U.S. Geological Survey, Illinois Water Science Center **Urbana, IL, USA**
I promoted and prioritized work; coordinated and prepared the scope of work and financial plans with annual budgets to ~$2.0M; determined project staffing needs and hired scientists with specialized experience; determined assignments, awards, and promotions; reviewed and ensured timely completion and quality of technical proposals, work plans, presentations, and reports; and evaluated employee performance. As a leader, I motivated scientific teams toward common goals. I guided and participated in project designs, data collection, analyses, and interpretation; promoted team workshops on scientific field data collection and modeling applications; identified, planned, promoted, and coordinated multi-state activities with cooperating companies, State and Federal agencies, National Synthesis Teams, and other related studies; devised and promoted new scientific approaches; and developed, participated and chaired reviews at science center, headquarter, and stakeholder meetings. As principal scientist, some of my key research areas are listed below:

- Upper Illinois River Basin Study, National Water Quality Assessment Program
- Urban land-use gradient study in the Upper Illinois River Basin
- Development and application of variably-saturated mass and energy transport model
- Source-water risk assessment in the Upper Illinois River Basin

Research Geophysicist, GS-1313-13 **1986 – 1996**
U.S. Bureau of Mines **Minneapolis, MN**
I promoted and prioritized work; coordinated and prepared the scope of work and financial plans with annual budgets to ~$1.0M; lead, coordinated, mentored and participated in international transdisciplinary research and consulting team activities that characterized, monitored, and modeled the response of mining-related environmental and health & safety concerns. I designed geophysical (surface, borehole, crosshole, tomographic), groundwater, and unsaturated zone studies, collected data, and developed and applied new modeling techniques and software. In addition to project leadership, I mentored visiting USGS scientists, doctoral students and post-doctoral fellows at universities in the US and abroad. Some research and international collaborations are listed below (see Research Achievements and Skills for details):

- Acid-mine drainage studies
- Cavity detection by geophysical
- Development of finite-element equations for coupled transport in variably-frozen soils
- Geotomographic applications to mineral deposits, in-situ leaching, mining hazards
- Geomechanical and geophysical technology for fractured rock
- Geophysical assessment of various mineral deposits
- Geophysical monitoring of injection/extraction of subsurface fluids
- Groundwater analytic element model software development/applications
- Hydromechanical flow and reactive transport in fracture rock
- Hydrothermal flow and transport in porous and fracture rock
- In-situ leach mining of tailings and fractured rock deposits
- Laboratory mechanical and acoustic (active/passive) testing of rocks
- Mine-structural integrity using geophysics (active/passive)
- Monitoring mining-induced stresses by seismic tomography
- Porous/fractured, saturated/unsaturated flow/transport methods/modeling
- Stochastic flow and transport in fractured rock
- Unsaturated mass and energy transport FEM model software development/application

- International collaboration: Australia (Western Mining Corporation); South Africa (University of Johannesburg), USA (US Dept of Army, and various mining companies)

Visiting scientist **2016**
Geoscience Australia, Groundwater Innovation Canberra, AU
Research focus: Planning discovery science for watershed applications

Visiting scientist **2012**
Empresa Brasileira de Pesquisa Agropecuária, Satellite Monitoring Campinas, BR
Research focus: Classifying soil and crop types from satellite hyperion data

Visiting Scientist **2010**
Scientific and Research Institute of Irrigation, Hydrogeology and Water Economy Bishkek, KG
Research focus: Modeling climate change on regional groundwater system

Visiting Scientist **2010**
USGS National Training Center Denver, CO, USA

Visiting scientist **2008**
Geological Survey of Brazil, Groundwater Section Fortaleza, BR
Research focus: Groundwater exploration in fractured crystalline terrain

UNIVERSITY EXPERIENCE

Associate Researcher - Honorary **2015-present**
Victoria University, School of Geography, Environment, and Earth Sciences Wellington, NZ

Associate Professor - Adjoint **2014-present**
University of Colorado, Department of Mathematical & Statistical Sciences Denver, CO, USA

Assistant Professor - Advisory board member **2010-present**
University of Colorado, Center for Computational and Mathematical Biology Denver, CO, USA

Lecturer – Adjunct **2009-2010**
University of Colorado, Department of Geography and Environmental Science Denver, CO, USA

Member of Graduate School **2006-2009**
Colorado School of Mines, Department of Geophysics Golden, CO, USA

Member of Graduate School **2004-2006**
University of Colorado, Department of Geography and Environmental Science Denver, CO, USA

Visiting Professor **2013**
University of Campinas, Center for Environmental Studies Campinas, BR

Visiting Professor **2013, 2008**
University of Brasilia, Geoscience institute Brasilia, BR

Visiting professor **2012**
University of Campinas, Center for Meteorological and Climate Research
Applied to Agriculture Campinas, BR

Visiting Professor **2008**
University of Campinas, Geosciences Institute Campinas, BR

Visiting Professor **2007**
University of Kuopio, Department of Environmental Sciences Kuopio, FN

Visiting Professor **2005**
Hohai University, Department of Water Resources - Global ranking #301 Nanjing, CN

Visiting Professor **2005**
Middle-East Peace Process, U.S. Department of State Budapest, HU

Visiting Professor **2003, 2004, 2005, 2006**
University of Central America, Dept. of Energy and Fluid Science San Salvador, ES

Visiting Professor **2003**
Colorado College, Dept. of Geology Colo Sprgs, CO, USA

Graduate Research Assistant **1995-1996**
University of Minnesota, U.S. Army High Performance Computing Center Minneapolis, MN, USA

Graduate Research Assistant **1984-1986**
University of Wisconsin, Geosciences Milwuakee, WI, USA

PUBLICATIONS

Refereed Articles (* ISI Web of Science)

1. Tindall, J., **Friedel, M.J.**, *in press*, Transport of Atrazine versus Bromide and δO^{18} in sand, Journal Water, Air, & Soil Pollution. [IF: 1.6] *

2. **Friedel, M.J.,** *in press*, Estimation and scaling of hydrostratigraphic units: application of unsupervised machine learning and multivariate statistical techniques to hydrogeophysical data, Hydrogeology Journal. [IF: 2.0] *

3. **Friedel, M.J.**, Esfahani, A., Iwashita, F., 2015, Toward real-time 3D mapping of surficial aquifers using a hybrid modeling approach, Hydrogeology Journal, 24(1), 211-229. [IF: 2.0] *

4. Esfahani, A.A., **Friedel, M.J.**, 2014, Forecasting conditional climate-change using a hybrid approach, Environmental Modelling & Software, 52, 83-97. [IF: 4.2] *

5. **Friedel, M.J.,** 2014, Data-driven modeling of background and mine-related acidity and metals in river basins, Environmental Pollution, 184, 530-539. [IF: 4.1] *

6. Moreira, L.P., **Friedel, M.J.**, França G.S., 2013, Uncertainty analysis in the joint inversion of receiver function and surface-wave dispersion, Paraná Basin, southeast Brazil. Bulletin of Seismological Society of America, 103 (3), 1981-1992. [IF: 1.9] *

7. **Friedel, M.J.**, Iwashtia, F., 2013, Hybrid modeling of spatial continuity for applications to environmental inverse problems, Environmental Modelling & Software, 43, 60-79 [IF: 4.2] *

8. **Friedel, M.J.,** 2012, Hybrid modeling to predict the economic feasibility of mining undiscovered porphyry copper deposits. Applied Soft Computing 13, 1016-1032. [IF: 2.9] *

9. **Friedel. M.J,** Asch, T., Oden, C. 2012, Hybrid analysis of multiaxis electromagnetic data for discrimination of munitions and explosives of concern. Geophysical Journal International, 190(2), 960–980. [IF: 2.4] *

10. **Friedel, M.J.**, 2012, Data-driven modeling of surface temperature anomaly and solar activity trends, Environmental Modelling & Software, 37, 217-232. [IF: 4.2] *

11. **Friedel, M.J.**, Souza, O.F., Iwashita, F., Yoshinaga, S. P, Silva, A M, 2012, Data-driven modeling for groundwater exploration in fractured crystalline terrain, Northeast Brazil, Hydrogeology Journal, 20(6), 1061-1080. [IF: 2.0] *

12. Iwashita, F., **Friedel, M.J.**, Rebeiro, G.F., Fraser, S.J., 2011, Intelligent estimation of hydrogeologic properties, Geoderma, 170, 1-10. [IF: 2.8] *

13. **Friedel, M.J.**, 2011, A data-driven approach for modeling post-fire debris-flow volumes and their uncertainty, Environmental Modelling & Software, 26(12), 1583-1598. [IF: 4.2]

14. **Friedel, M.J.**, 2011, Modeling hydrologic and geomorphologic responses across post-fire landscapes using a self-organizing map approach, Environmental Modeling and Software, 26(12), 1660-1674. [IF: 42] *

15. Iwashita, F., **Friedel, M.J.**, Souza-Filho, C.R., Fraser, S.J., 2011. Hillslope chemical weathering across Paraná, Brazil: A data mining-GIS hybrid approach. Geomorphology 132(3-4), 167-175. [IF: 2.8] *

16. **Friedel, M.J.**, 2008, Regularized Joint Inverse Estimation of extreme rainfall events in ungaged coastal basins of El Salvador, Natural Hazards Journal, 46(1), 15-34. [IF: 1.6] *

17. **Friedel, M.J.**, Smith, M.E., Erazo, A.M., and Litke, D., 2008, Probable flood predictions in ungaged coastal basins of El Salvador, Special issue: Methodologies in Hydrologic Modeling, Journal of Hydrologic Engineering, 13(5), 321-332. [IF: 2.0] *

18. Figueroa, M., Tindall, J.A., and **Friedel. M.J.**, 2007, Comparison of $^{18}O\delta$ composition of water extracted from suction lysimeters, centrifugation, and azeotropic distillation, Journal Water, Air, & Soil Pollution, 184(1-4), 63-75. [IF: 1.6] *

19. Liu, L., **Friedel, M.J.**, and Tindall, J.A., 2007, Biodegradation of PAHs and PCBs in soils and sludges, Journal of Water, Air, & Soil Pollution, 181(1-4), 281-296. [IF: 1.6] *

20. Liu, L., Tindall, J.A., **Friedel, M.J.**, and Zhang, W., 2007, Biodegradation of organic chemicals in soil/water microcosms system: model development, Journal of Water, Air, & Soil Pollution, 178(1-4), 131-143. [IF: 1.6] *

21. **Friedel, M.J.**, 2006, Predictive streamflow uncertainty in relation to calibration-constraint information, model complexity, and model bias, International Journal of River Basin Management, 4(1), 1-15. [IF: 0.8] *

22. Tindall, J.A., Weeks, E.P., **Friedel, M.J.**, and Nutt, A., 2005, Part 2: A field study of enhanced remediation of toluene in the vadose zone via a nitrate-rich nutrient solution, Journal of Water, Air, & Soil Pollution, 168(1-4), 359-389. [IF: 1.6] *

23. Tindall, J.A., **Friedel, M.J.**, Szmajter, R.J., and Cuffin, S.M., 2005, Part 1: Enhanced Bioremediation of Toluene in the Unsaturated Zone of A Shallow Unconfined Aquifer, Journal of Water, Air, & Soil Pollution, 168(1-4), 325-357. [IF: 1.6] *

24. Stearns, M., Tindall, J.A., Cronin, G., **Friedel, M.J.**, and Berquist E., 2005, Effects of Coal-Bed Methane Discharge Waters on the Vegetation and Soil Ecosystem in Powder River Basin, Wyoming, Journal of Water, Air, & Soil Pollution, 167(1-4), 33-57. [IF: 1.6] *

25. **Friedel, M.J.**, 2005, Coupled inverse modeling of vadose zone water, heat, and solute transport: calibration constraints, parameter nonuniqueness, and predictive uncertainty, Journal of Hydrology, 312(1-4), 148-175. [IF: 3.0] *

26. Scott, D.F., Williams, T.J., **Friedel, M.J.**, and Denton, D.K., 1999, Seismic tomography as a tool for measuring stress in mines, Mining Engineering, 51(1), 77-80. [IF: 1.0] *

27. Scott, D.F., Williams, T.J., **Friedel, M.J.**, and Denton, D.K., 1997, Relative stress conditions in an underground pillar, Homestake Mine, Lead, SD, International Journal of Rock Mechanics and Mining Sciences, 34(3), 653-654. [IF: 1.4] *

28. **Friedel, M.J.**, Jackson, M.J., and Olson, M.S., 1996, Tomographic imaging of coal pillar behavior: observations and implications. International Journal of Rock Mechanics and Mining Science, 33(1), 279-290. [IF: 2.0] *

29. **Friedel, M.J.**, Scott, D.F., and Williams, T.J., 1996, Temporal imaging of mine-induced stress changes using seismic tomography, Journal of Engineering Geology, 46, 131-141. [IF: 2.2] *

30. **Friedel, M.J.**, Scott, D.F., Jackson, M.J., Williams, T.J., 1996, 3-D tomographic imaging of anomalous conditions in a gold mine, Journal of Applied Geophysics, 36(1), 1-17. [IF: 1.4] *

31. **Friedel, M.J.**, Jackson, M.J., Scott, D.F., and Williams, T.J., 1995, 3-D tomographic imaging of anomalous conditions in a deep silver mine, Journal of Applied Geophysics, 34(1), 1-21. [IF: 1.4] *

32. **Friedel, M.J.**, 1993, Scale-Dependence in the hydrologic design of in situ copper leaching operations. Society for Mining, Metallurgy, and Exploration Transactions; 294, 1918-1926. [IF: 1.2]

33. Hanson, J.C., Tweeton, D.R., **Friedel, M.J.**, and Dahl, L., 1993, Fluid detection using electromagnetic geophysics. Geophysics: The Leading Edge. 12(9), 930-937. [IF: 1.6] *

34. **Friedel, M.J.**, and Schmidt, R.D., 1992, Effect of unsaturated conditions on the hydrology of in situ copper leaching, Mining Engineering, 2(11), 3-8. [IF: 1.1]

35. **Friedel, M.J.**, and Thill, R.E., 1991, U.S. Bureau of Mines Research on the Kasier Effect for determining stress in rock, Journal of Acoustic Emission, 10(1-2), S77-S89 [IF: 1.2]

Invited Book Chapters

36. **Friedel, M.J.**, 2011, Climate change effects on ecosystem services in the United States – issues of national and global security. In: Baba, A., Tayfur, G., Howard, K.W.F., Friedel, M.J., Chambel, A.,

2011, Climate Change and its Effect on Water Resources – Issues of National and Global Security, NATO Science for Peace and Security Science Series C. Environmental Security, vol. 3, Springer, Dordrecht, The Netherlands, 318 p.

37. **Friedel, M.J.**, 2006. Reliability in estimating urban groundwater recharge through the vadose zone: managing sustainable development in arid and semiarid regions. In: Tellam, J.H., Rivett, M.O., and Israfilov, R.G. (eds), Urban groundwater management and sustainability. NATO Science Series, IV. Earth and Environmental Sciences, Springer, Dordrecht, The Netherlands, vol. 74, 169-182.

38. **Friedel, M.J.**, 2006, Urbanization effects on ecological integrity in the Upper Illinois River Basin, USA. In: Baba, A., Howard, K.W.F., and Gunduz, O. (eds), 2006, Groundwater and Ecosystems, NATO Science Series, IV. Earth and Environmental Sciences – vol. 70, Springer, Dordrecht, The Netherlands, 71-92

39. Westman, E., **Friedel, M.J.**, Jackson, M.J., and Williams, E., 1995, Imaging coal structure stress distribution with seismic tomography. U.S. Bureau of Mines Technology Transfer Seminar: Mechanics and Mitigation of Violent Failure in Coal and Hard Rock Mines, of Coal Pillar Behavior, U.S. Bureau of Mines Special Publication 01-95, Coeur d' Alene, ID; Price, UT, Norton, VA; May, pp.101-119.

40. Scott, D.F., **Friedel, M.J.**, Jackson, M.J., and Williams, E., 1995, Use of Tomographic imaging as a tool to identify areas of high stress in remnant ore pillars in deep underground mines. U.S. Bureau of Mines Technology Transfer Seminar: Mechanics and Mitigation of Violent Failure in Coal and Hard Rock mines, of Coal Pillar Behavior, U.S. Bureau of Mines Special Publication, 01-95, Coeur d' Alene, ID; Price, UT, Norton, Va; May, pp. 323-335.

Refereed Reports

41. Daughney, C., Rissman, C., **Friedel, M.J.**, Morgenstern, U., Hodson, R., van Der R aaij, Rodway, E., Martindal, H., Pearson, L., Townsend, D., Kees., L., Moreau, M., Millar, R., Horton, T., 2015, Hydrochemistry of the Southland Region, GNS Science Report 2015/24, 214 pp.

42. **Friedel, M.J.,** Finn, C.A., and Horton, J.D., 2015, Hydrogeologic map of the Islamic Republic of Mauritania, Synthesis of hydrologic data, and chemical hydrologic map of the Islamic Republic of Mauritania: Phase V, deliverables 56, 57, and Added Value), chap. C *of* Taylor, C.D., ed., Second projet de renforcement institutionnel du secteur minier de la République Islamique de Mauritanie (PRISM-II): U.S. Geological Survey Open-File Report 2013–1280-C, 23 p., 2 pl., scale 1:1,000,000, http://dx.doi.org/10.3133/ofr20131280. [In English and French.]

43. Vicente, L.E., **Friedel, M.J.**, Iwashita, F., Koga-Vicente, A., 2013, Mapeamento de características de solos tropicais utilizando Self-Organizing Map aplicado à dados hiperespectrais, SBSR Brazilian Remote Sensing Symposium, April 2013, Foz do Iguaçu, PR, Brazil. [Proceedings]

44. Iwashita, F., **Friedel, M.J.**, Souza Filho, C.R., Fraser, S. J., 2011, Using self-organizing maps to analyze high-dimensional geochemistry data across Paraná, Brazil. In: Proceedings 15th Simpósio Brasileiro de Sensoriamento Remoto. Curitiba, Brazil, pp. 115-129.

45. **Friedel, M.J.**, 2008, Hydrologic model calibration strategy for the Islamic Republic of Mauritania, Africa, USGS Open File Report, 2008-1173, 13 pp.

=-

46. **Friedel, M.J.**, and Tindall, J.A., 2008, Reconnaissance study of water quality in the mining-affected Aries River basin, Romania, USGS Open File Report, 2008-1176, 36 pp.

47. **Friedel, M.J.**, and Linard, J.I., 2008, Initial sediment transport model of the mining-affected Aries River basin, Romania, USGS Open File Report, 2008-1171, 23 pp.

48. **Friedel, M.J.**, 2008, Environmental stratification and water-quality monitoring design, Mauritania, Africa, USGS Open File Report, 2008 -1137, 13 pp.

49. **Friedel, M.J.**, 2008, Inventory and review of existing PRISM hydrogeologic data for the Islamic Republic of Mauritania, Africa, USGS Open File Report, 2008-1138, 51 pp.

50. **Friedel, M.J.**, 2008, Hydrogeology of the Islamic Republic of Mauritania, Africa, USGS Open File Report, 2008-1136, 43 pp.

51. Elliot, J., Smith, M.E., **Friedel, M.J.**, and D. Litke. 2005, Post-fire hydrologic hazards study for the 2002 Hayman, Coal Seam, and Missionary Ridge wildfires, Colorado, U.S. Geological Survey, Science Investigations Report 2004-5300, 125 pp.

52. **Friedel, M.J.**, 2004, Simulated effects of the proposed Sulphur Gulch reservoir operations on Colorado River quantity and quality near Grand Junction, Colorado. U.S. Geological Survey Fact sheet, FS 2005-3031, 4 pp.

53. **Friedel, M.J.**, 2004, Stochastic modeling of the effects that Sulphur Gulch Reservoir may have on Colorado River quantity and salinity near Grand Junction, Colorado. U.S. Geological Survey, Science Investigation Report 2004-5253, 62 pp.

54. Arnold, T., **Friedel, M.J.,** and Warner, K.L., 2001, Hydrogeologic inventory of the upper Illinois River Basin – creating a large data base from well construction records. Illinois State Geological Survey Circular SP-1101, pp. 22-29

55. **Friedel, M.J.**, 2001, Simultaneous inverse estimation of coupled water, heat, and solute transport parameters with model validation and predictive analysis – applications to ground-water studies in arid and semi-arid regions of the U.S., Ph.D. Dissertation, University of Minnesota, Department of Water Resources Science, 253 pp. (Copyright 2001)

56. **Friedel, M.J.**, 2000, Documentation and verification of VST2D: a model for simulating transient, variably saturated, water-heat-solute Transport in heterogeneous, anisotropic, ground-water systems, U.S. Geological Survey, Water-Resources Investigations Report 00-4105, 125 pp.

57. Warner, Kelly L., Terrio, P., King, R., Groschen, G., Arnold, T., Morrow, W.S., **Friedel, M.J.**, and Harris, M.A., 2000, Potential drinking water concerns in ground and surface water in the Illinois River basin; U.S. Geological Survey perspective from the National Water Quality Assessment, Illinois water supplies; is the well running dry? Program and abstracts, pp.12-13

58. Arnold, T., and **Friedel, M.J.**, 1999, Effects of land use on recharge potential of surficial and shallow bedrock aquifers in the Upper Illinois River Basin, U.S. Geological Survey Water-Resources Investigations Report, 00-4027 18 pp.

59. **Friedel, M.J.**, 1998, Upper Illinois River Basin, National Water Quality Assessment study unit, U.S. Geological Survey Fact Sheet, FS-072-98, 4 pp.

60. Nieber, J.L., **Friedel, M.J.**, and Sharratt, B.S., 1997, Modeling equations for two-dimensional coupled heat, fluid, and solute transport in variably-saturated, variably-frozen soils, Cold Regions Research Laboratory Special Report 97-10. In: Proceedings International symposium on physics, chemistry and ecology of seasonally frozen soils, Fairbanks, Alaska, June 10-12, pp. 140-146.

61. **Friedel, M.J.**, Scott, D.F., and Williams, T.J., 1997, Investigation of a rock-burst site, Sunshine Mine, Kellogg, Idaho. In: Proceedings Of the 4th International Symposium on Rockbursts and Seismicity in Mines, Gibowicz and Lasocki (eds), Balkema, Krakow, Poland, August 11-14, pp. 311-314.

62. Scott, D.F, Williams, T.J., and **Friedel, M.J.**, 1996, Application of seismic tomography in underground mining. In: Proceedings 15th International Conference on Ground Control in Underground Mining, Golden, CO: Colorado School of Mines, Aug. 13-15, pp. 654-659.

63. Scott, D.F, Williams, T.J., and **Friedel, M.J.**, 1996, Application of seismic tomography to underground mining: part 1, Workshop: Annual International Meeting: Society of Exploration Geophysics Annual Meeting, Denver, CO, Nov. 15, pp. 2053-2056

64. Williams, T. J., Scott, D. F., and **Friedel, M.J.**, 1996, Application of seismic tomography to underground mining: Part 2, 66th Annual International Meeting: Society of Exploration Geophysics, Denver, CO, Nov. 1, pp. 2057-2059.

65. Jackson, M.J., **Friedel, M.J.**, Tweeton, D.R., Scott, D.F., and Williams, T.J., 1995, Imaging underground mine structures using seismic tomography. In: Proceedings Symposium on Application of Geophysics to Engineering and Environmental Problems, March, 1995, pp. 112-127.

66. Jackson, M.J., **Friedel, M.J.**, Tweeton, D.R., Scott, D.F., and Williams, T.J., 1995, Three-dimensional imaging of underground mine structures using geophysical tomography, with tests for resolution and robustness. In: Proceedings of 3rd Canadian Conference on Computer Applications in the Mineral Industry, Montreal, Quebec, Canada, October 22-25, pp. 23-32.

67. **Friedel, M.J.**, Scott, D.F., Jackson, M.J., Williams, T.J., and Killen, S.M., 1995, 3-D Seismic tomographic investigation of mechanical conditions in a deep US gold mine. In: Proceedings Mechanics of Jointed and Faulted Rock - 2, Vienna Austria, April 13-17, pp. 689-695.

68. **Friedel, M.J.**, 1995, SWHT: Simultaneous Water and Heat Transfer, U.S. Bureau of Mines, Open File Report 85-95, 28 pp.

69. **Friedel, M.J.**, 1995, Spatial variability of flow and transport properties at the Mineral Park mine-waste impoundment, U.S. Bureau of Mines Open File Report 84-95, 21 pp.

70. Moyle, P.R., Fay, J.M., and **Friedel, M.J.**, 1994, Integrated geophysical characterization of mine-waste sites in the Coeur d' Alene Mining District, ID. In: Proceedings Symposium on Application of Geophysics to Engineering and Environmental Problems, March 27-31, pp. 857-868.

71. **Friedel, M.J.**, Jackson, M.J., Williams, E., Olson, M.S., 1994, Tomographic imaging of coal pillar conditions: observations and implications. Society for Mining, Metallurgy, and Exploration Annual Meeting, February 14-17, Albuquerque, NM, Preprint 94-110, 17 pp.

72. **Friedel, M.J.**, and Wedepohl, E., 1994, Case studies of radio wave tomography at base metal and gold ore bodies in the USA and Southern Africa. Society of Mining Metallurgy, & Exploration Annual Meeting, Preprint 94-143, Albuquerque, NM, 1994, March 27-31, pp. 32-44.

73. Tweeton, D.R., Hanson, J.C., **Friedel, M.J.**, Dahl, L.J, Lee, D.O., Wayland, R.J., and Sternberg, B.K., 1994, A field test of electromagnetic geophysical techniques for locating simulated in situ mining lixiviant, U.S. Bureau of Mines Report of Investigation 9505, 35 pp.

74. Jackson, M., Wedepohl, E., **Friedel, M.J.**, and Hauser, K., 1993, Forward modeling of electromagnetic wave propagation in layered media: implications for cross-borehole radio-wave detection of voids in coal measure rocks. In: Proceedings 4th Tunnel Detection Symposium, Golden CO, September 20-24, pp. 399-412.

75. Nieber, J.L, **Friedel, M.J.**, and Munir, H.M., 1993, VARSAT2D: Finite-element analysis of variably saturated 2-dimensional flow, U.S. Bureau of Mines Information Circular 9373, 35 pp.

76. Hauser, K.L., and **Friedel, M.J.**, 1993, Geophysical techniques applied to cavity detection at the Wharf Mine, Lead, South Dakota. In: Proceedings 4th Tunnel Detection Symposium, Golden, CO., September 20-24, pp. 617-636.

77. **Friedel, M.J.**, and Jackson, M.J., 1993, Application of seismic tomography for assessing yield pillar stress conditions. In: Proceedings of 12th Conference on Ground Control in Mining, Lakeview Resort and Conference Center, Morgantown, WV, August 3-5, pp. 292-301.

78. **Friedel, M.J.**, Jessop, J.A., and Thill, R.E., 1992, Mining applications of seismic tomography. Annual International Meeting: Society of Exploration Geophysics Annual Meeting, November 10-14, pp. 58-62.

79. Thill, R.E., **Friedel, M.J.**, Jessop, J.A., and Jackson, M.J., 1992, Integrated geophysics and geotomography for ground control applications. In: Proceedings 4th Ground Control Symposium, Southern Illinois University, Mt.Vernon, IL, November 2-4, pp. 51-69.

80. Tweeton, D.R., Hanson, J.C., Friedel, M.J., and Dahl, L.J., 1992, Field tests of geophysical methods for monitoring the flow patterns of leach solution. In; Proceedings Engineering Foundation Conference, In Situ Recovery of Minerals II, October 25-30, Santa Barbara, CA, pp. 179-199.

81. Jessop, J.A., Borek, D.L., Jackson, M.J., Tweeton, D.R., and **Friedel, M.J.**, 1992, Evaluation of a stope leaching site using geotomography. In: Proceedings Engineering Foundation Conference, In Situ Minerals Recovery-II, Santa Barbara, CA, October 25-30, pp. 599-616.

82. Schmidt, R.D., Early, D., III, and M.J. **Friedel, M.J.**, 1992, Analysis and implications of dynamic transmissivity conditions during in situ copper leaching. In: Proceedings Engineering Foundation Conference, In Situ Recovery of Minerals II, Santa Barbara, October 25-30, pp. 259-286.

83. Jackson, M.J., Tweeton, D.R., and **Friedel, M.J.**, 1992, Approaches for optimizing the use of available information in crosshole seismic tomographic reconstruction. In: Proceedings GeoTech '92 Geocomp. Conference, Denver, CO, August 31-September 3, pp. 130-143.

84. Jessop, J.A., **Friedel, M.J.**, Tweeton, D.R., and Jackson, M.J., 1992. Fracture detection with seismic crosshole tomography for solution control in a stope. In: Proceedings Symposium on Application of Geophysics to Engineering and Environmental Problems, Oakbrook, IL, April 26-29, pp. 487-587.

85. **Friedel, M.J.**, Jones, P.M., and Schmidt, R.D., 1992, Geostatistical analysis of dynamic transmissivity during in situ copper leaching. In: Proceedings 23rd Int. Symp. App. Comp. Min. Ind., April 7-11, pp. 49-61.

86. Atkins, L.A.,.B. Dix, R.B., Ellenberger, J.L., **Friedel, M.J.,** and McLendon, J.T., 1992, Bureau of Mines Drilling Guidelines for Groundwater Protection. U.S. Bureau of Mines Open File Report, 15 pp.

87. **Friedel, M.J.**, Jessop, J.A., and Thill, R.E., 1991, Igneous rock mass fracture delineation using common offset radar reflection. Annual International Meeting, Society of Exploration Geophysics, November 10-14, pp. 504-506.

88. Hanson, J.C., Tweeton, D.R., **Friedel, M.J.**, and Dahl, L.J., 1991, A field test of electromagnetic methods for the detection of conductive plumes. Annual International Meeting: Society of Exploration Geophysics, November 10-14, pp. 569-572.

89. **Friedel, M.J.**, and Schmidt, R.D., 1991, Effect of an unsaturated setting on the hydrology of in situ copper leaching. Society for Mining, Metallurgy, and Exploration Annual Meeting, Preprint 91-161, Denver, CO, February 25-28, 11 pp.

90. Schmidt, R.D., and **Friedel, M.J.**, 1991, Application of computers for analysis of in situ leach mining hydrology. In: Proceedings Indo-U.S. Symposium on Computers in the Mining Industry, Dahnbad, India, November 11-13, pp. 121-135.

91. **Friedel, M.J.**, Jessop, J.A., and Thill, R.E., 1991, Delineation of fractures in igneous rock masses using common offset radar reflection. U.S. Bureau of Mines Report of Investigation 9424, 19 pp.

92. **Friedel, M.J.** and Thill, R.E., 1991, Rayleigh wave assessment of damage and integrity of mine structures. U.S. Bureau of Mines, Report of Investigation 9389, 13 pp.

93. **Friedel, M.J.**, 1991, Modeling in situ copper leaching in an unsaturated setting, U.S. Bureau of Mines, Report of Investigation 9386, 22 pp.

94. **Friedel, M.J**., and Roessler, K.S., 1991, Seismic signal analysis. Computer File, Mining Magazine, January, 1 p.

95. Thill, R.E., **Friedel, M.J**., and Hanson, J.C., 1990, Mining geophysics: a research perspective. In: Proceedings International Symposium on Borehole Geophysics for Petroleum, Hydrology, Mineral Engineering Applications, Tucson, AZ, February 1-3, 5 pp.

96. **Friedel, M.J.**, and Hanson, J.C., 1990, Assessment of ground penetrating radar for detecting hazardous abandoned mine openings and related features. In: Proceedings12th Annual National Abandoned Mine Land Conference, Breckenridge, CO, September 15, pp. 87-88.

97. **Friedel, M.J.,** and Hanson, J.C., 1990, An integrated geophysical approach to detection of abandoned mine openings. In: Proceedings 12th Annual National Abandoned Mine Land Conference, Breckenridge, CO, September 15, pp. 57-86.

98. Jessop, J.A., Thill, R.E., and **Friedel, M.J.**, 1990, Acoustic site characterization studies for in situ mining. Society for Mining, Metallurgy, and Exploration Annual Meeting, Preprint 90-184, Salt Lake City, UT, February 26-30, 11 pp.

99. Schmidt, R.D., **Friedel, M.J.**, and Behnke, K., 1990, Hydrologic considerations of underground in-place copper leaching. Society for Mining, Metallurgy, and Exploration Annual Meeting, Preprint 90-179, Salt Lake City, UT, February 26-March 1, 12 pp.

100. **Friedel, M.J.**, and Thill, R.E., 1990, U.S. Bureau of Mines research on the Kaiser Effect for determining stress in rock. In: Proceedings in International Joint Meeting, 1st Workshop on AE in Civil Engineering and 2nd Workshop on AE and Rock Fracture Mechanics, Kumamoto City, Japan, Oct. 29-31, pp. 54.

101. **Friedel, M.J.** and Thill, R.E., 1990, Stress determination in rock using the Kaiser Effect. U.S. Bureau of Mines, Report of Investigation 9286, 20 pp.

102. **Friedel, M.J.**, Jessop, J.A., Thill, R.E., and Veith, D.L., 1990, Electromagnetic investigation of abandoned mines in the Galena, KS Area. U.S. Bureau of Mines, Report of Investigation 9303, 20 pp.

103. **Friedel, M.J**., 1990, Bureau of Mines signal processing software - Concepts, expressions, and Tutorial. U.S. Bureau of Mines, Information Circular 9242, 40 pp.

104. **Friedel, M.J.,** 1986, A numerical investigation of the amplitude of ground motion radiated by a VIBROSEIS system vibrator. M.S. Thesis, University of Wisconsin-Milwaukee (QE 1000.F899), Department of GeoSciences, 214 pp.

Submitted for Publication

105. **Friedel, M.J.**, Vicente, E., Iwashita, F., Koga-Vicente, A., Franceschini, M.H.D, *in review*, An ensemble training scheme for unsupervised landscape classification of Hyperion satellite imagery with independent hyperspectral libraries, Applied Soft Computing.

106. Iwashita, F., **Friedel, M.J.**, Ferreira, F.J.F, *in review*, Characterizing spatially-limited hydrogeologic properties of the Serra-Geral transboundary aquifer: Estimating hydraulic parameters and potential connectivity with the Guarani aquifer, Environmental Monitoring and Assessment.

107. **Friedel, M.J.,** *in revison*, Hydrogeophysical Modeling of Geothermal Field Data. GNS Science Report, 10 pp.

108. **Friedel, M.J**., Moreira, L.P., *in revision*, Joint-inverse framework with PEST examples to improve subsurface modeling. GNS Science Report, 35 pp.

109. Tindall, J., **Friedel, M.J**., *in review*, Transport of Atrazine and Dicamba through silt and loam soils, Journal Water, Air, & Soil Pollution.

110. Tindall, J., **Friedel, M.J**., *in review*, Transport of Alachlor and bromide through silt and loam soils, Journal Water, Air, & Soil Pollution.

Reports Unpublished

111. Moreira, L.P., **Friedel, M.J.**, França G.S., 2013, Joint inversion of receiver function, surface wave dispersion, and magnetotelluric data for 2D crustal modeling.

112. **Friedel, M.J**., Moreira, L.P., 2013. Joint-inverse framework with PEST examples to improve subsurface modeling, Annual Report, Energy and Minerals Program, USGS. See also 2013 AGU abstract (S23A-2469).

113. Koga-Vicente, A, **Friedel, M.J.**, 2012, Modeling the effects of climate-variability on hydrometeorological risks along coastal São Paulo State, Brazil.

114. Litvak, R.G., **Friedel, M.J.**, 2012. Evaluation of measures to mitigate ground-water flooding in Bishkek region of Kyrgyzstan, Final Technical Report submitted to U.S. Civilian Research and Development Foundation (through Kyrgyz Hydrogeology and Water Economy Problems Laboratory) cooperative grants program (Award Number: KYG2-2936-BI-09), 33 pp.

115. **Friedel, M.J.**, 2011. Guidance document: Considerations for improving USGS stochastic mineral resource assessments, Annul Report, Energy and Minerals Program, USGS. See also 2011 AGU union session (Pres. 107).

116. Wnuk, C., **Friedel, M.J.**, R. Olson, D. Luppnow, 2007, Hazards risk mitigation and emergency preparedness project: technical assistance for mining waste facilities, Administrative report submitted to World Bank (through Futures Group), 753 pp

117. **Friedel, M.J.**, M.I.L. Ionescu, and M.J. Alder, 2007, Design of short and long term environmental monitoring system to evaluate spill response and effectiveness of tailing management and waste dump facilities, rehabilitation activities for maintaining surface and groundwater quality in the Aries River basin, Romania, Administrative Report submitted to World Bank (through Futures Group), 26 pp.

118. Smith, M., **Friedel, M.J.**, 2006, Soliette River flood hazard warning system – review as a function of rainfall quantity and rainfall intensity, Administrative Report submitted to United States Agency International Development, 19 pp

Reports in Preparation (research completed)

1. **Friedel, M.J.**, *in preparation*, Modeling mineral-resource effects on aquatic ecosystems using machine learning tools, Environmental Pollution.

2. **Friedel, M.J.**, *in preparation*, Intelligent scaling of ground-water recharge measurements, Ground Water Journal.

3. **Friedel, M.J.**, *in preparation*, Machine-learning paradigm for predicting climate-change effects on ground water recharge in the Midwestern United States, Ground Water Journal.

4. **Friedel, M.J.**, *draft*, Modeling warm-season persistence of the El Niño-Southern Oscillation phenomena over the past 2,000 years, Environmental Modelling & Software.

CONFERENCE PRESENTATIONS (presented unless otherwise noted)

1. **Friedel, M.J.,** 2016, Machine-learning based assistance for groundwater model calibration, Water Infrastructure & the Environment, 28 Nov – 2 Dec, 2016, Queenstown, New Zealand.

2. **Friedel, M.J**., 2016, Smart aquifer characterization and mapping with machine-learning and evolutionary techniques, Australian Earth Sciences Convention, Adelaide, Australia, 26-30 June. [INTERNATIONAL, KEYNOTE]

3. **Friedel, M.J.,** Cox, S., Williams, C. 2016, Holden, C. 2016, Evaluating the role of large earthquakes on aquifer dynamics using data fusion and knowledge discovery techniques, poster EGU016-3327, Session GM4.2/HS11.12/NH4.9 - Perturbation of Earth's surface systems by earthquakes, European Geosciences Union General Assembly, 17-22 April, 2016, Vienna, Austria.

4. **Friedel, M.J.,** Buscema, M. 2016, Aquatic ecosystem modeling under natural and anthropogenic stresses: using an artificial adaptive system to select optimal information for unbiased predictions with reduced uncertainty, poster EGU016-18106, Session NP4.5/ESSI1.5 – Big data and machine learning in geosciences, European Geosciences Union General Assembly, 17-22 April, 2016, Vienna, Austria.

5. **Friedel, M.J.,** 2016, An ensemble training scheme for machine-learning classification of Hyperion satellite imagery, poster EGU016-3329, Session BG4.9 - Mapping, Monitoring & Modelling of Vegetation Characteristics using Earth Observation, European Geosciences Union General Assembly, 17-22 April, 2016, Vienna, Austria.

6. **Friedel, M.J.,** 2015, Data fusion and knowledge extraction in hydrogeology (85836), Advances in hydrogeophysics posters, H13A-1489, American Geophysical Union, December 2015, San Francisco, CA.

7. Moriera, L.P, **Friedel, M.J.,** 2015, Hybrid geophysical inversion using genetic algorithm and gradient descendant methods (65813), Joint inversion methods and other interpretation strategies to integrate multi-disciplinary geophysical data, NS51A-1961, American Geophysical Union, December 2015, San Francisco, CA. (Presented by Moreira)

8. **Friedel, M.J.,** Rawlinson, Z, 2015, Data to knowledge: hydrogeophysical data fusion and estimation of aquifer properties in the Otago region, NZ, Hydrologic Society Meeting, December 3-5, 2015, Hamilton, NZ.

9. **Friedel, M.J.,** Rissmann, C., Daughney, C., Kees. L., 2015, Data to knowledge: identifying lithologic controls on GW/SW interaction using machine-learning and clustering techniques, Southland, NZ, Hydrologic Society Meeting, December 3-5, 2015, Hamilton, NZ.

10. **Friedel, M.J.,** Buscema, M., 2015, Artificial adaptive systems: data to knowledge in environmental science, Hydrologic Society Meeting, December 3-5, 2015, Hamilton, NZ.

11. Daughney, C., Rissmann, C., **Friedel, M.J**., Hodson, R., Morgenstern, U., Martindale, H., Rodway, W., Moreau, M., Kees, L., 2015, Hydrochemistry and water dating for characterisation of the Southland regional groundwater-surface water system. Hydrologic Society Meeting, December 3-5, 2015, Hamilton, NZ. (Presented by Daughney)

12. **Friedel, M.J.,** 2015, Using artificial adaptive systems to select input for ecosystem models, 2015 International conference on water resource and environment, July 25-28, Beijing, China.

13. Daughney, C., Rissmann, C., **Friedel, M.J**., Hodson, R., Morgenstern, U., Martindale, H., Rodway, W., Moreau, M., Kees, L., 2015, Hydrochemistry and water dating for characterisation of a regional groundwater-surface water system, Southland, New Zealand. 42nd IAH Congress - AQUA2015 - Hydrogeology: Back to the Future!, September 13-18, Roma, Italy. (Presented by Daughney)

14. **Friedel, M.J.,** Rawlinson, Z., Westerhoff, R., 2015, Intelligent mapping of an alluvial aquifer in the Otago region, New Zealand. poster EGU015-7433, Hydrogeophysics in subsurface hydrology (HS8.1.2), European Geosciences Union General Assembly, April, 2015, Vienna, Austria.

15. Vicente, L., Koga-Vicente, A., **Friedel, M.,** Victoria, D., Zullo, J., Gomes, D., Bayma-Silva., G., 2014, Land use and land cover change modeling using remote sensing and soft computing approach to assess sugarcane expansion impacts in tropical agriculture, B33E-0215, Mapping, Methods, Modeling,

and Monitoring: Agicultureas For Means of Global Change Assessment I Posters, American Geophysical Union, December 2014, San Francisco, CA. (Presented by Vicente)

16. Moreira, L., da-Cunha, L., **Friedel, M.**, 2104, Phosphate mineral deposits characterization using multivariate data and SOM-based processing, NG31A-3790, Neural Networks in Geophysics Posters, American Geophysical Union, December 2014, San Francisco, CA. (Presented by Moreira)

17. **Friedel, M.J.,** 2014, Modeling the effects of stressors on aquatic ecosystems, H11H-1251, Soil and Water: Delivering Valuable Ecosystem Services: Land Use Effects (Oral), 2014 Water Symposium, Integration: The Final Frontier, November 25, 2014, Blenheim, NZ.

18. Rawlinson, Z., **Friedel, M.J.,** Westerhoff, R., 2014, Mapping hydrogeological properties using helicopter electromagnetic (HEM) data In Otago, New Technologies (oral), 2014 Water Symposium, Integration: The Final Frontier, November 25, 2014, Blenheim, NZ. (Presented by Rawlinson)

19. **Friedel, M.J**., Esfahani, A., 2013, Influence of global volcanic processes on climate modulation in the southwestern US, 132-2 (205), Session 132, T24. Climate Change in the Interior Western United States from the Last Glacial Maximum to the Holocene (Posters), Geological Society of America, Joint Annual Meeting, Denver, Colorado, 27-30 Oct., 2013.

20. Vicente, L.E., **Friedel, M.J**., Iwashita, F., Koga-Vicente, A., 2013, Mapeamento de características de solos tropicais utilizando Self-Organizing Map aplicado à dados hiperespectrais, SBSR Brazilian Remote Sensing Symposium, April 2013, Foz do Iguaçu, PR, Brazil. [INTERNATIONAL] (Presented by Vicente)

21. **Friedel, M.J.,** 2013, Big data integration for regional hydrostratigraphic mapping, H11H-1251, Regional groundwater systems: advances in modeling, characterization, and applications I Posters, American Geophysical Union, December 2013, San Francisco, CA.

22. Moreira, L., **Friedel, M.J**., 2013, A hybrid data-integration scheme for improved crustal imaging, S23A-2469: Advances in seismic imaging: Towards integrated GeoModels on all scales – Shallow/Industry III Posters, American Geophysical Union, December 2013, San Francisco, CA.

23. **Friedel, M.J.**, 2014, Uncertainty and upscaling in rainfall-recharge modeling, NIWA Rainfall Recharge Workshop, Christchurch, NZ, August 26, 2014 (no abstract).

24. Lins, D.B, Zullo, J, **Friedel, M.J.,** 2013, Integrating vegetation index time series and meteorological data to understand the effect of the land use/land cover in the climatic seasonality of the Brazilian Cerrado, GC23B-0928, Global Environmental Change General Contributions II Posters, American Geophysical Union, December 2013, San Francisco, CA. (Presented by Lins)

25. Vicente, L.E.,Koga-Vicente, A., **Friedel, M.J**., Victoria, D., Gomes, D., Bayma, G., Zullo, J., 2013, Modeling tropical land-use and land-cover change related to sugarcane crops using remote sensing and soft computing techniques, B41A: Earth Observations for Global Agricultural Monitoring II Posters, American Geophysical Union, December 2013, San Francisco, CA. (Presented by Vicente)

26. Lins, D.B, Zullo, J, **Friedel, M.J**., 2013, Downscaling in climate models: an application for generation of alcohol production scenarios in Brazil, 345-3 145, Session 345, T79 Geochemical mapping at regional to continental scales (posters). Climate Change in the Interior Western United States from the Last Glacial Maximum to the Holocene, Geological Society of America, Joint Annual Meeting, Denver, Colorado, 27-30 Oct., 2013. (Presented by Lins)

27. Esfahani, A.A., **Friedel, M.J**., 2012, A fractal approach to the climate of southwestern United States, 29th IUGG Conference on Mathematical Geophysics, Poster Session 1, Informatics, Edinburgh, Scotland, 13 June [INTERNATIONAL] (Presented by Esfahani)

28. Moreira, L., **Friedel, M.J**., Franca, G., 2012, Joint inversion of receiver function, surface wave dispersion, and magnetotelluric data for 2D crustal modeling, Nonlinear geophysics session NG31B-1582, American Geophysical Union, December 2012, San Francisco, CA.

29. **Friedel, M.J.,** Esfahani, A., Abraham, J., 2012, Application of machine-learning to characterize an alluvial aquifer in western Nebraska, Hydrology session H13B-1327, American Geophysical Union, December 2012, San Francisco, CA

30. **Friedel, M.J**., Finn, C.A., Horton, J.D., 2012, Hydrogeology Ground-water flow, hydrostratigraphy, and potential water-resource targets in Mauritania, Africa, Hydrology session H13B-1327, American Geophysical Union, December 2012, San Francisco, CA

31. **Friedel, M.J**., 2012, Remote detection, classifying, and imaging using a hybrid paradigm, U.S. Department of Army, Engineer Research Development Center, 14 November, 2012, Arlington, Virginia. [INVITED] (no abstract)

32. **Friedel, M.J.,** Finn, C.A., Horton, J.D., 2012, Hydrogeology of Mauritania, Africa, Mauritania Minerals Project Workshop, Denver, CO, 13 June (no abstract)

33. **Friedel, M.J**., Esfahani, A., Schmidt, T.S., Smith, K., Mast, M.A., 2012, Connectivity mapping among variables in a mining-aquatic ecosystem, poster presentation (abstract #32), EPA Hardrock Mining Conference: Advancing Solutions for a New Legacy, Denver, CO, 3-5 Apr.

34. **Friedel, M.J**., Schmidt, T.S., Smith, K., Mast, M.A., 2012, Development of Aquatic-Mining Ecosystem Models Using Computational Intelligence, poster presentation (abstract #30), USEPA Hardrock Mining Conference: Advancing Solutions for a New Legacy, Denver, CO, 3-5 Apr.

35. Moreira, L.P., **Friedel, M.J.,** França G.S., 2012, Uncertainty in crustal imaging of the Paraná Basin. European Geosciences Union General Assembly, PSD5.5 - Active seismic investigations of the Earth's crust, poster XY487, 24 April.

36. Vicente, E., **Friedel, M.J**., Iwashita, F., 2011, Landscape discrimination in Brazil using hyperion data and a self-organizing map approach, Union session (U22b) oral presentation at 2011 Fall Meeting, AGU, San Francisco, Calif., 5-9 Dec. (Presented by Vicente)

37. Iwashita, F., **Friedel, M.J**., Fraser, S., 2011, Application of soft computing in hydrogeologic characterization of the Serra Geral-Guarani aquifer system, Parana state, Brazil, Union session (U22b) oral presentation at 2011 Fall Meeting, AGU, San Francisco, Calif., 5-9 Dec. (Presented by Iwashita)

38. **Friedel, M.J.,** 2011, Applications of soft computing in undiscovered global porphyry copper assessments, Union session (U22b) oral presentation at 2011 Fall Meeting, AGU, San Francisco, Calif., 5-9 Dec. [INVITED]

39. **Friedel, M.J.,** 2011, Computational intelligence in earth systems – applied soft and hybrid modeling, U.S. Department of Army, Engineer Research Development Center, 30 November, 2011, Vicksburg, Mississippi. [INVITED] (no abstract)

40. Asch T., **Friedel, M.J**., 2011, ALLTEM UXO discrimination results from the Aberdeen proving ground using a hybrid generalized neural analysis standard dipole inversion classification scheme, In: Advances in Classification Methods for Military Munitions Response, Symposium on the Application of Geophysics to Engineering and Environmental Problems, April 12, Charleston, South Carolina. (Presented by Asch)

41. Esfahani, A. **Friedel, M.J**., 2011, A fractional climate forecast for southern and southwestern United States, Land-climate interactions from models and observations: Implications from past to future climate, poster session CL2.15, European Geosciences Union General Assembly, 3-7 April, 2011, Vienna, Austria. [INTERNATIONAL]

42. Moreira, L.P., **Friedel, M.J**., 2011, Joint inversion of receiver function, surface wave dispersion, and magnetotelluric data for 2D crustal modeling, The Lithosphere-Asthenosphere Boundary (LAB) Dilemma, poster session GD2.4/SM4.1/TS10.2, European Geosciences Union General Assembly, 3-7 April, 2011, Vienna, Austria. [INTERNATIONAL]

43. Esfahani, A. **Friedel, M.J**., 2011, A fractional climate forecast for southern and southwestern United States, Land-climate interactions from models and observations: Implications from past to future climate, poster session CL2.15, European Geosciences Union General Assembly, 3-7 April, 2011, Vienna, Austria.

44. **Friedel, M.J**., Long, K., 2011, A data-driven economic filter for stochastic mineral assessments, Soft Computing Techniques in Geosciences, poster session NP1.3/ESSI21, European Geosciences Union General Assembly, 3-7 April, Vienna, Austria. [INTERNATIONAL]

45. **Friedel, M.J**., 2011, El Niño-Southern Oscillation (ENSO) phenomenon – event reconstruction and analysis over the past 2000 years, ENSO – Dynamics, predictability, poster session NP2.1, European Geosciences Union General Assembly, 3-7 April, Vienna, Austria. [INTERNATIONAL]

46. Iwashita, F., F., **Friedel, M.J**., Souza Filho, C.R., Fraser, S. J., 2011, Using self-organizing maps to analyze high-dimensional geochemistry data across Paraná, Brazil. In: Proceedings 15th Simpósio Brasileiro de Sensoriamento Remoto. Curitiba, Brazil. [INTERNATIONAL] (Presented by Iwashita)

47. **Friedel, M.J**., 2010, Post-fire debris flow prediction using a two-step hybrid approach, U.S. Geological Survey, 3rd Modeling Conference, Denver Colorado, June, 2010.

48. **Friedel, M.J**., 2010, Intelligent post-fire hydrologic and geomorphic landscape modeling, U.S. Geological Survey, 3rd Modeling Conference, Denver, Colorado, June, 2010.

49. **Friedel, M.J**., 2010, Intelligent exploration for shallow groundwater in fractured rock systems, U.S. Geological Survey, 3rd Modeling Conference, Denver, Colorado, June, 2010.

50. **Friedel, M.J**., 2010, Forecasting climate change effects on ground water recharge using an unsupervised artificial neural network, U.S. Geological Survey, 3rd Modeling Conference, Denver, Colorado, June, 2010.

51. Brown, P. and **Friedel, M.J**. 2010, Overview of new Monte Carlo software for quantitative mineral resource estimation, U.S. Geological Survey, 3rd Modeling Conference, Denver, Colorado, June, 2010. (Presented by Brown)

52. Brown, P. and **Friedel, M.J**., 2010, Test results comparing the new US Geological Survey Monte Carlo quantitative resource estimation simulation software application to MARK3, U.S. Geological Survey, 3rd Modeling Conference, Denver, Colorado, June, 2010. (Presented by Brown)

53. Iwashita, F., Silvana A., Vieira Monteiro, A.M., **Friedel, M.J**., 2010, Evaluating the effects of positioning errors on the accuracy of species distribution models using synthetic data, U.S. Geological Survey, 3rd Modeling Conference, Denver, Colorado, June, 2010. (Presented by Iwashita)

54. Iwashita, F., **Friedel, M.J**., Carlos de Souza-Filho, 2010, Surveying soil chemical weathering in Parana state/Brazil: A data mining-GIS hybrid approach, U.S. Geological Survey, 3rd Modeling Conference, Denver, Colorado, June, 2010. (Presented by Iwashita)

55. Manning, A., **Friedel, M.J.,** Verplanck, P.L., Todd, A.S., 2010, Applying numerical modeling to evaluate the significance of climate and hydrology in the formation of natural acid-rock drainage in mineralized watersheds. Session 74: Integrated approaches to modeling geochemical, hydrological, and ecological processes in watersheds, Geological Survey of America, Joint Annual Meeting, Denver, Colorado, 31 October - 3 November, 2010. (Presented by Manning)

56. **Friedel, M.J**., 2010, Nonlinear modeling of coupled watershed processes using a data-driven approach, Session 74: Integrated approaches to modeling geochemical, hydrological, and ecological processes in watersheds, Geological Survey of America, Joint Annual Meeting, Denver, Colorado, 31 Oct.- 3 Nov, 2010.

57. Koga-Vicente, A., **Friedel, M.J**., 2010, Comparison of empirical and data driven hydrometeorological hazard models on coastal cities of São Paulo, poster NH51A-1220 presented at 2010 Fall Meeting, AGU, San Francisco, Calif., 13-17 Dec. (Presented by Koga-Vicente)

58. **Friedel, M.J**., 2010, Hindcasting 2000 years of Pacific sea and land surface temperature changes, poster H21G-1125 presented at 2010 Fall Meeting, AGU, San Francisco, Calif., 13-17 Dec.

59. Esfahani, A.A., **Friedel, M.J**., 2010, The fractal nature of climate change - 2000 years in retrospect, H21G-1126 presented at 2010 Fall Meeting, AGU, San Francisco, Calif., 13-17 Dec.

60. Iwashita, F., **Friedel, M.J**., Ribeiro, G.F., Fraser, S.J., de Souza-Filho, C.R., 2010, Using self-organizing maps to predict soil texture and hydraulic conductivity in the Poços de Caldas, Modelagem numérica e experimental de processos geológicos, Grande Área: MÉTODOS E TÉCNICAS EM GEOLOGIA, 45º Congresso Brasileiro de Geologia, Belem, Brazil, October 26-31. [INVITED, INTERNATIONAL] (Presented by Iwashita)

61. Moreira, L.P., França G.S., **Friedel, M.J**., 2010, Joint inversion of receiver function and surface waves using a regularized Gauss-Marquardt-Levenberg nonlinear method, EOS Trans. AGU, 91(26), Jt. Assem. Suppl., Abstract, S21A-O4: 8–13 August, Foz do Iguaçu - PR, 85862–210, Brazil. [INTERNATIONAL] (Presented by Moreira)

62. **Friedel, M.J**., 2010, Climate change effects on ecosystem services in the United States – issues of national and global security, NATO Advanced Study Workshop – Climate change Effect on Water Supplies – Issues of National and Global Security, Izmir, Turkey, Sept.1-5, 2010. [INTERNATIONAL, KEYNOTE]

63. Johnson, R.H., Manning, A.H., and **Friedel, M.J**., 2009, Evaluating the utility of watershed-scale numerical models in the U.S. Geological Survey's mineral, environmental assessment project, Toward

More Effective Use of Ground Water Modeling II: Improved Conceptual Models and Data Integration 2009 Ground Water Summit: The Science and Engineering Conference, April 21, 2009. (Presented by Johnson)

64. **Friedel, M.J.,** 2008, Overview of USGS groundwater research activities, INMET, Brasilia, Brazil – Invitation to speak about USGS and personal research [INVITED] (no abstract)

65. **Friedel, M.J.**, 2008, Methods for predicting wildfire-induced debris flows, Integrated Wildfire, presentation to USGS Central Region management, Snow Mountain Ranch, Tabernash, CO, Sept. 11, 2008. [INVITED] (no abstract)

66. **Friedel, M.J.,** 2008. Hazards and risks – flooding, 2nd USGS Modeling conference, National Hazards Panel, Perdido Beach, Alabama, February, 2008. [INVITED, KEYNOTE]

67. **Friedel, M.J**., 2008, Application of stochastic modeling to forecast likely urbanization effects on ecological integrity in the Upper Illinois River Basin, USA, Extended abstract, United States Geological Survey, 2nd Modeling Conference, Gulf Shores, Alabama, February, 10-15, 2008

68. **Friedel, M.J**., 2008, Joint inverse modeling to estimate extreme rainfall events and their uncertainty in ungauged coastal basins, El Salvador, Central America, Extended abstract, United States Geological Survey, 2nd Modeling Conference, Gulf Shores, Alabama, February, 10-15, 2008

69. **Friedel, M.J**., 2008, Joint inverse modeling to estimate flood-flow depths and their uncertainty in ungauged coastal basins, El Salvador, Central America, Extended abstract, United States Geological Survey, 2nd Modeling Conference, Gulf Shores, Alabama, February, 10-15, 2008

70. **Friedel, M.J**., Souza, O.F., Yoshinaga, S. P, Silva, A M, 2008, Application of a joint inversion strategy to improve electromagnetic imaging of hydrogeologic structures in Northeastern Brazil, EOS Trans. AGU, 89(53), Fall Meet. Suppl., Abstract, NS31A-1224.

71. **Friedel, M.J**., 2008, Quantifying ground-water recharge using a coupled water-heat-solute transport model: optimal nonlinear parameter estimation, nonuniqueness, and predictive uncertainty, Trans. AGU fall meeting, San Francisco, CA, Dec 10, 2008.

72. Johnson, R.H., and **Friedel, M.J**., 2008, Factoring uncertainty into restoration modeling of in-situ leach uranium mines, 330-8, Hydrogeology III - Uranium, Metals, and Other Contaminants in Groundwater, Geological Survey of America, 2008 Joint Annual Meeting, 5-9 Oct. 2008. (Presented by Johnson)

73. **Friedel, M.J**., 2008, Numerical modeling strategies in resource assessments – past, present, and future. SP 41. Modelagem numérica e experimental de processos geológicos, Grande Área: MÉTODOS E TÉCNICAS EM GEOLOGIA**,** 44º Congresso Brasileiro de Geologia, Curitiba, Brazil, October 26-31. [INTERNATIONAL, KEYNOTE]
74. Tindall, J.A., Figueroa-Johnson, M., and **Friedel, M.J**., 2007, Comparison of soil-water sampling techniques, Trans. AGU, 83(42), Fall Meet. Suppl., H53F-1489. (Presented by Tindall)

75. **Friedel, M.J**., 2007, Assessment and management of mining-related environmental risks with applications, University of Kuopio, Kuopio, Finland [INVITED, INTERNATIONAL]

76. **Friedel, M.J.,** 2007, Overview of hazards risk mitigation and emergency preparedness project, Bucharest, Romania, presentation to World Bank Experts, stakeholders, and concerned citizens, 2007. [INVITED, INTERNATIONAL]

77. **Friedel, M.J**., 2006, Overview of hazards risk mitigation and emergency preparedness project, Bucharest, Romania, presentation to World Bank Experts, stakeholders, and concerned citizens, January, 2006. [INVITED, INTERNATIONAL] (no abstract)

78. **Friedel, M.J**., 2005, Combined groundwater-geophysical inverse modeling to reduce predictive uncertainty, presentation as part of Groundwater Resources Program research initiative in Linking Geologic Models to MODFLOW, DFC, Bldg 53, Central Region conference room, F1216, Lakewood, CO, presentation to regional groundwater specialist (A. Burns) and invited scientists, June 16, 2005. [INVITED (no abstract)

79. Figueroa, M., Tindall, J.A., and **Friedel, M.J**., 2006, Comparison of $d^{18}O$ composition of water extracted from suction lysimeters, centrifugation, and azeotropic distillation, Trans. AGU, 83(42), Fall Meet. Suppl., H13-6703 (Presented by Figueroa)

80. Little, J., Tindall, J.A., and **Friedel, M.J**, 2005, Scaling relations between laboratory and field scale hysteretic measurements for a coarse sandy loam soil, Trans. AGU, 83(42), Fall Meet. Suppl., H13-6703. (Presented by Little)

81. **Friedel, M.J**., 2005, Effects of Coal-bed methane discharge waters on vegetation and soil ecosystem in Powder River Basin, Wyoming, USA, International Symposium on Methodology in Hydrology, Nanjing, China, Oct. 30 - Nov. 2, 2005. [INTERNATIONAL, KEYNOTE]

82. **Friedel, M.J**., 2005, Simultaneous estimation of recurrent rainfall amounts in ungaged coastal basins of El Salvador, International Symposium on Methodology in Hydrology, Nanjing, China, Oct. 30 - Nov. 2, 2005. [INTERNATIONAL, KEYNOTE]

83. **Friedel, M.J**., 2005, Probable flooding in ungaged coastal basins of El Salvador, International Symposium on Methodology in Hydrology, Nanjing, China, Oct. 30 -Nov. 2, 2005. [INTERNATIONAL, KEYNOTE]

84. **Friedel, M.J**., 2005, Urbanization effects on ecological integrity in the Upper Illinois River Basin, USA, NATO Advanced Study Workshop - Groundwater and Ecosystems, Canakkale, Turkey, Sept. 5-7, 2005. [INTERNATIONAL, KEYNOTE]

85. Little, J., Tindall, J.A., and **Friedel, M.J**., 2004, Correlated moisture content, pressure and temperature data for development of hysteretic moisture retention curves, Trans. AGU, 83(42), Fall Meet. Suppl., H33B-0464. (Presented by Little)

86. **Friedel, M.J**., 2004, Reliability in urban ground-water recharge estimates through the vadose zone: managing sustainable development in arid and semiarid regions, NATO Advanced Study Institute - Management and Sustainable Development of Urban Groundwater Systems, Baku, Azerbiajan, Aug. 10-20, 2004. [INTERNATIONAL, KEYNOTE]

87. **Friedel, M.J**., 2003, Potential post-fire debris flow hazards associated with Wulfsohn and Gelenwood alluvial fans, Glenwood Springs, Colorado, presentation to Mayor and city council, May 28, 2003. [INVITED] (no abstract)

88. **Friedel, M.J**., 2003, Predicting maximum likely debris flows: from pre-fire streamflow measurements to post-fire hazard mapping, presentation at Colorado Stream Gauging Symposium, 2003, Breckenridge, CO, May 8, 2003. [INVITED]

89. **Friedel, M.J**., 2002, Application of genetic algorithms and programming to water resource problems, oral and cyber presentation to USGS earth scientists, USGS National Training Center, Lakewood, CO, December 4, 2002. (no abstract)

90. **Friedel, M.J.,** 2002, Stochastic modeling of quantity and quality of Colorado River streamflow following development and operation of Sulphur Gulch reservoir, presentation to Denver Water and Northern Colorado Water Conservancy District management and engineers, and attorneys of Trout-Whitman, Loveland, CO, November 22, 2002. [INVITED] (no abstract)

91. **Friedel, M.J**., 2002, Application of stochastic simulation to assess the effects of development and operation of Sulphur Gulch reservoir on changes in Colorado Water Quality, presentation to Denver Water and Northern Colorado Water Conservancy District management and engineers, Denver Water, Denver, CO, August 9, 2002. [INVITED] (no abstract)

92. **Friedel, M.J**., 2002, Drought effects on water quantity and quality. U.S. Geological Survey drought workshop, Pueblo, CO, July, 2002. [INVITED]

93. **Friedel, M.J**., 2002, Drought effects on water quantity and quality. U.S. Geological Survey drought workshop, Greeley, CO, July, 2002. [INVITED]

94. **Friedel, M.J**., 2002, Transport model parameter nonuniqueness and its effect on recharge prediction in a coupled variably saturated ground-water system. U.S. Geological Survey artificial recharge workshop, Sacramento, CA, April, 2002.

95. **Friedel, M.J**., 2002, Coupled ground-water model calibration and predictive analysis - space age technology or science fiction? U.S. Geological Survey, Recharge Estimation Workshop, Lakewood, CO, February 26, 2002. [INVITED]

96. **Friedel, M.J**., 2002, Salinity issues in Western United States. Proceedings Western drought effects on water quantity and quality. American Institute of Hydrology, Minneapolis, MN, August 9, 2002. [INVITED]

97. **Friedel, M.J**., 2002, Quantifying ground-water recharge using a coupled water-heat-solute transport model: optimal nonlinear parameter estimation, nonuniqueness, and predictive uncertainty, Trans. AGU fall meeting, San Francisco, CA, Dec 10, 2002.

98. **Friedel, M.J**., 2002, Quantifying ground-water recharge using a coupled water-heat-solute transport model: nonlinear parameter estimation, nonuniqueness, and predictive uncertainty, Trans. AGU, 83(42), Fall Meet. Suppl., H21D-0860, 2002.

99. **Friedel, M.J**., 2001, Developed and presented seminar on Model calibration and simulation of urbanization and its effects on ecological integrity. U.S. Geological Survey, Colorado-District, Denver, CO, Jan. 2001. [INVITED] (no abstract)

100. **Friedel, M.J.,** 2001, Developing an Urbanization TMDL ... good, bad, and the ugly. Upper Illinois River Basin - National Water Quality Assessment liaison meeting, Chicago, IL, April 20, 2001. (no abstract)

101. **Friedel, M.J.,** 2001, Overview of VST2D model applications and future extensions to regional ground-water specialists and ground-water resources program management, Lakewood, CO, Oct. 9, 2001. [INVITED] (no abstract)

102. Arnold, T., **Friedel, M.J**., and Warner, K.L., 2001, Hydrogeologic inventory of the upper Illinois River Basin – creating a large data base from well construction records. Geological Society of America April 22, 2001 in Bloomington, Illinois. (Presented by Arnold)

103. **Friedel, M.J**., 2001, Salinity overview of water resources in the South Platte River Basin, A Colorado Salinity/Selenium Symposium and Workshop, Soil Water Conservation Society, Colorado Springs, CO, October 4, 2001. [INVITED] (no abstract)

104. **Friedel, M.,** 1999, VST2D – Variably saturated water-heat-solute transport model. U.S. Geological Survey - Unsaturated Zone Interest Group, Menlo Park, CA, Jan. 13, 1999. [INVITED] (no abstract)

105. **Friedel, M.J.,** 1999, Ground-water risk assessment – Cyprus mine tailings impoundment. U.S. Geological Survey - Unsaturated Zone Interest Group, Menlo Park, CA, Jan. 13, 1999. [INVITED]

106. **Friedel, M.J**., 1998, Developed and presented seminar on land use gradient study: predicting the effects of urbanization on water quality. U.S. Geological Survey, National Water Quality Assessment Leadership Team, Reston, VA, Dec. 1998. [INVITED] (no abstract)

107. **Friedel, M.J**., 1998, Probabilistic assessment of source drinking water in the Upper Illinois River Basin. U.S. Geological Survey, National Water Quality Assessment Leadership Team, Reston, VA, Dec. 1998. [INVITED] (no abstract)

108. Nieber, J.L., **Friedel, M.J.,** and Sharratt, B.S., 1997, Modeling equations for two-dimensional coupled heat, fluid, and solute transport in variably-saturated, variably-frozen soils, CRREL Special Report 97-10: Proceedings International symposium on physics, chemistry and ecology of seasonally frozen soils, Fairbanks, Alaska, June 10-12, pp. 140-146. [INVITED]

109. Scott, D.F, Williams, T.J., and **Friedel, M.J.,** 1996, Application of seismic tomography in underground mining, Proceedings 15th International Conference on Ground Control in Underground Mining, Golden, CO, Aug. 13-15. [INVITED]

110. Williams, T. J., Scott, D. F., and **Friedel, M.J**., 1996, Application of seismic tomography to underground mining: Part 2, 66th Annual International Meeting: Society of Exploration Geophysics, Denver, CO, Nov. 15. pp. 2057-2059. (Presented by Williams)

111. Scott, D. F., Williams, T.J., and **Friedel, M.J.,** 1996, Application of seismic tomography to underground mining: Part 1, 66th Annual International Meeting: Society of Exploration Geophysics, Denver, CO, Nov. 15, pp. 2053-2056. (Presented by Scott)

112. Scott, D.F., **Friedel, M.J.**, Jackson, M.J., and Williams, E., 1995, Use of tomographic imaging as a tool to identify areas of high stress in remnant ore pillars in deep underground mines. U.S. Bureau of Mines Technology Transfer Seminar: Mechanics and Mitigation of Violent Failure in Coal and Hard Rock mines, of Coal Pillar Behavior, U.S. Bureau of Mines Special Publication, 01-95, Coeur d' Alene, ID; Price, UT, Norton, Va; May, pp. 323-335. [INVITED]

113. Westman, E., **Friedel, M.J.**, Jackson, M.J., and Williams, E., 1995, Imaging coal structure stress distribution with seismic tomography. U.S. Bureau of Mines Technology Transfer Seminar: Mechanics and Mitigation of Violent Failure in Coal and Hard Rock Mines, of Coal Pillar Behavior, U.S. Bureau of Mines Special Publication 01-95, Coeur d' Alene, ID; Price, UT, Norton, VA; May, pp.101-119. [INVITED]

114. Jackson, M.J., **Friedel, M.J.**, Tweeton, D.R., Scott, D.F., and Williams, T.J., 1995, Imaging underground mine structures using seismic tomography. Proceedings Symposium on Application of Geophysics to Engineering and Environmental Problems, March, 1995, pp. 112-127. (Presented by Jackson)

115. **Friedel, M.J.**, Scott, D.F., Jackson, M.J., Williams, T.J., and Killen, S.M., 1995, 3-D seismic tomographic investigation of mechanical conditions in a deep US gold mine, Proceedings Mech. Jointed and Faulted Rock-2, Vienna Austria, April 13-17, pp. 689-695. [INVITED, INTERNATIONAL]

116. Jackson, M.J., **Friedel, M.J.**, Tweeton, D.R., Scott, D.F., and Williams, T.J., 1995, Three-dimensional imaging of underground mine structures using geophysical tomography with tests for resolution and robustness. Proceedings CAMI '95: 3rd Canadian Conference on Computer Applications in the Mineral Industry, Montreal, Quebec, Canada, October 22-25. [INVITED]

117. Moyle, P.R., Fay, J.M., and **Friedel, M.J.**, 1994, Integrated geophysical characterization of mine-waste sites in the Coeur d' Alene Mining District, ID. Proceedings Symposium on Application of Geophysics to Engineering and Environmental Problems, March 27-31, pp. 857-868. (Presented by Moyle)

118. **Friedel, M.J.**, and Wedepohl, E., 1994, Case studies of radio wave tomography at base metal and gold ore bodies in the USA and Southern Africa. Society of Mining Metallurgy, & Exploration, Albuquerque, NM, 1994, March 27-31, pp. 32-44. [PRESENTED]

119. **Friedel, M.J.**, 1994, Integrated geophysical technology for void detection and geological/hydrological characterization. U.S. Bureau of Mines - Abandoned Mine Land Geophysical Workshop, Minneapolis, MN, March 24, 1994.

120. **Friedel, M.J.,** 1994, 3D tomographic imaging of anomalous conditions in a deep mine. Paper presented at Symposium on Application of Geophysics to Engineering and Environmental Problems, Boston, MA, March, 20-25, 1994, pp. 92-107.

121. **Friedel, M.J**., Jackson, M.J., Williams, E., Olson, M.S., 1994, Tomographic imaging of coal pillar conditions: observations and implications. Society of Mining Metallurgy, & Exploration Annual Meeting, February 14-17, Albuquerque, NM, Preprint 94-110, 17p.

122. **Friedel, M.J.,** and J. Jackson, M.J., 1993, Application of seismic tomography for assessing yield pillar stress conditions. Paper presented at Twelfth Conference on Ground Control in Mining, Lakeview Resort and Conference Center, Morgantown, WV, August 3-5, 1993, pp. 292-301. [INVITED]

123. Hauser, K.L., and **Friedel, M.J.,** 1993, Geophysical techniques applied to cavity detection at the Wharf Mine, Lead, South Dakota. Proceedings 4th Tunnel Detection Symposium, Golden, CO., pp. 617-636. (Presented by Hauser)

124. Jackson, M., Wedepohl, E., **Friedel, M.J**., and Hauser, K., 1993, Forward modeling of electromagnetic wave propagation in layered media: implications for cross-borehole radio-wave detection of voids in coal measure rocks. Proceedings 4th Tunnel Detection Symposium, Golden CO, pp. 399-412. (Presented by Jackson)

125. **Friedel, M.J**., Jessop, J.A., and Thill, R.E., 1992, Mining applications of seismic tomography. Proceedings 62nd Annual International Meeting: Society of Exploration Geophysics, New Orleans, LA, November 10-14, pp. 58-62.

126. Thill, R.E., **Friedel, M.J.**, Jessop, J.A., and Jackson, M.J., 1992, Integrated geophysics and geotomography for ground control applications. Proceedings 4th Ground Control Symposium, Southern Illinois University, Mt.Vernon, IL, November 2-4, pp. 51-69. (Presented by Thill)

127. Jessop, J.A., Borek, D.L., Jackson, M.J., Tweeton, D.R., and **Friedel, M.J.**, 1992, Evaluation of a stope leaching site using geotomography. Proceedings Engineering Foundation Conference, In Situ Minerals Recovery-II , Santa Barbara, CA, October 25-30, pp. 599-616. (Presented by Jessop)

128. Schmidt, R.D., Early, D., III, and **Friedel, M.J.**, 1992, Analysis and implications of dynamic transmissivity conditions during in situ copper leaching. Proceedings Engineering Foundation Conference, In Situ Recovery of Minerals II, Santa Barbara, October 25-30, pp. 259-286. (Presented by Schmidt)

129. Tweeton, D.R., Hanson, J.C., **Friedel, M.J.**, and Dahl, L.J., 1992, Field tests of geophysical methods for monitoring the flow patterns of leach solution. Proceedings Engineering Foundation Conference, In Situ Recovery of Minerals II, October 25-30, Santa Barbara, CA, pp. 179-199. (Presented by Tweeton)

130. Jackson, M.J., Tweeton, D.R., and **Friedel, M.J.**, 1992, Approaches for optimizing the use of available information in crosshole seismic tomographic reconstruction. Proceedings GeoTech '92 Geo-Computing Conference, Denver, CO, August 31-September 3, pp. 130-143.

131. Jessop, J.A., **Friedel, M.J.**, Tweeton, D.R., and Jackson, M.J., 1992. Fracture detection with seismic crosshole tomography for solution control in a stope. Proceedings Symposium on Application of Geophysics to Engineering and Environmental Problems, Oakbrook, IL, April 26-29, pp. 487-587.

132. **Friedel, M.J.**, M. Jones, P.M., and Schmidt, R.D., 1992, Geostatistical analysis of dynamic transmissivity during in situ copper leaching. Proceedings 23rd International Symposium on Applications of Computers in Mining Industry, April 7-11, pp. 49-61. [INVITED]

133. **Friedel, M.J.**, 1992, Scale-dependence In the hydrologic design of in situ copper leaching operations: Paper presented at Society for Mining, Metallurgy, and Exploration annual meeting, Reno, Nevada, Feb. 18, 1992. (published as Friedel, M.J., 1993, Scale-Dependence in the Hydrologic Design of In Situ Copper Leaching Operations. Society of Mining Engineers Transactions, Vol. 294, pp 1918-1926.)

134. **Friedel, M.J**., Jessop, J.A., and Thill, R.E., 1991, Igneous rock mass fracture delineation using common offset radar reflection. Proceedings 61st Annual International Meeting: Society of Exploration Geophysics, November 10-14, pp. 504-506.

135. Hanson, J.C., Tweeton, D.R., **Friedel, M.J.**, and Dahl, L.J., 1991, A field test of electromagnetic methods for the detection of conductive plumes. Annual International Meeting: Society of Exploration Geophysics, November 10-14, pp. 569-572. (Presented by Hanson)

136. **Friedel, M.J.** and Hanson, J.C., 1990, An integrated geophysical approach to detection of abandoned mine openings. Proceedings 12th Annual National Abandoned Mine Land Conference, Breckenridge, CO, September 15, pp. 57-86. [PRESENTED]

137. **Friedel, M.J.** and Schmidt, R.D., 1991, Effect of an unsaturated setting on the hydrology of in situ copper leaching. Society for Mining, Metallurgy, and Exploration Ann. Mtg., Preprint 91-161, Denver, CO, February 25-28, 11 pp. (published as Friedel, M.J., 1992, Effect of Unsaturated Conditions on the Hydrology of In Situ Copper Leaching. Society of Mining Engineers Transactions, Vol. 294, pp 1029-1036.)

138. Schmidt, R.D. and **Friedel, M.J.**,. 1991, Application of computers for analysis of in situ leach mining hydrology, Proceedings Indo-U.S. Symposium on Computers in the Mining Industry, Dahnbad, India, November 11-13, pp. 121-135. [INVITED, INTERNATIONAL] (presented by Schmidt)

139. **Friedel, M.J.** and Hanson, J.C., 1990, Assessment of ground penetrating radar for detecting hazardous abandoned mine openings and related features. Proceedings12th Annual National Abandoned Mine Land Conference, Breckenridge, CO, September, pp. 87-55.

140. **Friedel, M.J.,** 1990, Common offset radar profiling for detection of fractures igneous rock. Poster presented at Geophysical Solutions to Geologic Problems of Continental Interiors: A Minnesota Workshop, Minnesota Geologic Survey, Minneapolis, Minnesota, March 4-6, pp 12-15.

141. Schmidt, R.D., **Friedel, M.J.,** and Behnke, K., 1990, Hydrologic considerations of underground in place copper leaching. Society for Mining, Metallurgy, and Exploration Ann. Mtg., Preprint 90-179, Salt Lake City, UT, February 26-March 1, 12 pp. [PRESENTED]

142. Jessop, J.A., R.E. Thill, and **Friedel, M.J.**, 1990, Acoustic site characterization studies for in situ mining. Society for Mining, Metallurgy, and Exploration Annual Meeting, Preprint 90-184, Salt Lake City, UT, February 26-30, 11 pp. [PRESENTED]

143. Thill, R.E., **Friedel, M.J.** and Hanson, J.C., 1990, Mining geophysics: a research perspective. Proceedings International Symposium on Borehole Geophysics in Petroleum, Hydrology, Mining, and Engineering Applications, Tucson, AZ., February 1-3, 5 pp. [INVITED]

144. **Friedel, M.J**., and R.E. Thill. 1990, U.S. Bureau of Mines research on the Kaiser Effect for determining stress in rock. Proceedings in International Joint Meeting, 1st Workshop on AE in Civil Engineering and 2nd Workshop on AE and Rock Fracture Mechanics, Kumamoto City, Japan, Oct. 29-31, pp. 54. [INVITED, INTERNATIONAL]

GRANT

1. US Bureau of Mines, Advanced Mining Program, Geomechanical and geophysical technology for evaluating rock masses for in situ mining, PI: Michael J. Friedel. Funding: 1985-1994, $960

2. US Bureau of Mines, Health and Safety Program, Assessment of damage and integrity of mine structures, Funding: Health and Safety Program, Funding: 1986-1995, $780k

3. US Bureau of Mines, Abandoned Mine Land Program, Cavity detection using geophysical methods, Funding: Abandoned Mine Land Program, Funding: 1989-1993, $575k

4. US Bureau of Mines, Advanced Mining Program, Characterization and remediation of acid mine drainage from a metal-mine waste impoundment, Funding: 1991-1995, $550k

5. US Bureau of Mines, Advanced Mining Program In situ leach mining of unsaturated Chalcocite ore, Funding: 1990-1995, $450k

6. US Department of Health, National Institute of Occupational Health, Tomographic imaging of deep underground metal mines, Funding: 1996, $45K

7. US Department of Agriculture, Agricultural Research Service, Vadose-zone leaching of agricultural chemicals, Funding: 1996, $35k.

8. US Geological Survey, National Water Quality Assessment Program, Upper Illinois River Basin study, Funding: Funding: 1997-2001, $8M

9. US Geological Survey, Toxics Program Variably-saturated transport in 2-dimensions - VST2D, Funding: 1999, $35k

10. US Geological Survey, National Water Quality Assessment Program, Agricultural land-use survey - understanding effect of drought on dry-land wheat farming, Funding: 2001-2002, $150

11. US Department of Homeland Security, Federal Emergency Management Agency, Post-wildfire technical assistance, Funding: 2002-2004: $550k.

12. Northern Colorado Water Conservancy District and Denver Water, Stochastic modeling of the effects that Sulphur Gulch reservoir may have on Colorado River near Grand Junction, CO, Funding: 2002-2004, $950k.

13. US Geological Survey, National Water Quality Assessment Program, Preferential flow and transport in the High Plains aquifer, Funding: Funding: 2003-2004, $75k

14. US Geological Survey, Venture Capital Fund, Improvements to conceptual wildfire-induced flood models, Funding: 2003-2004, $35k.

15. US Agency for International Development, Office of Federal Disaster Assistance, Technical assistance with coastal flood predictions, El Salvador, Funding: 2003-2004, $65k.

16.US Department of Health, National Institute of Occupational Health, Development of predictive equations using knowledge discovery techniques, Funding 2003-2004, $35k

17. US Department of Homeland Security, Federal Emergency Management Agency, Post-wildfire flood potential in Willow & Mitchell creek watersheds, Funding 2004-2005, $135k.

18. US Department of Army, Strategic Environmental Research and Development Program, Tensor magnetic gradient system, Funding: 2005-2006, $55k.

19. United Nations Development Program, Technical assistance with real time flood warning system, Haiti, Funding: 2005-2006, $120k.

20. US Geological Survey, Mineral Resources Program, National Maps - source/process studies of selected contaminants associated with mineral deposits, Funding: 2005-2007, $150k.

21. World Bank, Technical assistance with hazards risk mitigation and emergency preparedness, Romania, Funding: 2005-2007, $900k.

22. US Department of State, Technical assistance to Middle East process, Funding: 2005, $68k.

23. World Bank, Technical assistance with mineral and water-resource assessment, Mauritania, Funding: 2006-2008, $1.2M.

24. US Geological Survey, Mineral Resources Program Alternate modeling paradigms and methods to evaluate uncertainty, Funding: 2006-2012, $500k.

25. US Geological Survey, Mineral Resources Program, Stochastic mineral-resource software development, Funding: 2008-2011, $1M.

26. Civilian Research & Development Foundation, Evaluation of measures to mitigate ground-water flooding in Bishkek region of Kyrgyzstan, Funding: 2009-2010, $65k.

27. Fundação de Amparo à Pesquisa do Estado de São Paulo, Brazil, Joint evaluation and prediction of subsurface attributes from hydrogeologic and airborne geophysical measurements using data mining and knowledge discovery techniques, Funding: 2009-2010, $50k.

28.US Army, Strategic Environmental Research and Development Program, UXO Discrimination, Funding: 2010-2011, $40k.

29. World Bank, Technical assistance with water-resource assessment, Mauritania, Funding: 2011-2012, $100k.

30. US Geological Survey, Mineral Resources Program Joint inversion of disparate data, Funding: 2013 $175k.

31. US Geological Survey, Mineral Resource Program Seismic-magnetotelluric joint inversion to improve understanding of sediment-hosted gold deposits (Battle Mountain-Eurkea mineral belt, Carlin-trend), northern Nevada, Funding: 2014, $150k.

32. North Atlantic Treaty Organization, Water and environmental security: NATO advanced research workshop: climate-change effects on water resources– issues of national and global security, Izmir, Turkey, Funding: 2010, $65k.

33. National Council for Scientific and Technological Development, CNPQ, Improved crustal and upper mantle imaging using disparate geophysical data and joint inverse techniques, Funding: 2010-2011, $35k.

34. State of Nebraska, Estimation of Subsurface Attributes Using Hydrogeologic and Geophysical Measurements (Hydrogeologic Framework for Glacial Aquifers), Funding: 2011, $25k.

35. US Department of Army, Engineer Research Development Center, Near real-time imaging of heterogeneity in a glacial aquifer (Geophysical Remote Sensing – "The Chameleon**"),** Funding: 2012-2013, $65k

36. US Department of Army, Engineer Research Development Center, Reliability of geophysical instrument response to unexploded ordnance, Funding: 2012-2013, $250k.

37. Fundação de Amparo à Pesquisa do Estado de São Paulo, Brazil, Evaluation of uncertainty in Amazonian gold occurrence using airborne radiometric data and soft computing, Funding: 2013, $35k.

38. Fundação de Amparo à Pesquisa do Estado de São Paulo, Brazil, Hierarchical scenarios of climate change from the perspective of evolutionary landscape dynamics, Funding: 2013-2014, $35k.

39. GNS Science, Strategic Development Fund, Our rising tide – evaluating the regional impact of sea level change in New Zealand, Funding: 2016-2017, $150k.

40. Geoscience Australia, Improved groundwater system mapping and characterisation workflows using machine-learning and evolutionary techniques I, Funding: 2016, $40k

41. Geoscience Australia, Improved groundwater system mapping and characterisation workflows using machine-learning and evolutionary techniques II, Funding: 2016-2017, $150k.

External Proposals (submitted)

42. Environment Canterbury Regional Council, New Zealand, Probabilistic modeling of Canterbury lithological data for input into numerical hydrological models, 2016, $56k

43. Zealand Ministry of Business, Innovation, & Employment, China Research Alliance, Groundwater as an adaptation for climate change, Funding: 2016, $242k

44. Environment Southland Regional Council, Data fusion and machine-learning applied to GW/SW system data, Funding: 2016, $37

External Proposals (under development)

45. World Bank, Groundwater resource and vulnerability assessments in SW Pacific island nations (US Geological Survey, Geoscience Australia, GNS Science, Aarhus University, SW Pacific Government Agencies), Funding: 2017, ($XX0M)

UNIVERSITY TEACHING

Undergraduate

Quantitative Hydrogeology (GEOL 250), Colorado College, Department of Geology, Colorado Springs, CO, block 3, 2003 (4 credits).

*Unsaturated zone hydrology (*ENVS5500), Department of Environmental Science, University of Colorado, Denver, CO, Fall semester, 2004, 2005, 2006, 2008 (4 credits; co-taught with Dr. James Tindall).

*Applied Statistics for the Natural Sciences (*ENVS5600/GEOG 4770/GEOL 4/577-001), Department of Environmental Science, University of Colorado, Denver, CO, Fall semester, 2009. (4 credits)

Graduate

Modeling Coastal Water Flooding, Mud and Debris Flows, University of Centroamericana-Jose Simeon Canas, Department of Energy and Fluid Science, San Salvador, El Salvador, fall semester, 2003 (4 credits; developed and taught).

Model Calibration and Predictive Analysis in Earth Science, Universidad Centroamericana-José Simeón Cañas, Department of Energy and Fluid Science, San Salvador, El Salvador fall semester, 2004, 2005 (4 credits; developed and taught)

Assessing and Managing Risks Associated with Hazards in our Environment, Universidad Centroamericana-José Simeón Cañas, Department of Energy and Fluid Science, San Salvador, El Salvador, summer semester, 2005 (4 credits; developed and taught).

Advanced Concepts in Watershed Management, Universidad Centroamericana-José Simeón Cañas, Department of Energy and Fluid Science, San Salvador, El Salvador, fall semester, 2006 (4 credits; developed and taught).

Assessing and Managing Environmental Risks, Universidad Centroamericana-José Simeón Cañas, Department of Energy and Fluid Science, San Salvador, El Salvador, summer semester, 2006 (4 credits; developed and taught).

Ecological Risk Assessment, Department of Environmental Science, University of Kuopio, Finland, fall semester, 2007 (2 credits; Co-developed and co-taught).

M*ulticomponent reactive transport modeling for mining environments*, Department of Environmental Science, University of Kuopio, Finland, fall semester, 2007 (4 credits; Co-developed and co-taught).

Model fitting, calibration, uncertainty analyses in the geosciences, Institute of Geosciences, University of Brasilia, Brasilia, Brazil, spring semester, 2008 (4 credits; developed and taught).

Model fitting, calibration, uncertainty analyses in the geosciences, Instituto de Geociências, Universidade Estadual de Campinas, Campinas, Brazil, spring semester, 2008 (4 credits; developed and taught).

Hydrogeophysics, Institute of Geosciences, University of Brasilia, Brasilia, Brazil, summer semester, 2008 (4 credits; developed and taught).

Hydrogeophysics, Instituto de Geociências, Universidade Estadual de Campinas, Campinas, Brazil, summer semester, 2008 (4 credits; developed and taught).

Groundwater modeling, Institute of Geosciences, University of Brasilia, Brasilia, Brazil, Spring semester, 2013 (4 credits; developed and taught).

Multivariate statistics, machine-learning, and hybrid modeling, Instituto de Geociências, Universidade Estadual de Brasilia, Brasila, Brazil, winter semester, 2013 (3 credits; developed and taught).

Applied modeling and uncertainty analysis in earth science, Center for Environmental Studies, Universidade Estadual de Campinas, Campinas, Brazil, winter semester, 2013. (4 credits; developed and taught)

Artificial Adaptive Mathematical Models in Medicine and the Environment (MATH 4/5779), Department of Mathematical and Statistical Sciences, University of Colorado, Denver, USA, winter semester, 2013. (4 credits; co-developed and co-taught)

UNIVERSITY SERVICE

Post-doctoral

Advisor

Dr. Lihong Meng, Gannan Normal University, China 2016
Data-driven modeling of the water footprint for regions of New Zealand
Dr. Lucas Moreira, University of Brasilia, Brazil 2015
Hybrid software for numerical inverse problems
Dr. Cleyton Carnerio, University of Sao Paulo, Brazil 2013
Uncertainty quantification in airborne mineral mapping

Co-Advisor

Dr. Andrea Koga-Vicente, University of Colorado 2014
Modeling climate-sugar cane dynamics using a topologically weighted centroid
Dr. Eduardo Vicente, University of Colorado 2014
Classifying landscape features by machine learning

Graduate Students

Co-Advisor

Raul Rechden	Victoria University, NZ	PhD	In progress
Shale gas: a new generation for New Zealand			
Daniela Lins	University of Campinas, Brazil	PhD	In progress
Hierarchical scenarios of climate change and evolutionary landscape dynamics			
Akbar Eshfani	University of Colorado, USA	MS	2012-2013
Forecasting conditional climate change in southwestern, United States			
Lucas P. Moriera	University of Brasilia, Brazil	PhD	2010-2013
Joint inversion of receiver functions and surface water measurements for crustal imaging			
Fabio Iwashita	University of Campinas, Brazil	PhD	2009-2011
Prediction of water quality in central Brazil from hydrogeologic and airborne geophysical measurements using data mining and knowledge discovery techniques			
Andréa Koga Vicente	University of Campinas, Brazil	PhD	2009-2010
Uncertainty in spatialization of extreme precipitation events near Serra do Mar			
Maria A. Figueroa	University of Colorado, USA	MS	2006-2007
Comparison of δO^{18} water from suction lysimeters, centrifugation, and azeotropic distillation			
Mark E. Smith	Colorado State University, USA	PhD	2007
Prediction methodologies for coastal and urban flooding in ungauged basins of El Salvador			
Justin Little	University of Colorado, USA	MS	2006
Scaling; laboratory versus field scale hysteretic measurements for a coarse sandy soil			

Maria Stearns	University of Colorado, USA	MS	2003-2004
Effects of coal-bed methand discharge on vegetation and soil ecosystem in Powder River basin			
Chuenamol Sethaputra	University of Colorado, USA	MS	2002-2004
Dual porosity techniques for predicting macropore transport			
Elizabeth Murphy	University of Illinois, USA	MS	2001-2002
Predicting hydrologic variables in watersheds along an urban gradient			

Undergraduate Students

Akbar Eshfani	University of Colorado, USA	BS	2010
Morgan Erlich	University of Colorado, USA	BS	2009

Committee member

Akbar Eshfani	University of Colorado, USA	MS	2013
Forecasting conditional climate change in southwestern, United States			
Erin Wallin	Colorado School of Mines, USA	PhD	2008
Evaluation of high-frequency sounding for detection and monitoring of DNAPL contaminants			
Oderson A. De Souza Filho	University of Campinas, Brazil	PhD	2008
Dados aerogeofisicos e geologicos aplicados a selecáo de areas favoràveis para agua subterränea no dominic cristalino do Ceará, Brasil			

Invited Seminars

Tblisi State University, Role of large earthquakes on aquifer dynamics, 2016
University of Colorado, Computationally-intelligent solutions in hydrogeology, 2015
Tblisi State University, Alternate modeling paradigms in hydrogeology, 2015
University of Colorado, Computationally-intelligent solutions in hydrogeology, 2015
GNS Science, New Zealand, Computationally-intelligent solutions in hydrogeology, 2014
Swiss Technical University, Switzerland, New frontiers in experimental hydrogeology, 2014
University of Campinas, Brazil, Forecasting climate change using a hybrid approach, 2013
University of Campinas, Brazil, Climate change – applications of soft and hybrid modeling, 2012
University of Brasilia, Brazil, Numerical modeling strategies in resource assessments, 2008
University of Campinas, Brazil, Overview of hydrogeologic studies at the USGS, 2008
Central American University, El Salvador, Simulating hurricane-induced coastal flooding, 2006
Central American University, El Salvador, Estimating rainfall in ungauged coastal basins, 2006
Hungarian Academy of Sciences, Hungary, Effects of urbanization on biological integrity, 2005
Hohai University, China, Simulated effects of Sulphur Gulch reservoir operations, 2005
Hohai University, China, Parameter estimation, model calibration, and uncertainty analysis, 2005
Hohai University, China, Predicting effects of urbanization on ecological integrity, 2005
Hohai University, China, Improved estimation of recharge through the vadose zone, 2005
University of Colorado, Unsaturated zone flow and transport modeling 2004
University of Colorado, Coupled-inverse modeling to assess artificial recharge, 2004
University of Minnesota, Stochastic simulation and optimization of reservoir parameters, 2002
University of Minnesota, Estimating coupled water-heat-solute transport parameters, 2002
University of Minnesota, Simulating urbanization effects on ecological integrity, 2001
Radford University, Mining applications of seismic tomography, 1996
University of California, Dynamic transmissivity during in-situ copper leaching, 1992
Columbia University, Geotomographic applications in mining, 1992
Michigan Technological University, In-situ mining, 1991
University of Wisconsin, Mining applications of geotomography, 1991

RELATED PROFESSIONAL EXPERIENCE

Rendering Scientific Judgment

Technical reviewer for scientific journals

Ground Water Journal, 2003-present
Vadose Zone Journal, 2002-present
Journal of Applied Geophysics, 1993-present
Journal of Engineering Geology, 1993-present
Journal of Coal Geology, 1993-present
Water Resources Research, 2006-present
Journal of Hydrology, 2006-present
Israel Science Foundation, 2008

Technical reviewer for US agencies

Manuscripts and proposals

U.S. Geological Survey
U.S. Environmental Protection Agency
U.S. Center for Disease Control, NIOSH
U.S. Bureau of Mines manuscripts
U.S. Bureau of Mines proposals

Special publications

U.S. Geological Survey surface water software (PULSE, RORA, PART) and user's guide, 2000
U.S. Geological Survey geostatistics web page primer, 2002
U.S. Geological Survey geostatistics textbook (R. Olea), 232 p., 2008

Selection and planning committees

Member, Committee on unsaturated zone for hydrology, American Geophysical Union, discipline, planning, proposal selection: 2004, 2005, 2006, 2007, 2008, 2009, 2010

Member, Program direction, planning, and technical review committee, senior staff, Colorado Water Science Center U.S. Geological Survey: 2001, 2002, 2003, 2004

Member, Agricultural flow and transport program committee, direction and long-range planning, National Water Quality Assessment U.S. Geological Survey: 2002, 2003

Member, Program direction, planning, and technical review committee, Illinois Water Science Center U.S. Geological Survey: 1997, 1998, 1999, 2000, 2001

Member, Reactive unsaturated zone transport model development program committee, direction and long-range planning, U.S. Geological Survey, National Research Program, 2001

Member, Characterization of hazardous waste sites using geophysical technology committee, long-range planning, Environmental Technology Program, Bureau of Mines, 1995

Member, Well-drilling guidelines to reduce liability for groundwater pollution committee, U.S. Bureau of Mines, 1995

Member, Ground control committee, proposal selection, and funding; Health and Safety program, U.S. Bureau of Mines 1993, 1994, 1995

Peer-Review and Expert Panels

Advisory Board, Center for Computational and Mathematical Biology, University of Colorado	2012- present
Member, National Hazards Panel, U.S. Geological Survey	2008
Member, research grade evaluation panel, U.S. Geological Survey	2005
Member, research grade evaluation panel, U.S. Geological Survey	2004

Chairperson of Scientific Meetings

Chair, Research discovery paradigms in earth systems science (IN037), Earth and Space Science Informatics (Session ID: 12529), American Geophysical Union, San Francisco, CA, 2016

Co-chair, Regional Groundwater Systems: Advances in modeling, characterization, and applications I, Hydrology session H14E (oral), American Geophysical Union, San Francisco, CA, 2013

Co-chair, Regional Groundwater Systems: Advances in modeling, characterization, and applications II, Hydrology session H13O (oral), American Geophysical Union, San Francisco, CA, 2013

Co-chair, Regional Groundwater Systems: Advances in modeling, characterization, and applications II, Hydrology session H11H (poster), American Geophysical Union, San Francisco, CA, 2013

Co-chair, Characterization of Groundwater Systems, Hydrology oral sessions H11K and H12A (oral), and H13B poster session, American Geophysical Union, San Francisco, CA, 2012

Co-chair, Advanced Computational Modeling Paradigms for Hydrologic Systems, Hydrology poster session H21A, American Geophysical Union, San Francisco, CA, 2012

Co-chair, Uncertainty Assessment, Optimization, and Sensitivity Analysis in Integrated Hydrologic Modeling as Applications of Hydroinformatics III, Hydrology oral session H34D, American Geophysical Union, San Francisco, CA, 2011

Co-chair, Computational Intelligence in Earth and Space Systems, Union poster session U22a, American Geophysical Union, San Francisco, CA, 2011

Co-chair, Computational Intelligence in Earth and Space Systems, Union oral session U22b, American Geophysical Union, San Francisco, CA, 2011

Chair, Empirical, Numerical, Soft, and Hybrid Modeling, Environment and Environmental Security NATO Advanced Research Workshop series: Climate change Effect on Water Supplies – Issues of National and Global Security, Izmir, Turkey, 2010 [INVITED, INTERNATIONAL]

Co-chair, Water Resources Science and Strategies for Adaptation to Climate Variability and Change III, Hydrology oral session H24F, American Geophysical Union, San Francisco, CA, 2010

Co-chair, Water Resources Science and Strategies for Adaptation to Climate Variability and Change II, Hydrology oral session H21G, American Geophysical Union, San Francisco, CA, 2010

Co-chair, Water Resources Science and Strategies for Adaptation to Climate Variability and Change I, Hydrology poster session H21G, American Geophysical Union, San Francisco, CA, 2010

Co-chair, Climate Change Effects on Ecosystem Services – Issues of Global Security, Natural Hazards oral session, H93, American Geophysical Union, San Francisco, CA, 2010

Co-chair, Quantitative Resource Assessments – Past, Present, and Future, Natural Hazards oral session, NH17, American Geophysical Union, San Francisco, CA, 2010

Co-chair, Advanced Inverse Strategies for Improved Characterization and Assessment of Groundwater, Mineral, and Petroleum Resources I, Near Surface geophysics poster session, NS31A, American Geophysical Union, San Francisco, CA, 2009

Co-chair, Advanced Inverse Strategies for Improved Characterization and Assessment of Groundwater, Mineral, and Petroleum Resources I, Near Surface geophysics oral session, NS41A, American Geophysical Union, San Francisco, CA, 2009

Co-chair, Relationship of Natural and Anthropogenic Hazards to National and Global Security, Public Affairs poster session, PA21B, American Geophysical Union, San Francisco, CA, 2009

Co-chair, Application of Joint Inverse Methods for Improved Characterization and Assessment of Ground-Water, Mineral, and Petroleum Resources, Near Surface geophysics poster session, NS31A, American Geophysical Union, San Francisco, CA, 2008

Co-chair, Multi-Scale Unsaturated Zone Flow and Contaminant Transport Processes, Hydrology poster session H13F, American Geophysical Union, San Francisco, CA, 2008

Co-chair, Improved Estimation and Prediction in Earth Science Through Integration of Multiple Data Sets and Model Types, Near surface geophysics oral session, NS43A, American Geophysical Union, San Francisco, CA, 2007

Co-chair, Preferential flow and transport in variably saturated porous media, Hydrology poster session, H33, American Geophysical Union, San Francisco, CA, 2006

Chair, Flood predictions in ungauged basins, Oral session, International Symposium – Methods in Hydrology, Hohai University, Nanjing, China, 2005 [INVITED, INTERNATIONAL]

Co-chair, Special session - Flood predictions in ungauged basins, International Symposium - Methods in Hydrology, November, Nanjing, China, 2005 [INVITED, INTERNATIONAL]

Chair, Water Quality, NATO Advanced Study Workshop - Groundwater and Ecosystems, Canakkale, Turkey, 2005 [INVITED, INTERNATIONAL]

Co-chair, Spatial Relations Between Plants, Soil, and Water in the Vadose Zone, American Geophysical Union, Hydrology poster session, H12, American Geophysical Union, San Francisco, CA, 2005

Co-chair, Preferential flow and transport in variably saturated porous media, American Geophysical Union oral session, H13I, American Geophysical Union, San Francisco, CA, 2005

Chair, Regional Overviews, NATO Advanced Research Workshop series: Urban Groundwater Management and Sustainability, Baku, Azerbiajan, 2004 [INVITED, INTERNATIONAL]

Co-chair, Preferential flow and transport in variably saturated porous media, Hydrology poster session, H33B, American Geophysical Union, San Francisco, CA, 2004

Co-chair, Preferential Flow and Transport in Variably Saturated Porous Media, Hydrology oral session, H33A, American Geophysical Union, San Francisco, CA, 2004

Co-Chair, Model Calibration, Parameter Nonuniqueness, and Predictive Uncertainty Associated With Flow and Transport in Variably Saturated Media, hydrology poster session, H12A, American Geophysical Union, San Francisco, CA, 2003

Chair, Annual liaison meetings, budget conference calls, project reviews, Upper Illinois River Basin, National Water Quality Assessment Program, USGS, 1997-2001

Convener of Conference and Workshops

Co-convener, Environment and Environmental Security NATO Advanced Research Workshop series: Climate change Effects on Water Resources– Issues of National and Global Security, Sept.1-5, 2010, Izmir, Turkey [INVITED, INTERNATIONAL]

Editor and Board Member

Editorial board member, The Open Civil Engineering Journal, Bentham Science publishers, 2007-2014

Associate editor, The Journal of Water and Energy Security, Bentham Science publishers, new start in 2013

Co-editor, 2013, NATO Advanced Research book on Climate Change and its Effect on Water Resources-Issues of National and Global Security, Climate change and its effect on water supplies - Issues of National and Global Security, NATO Science for Peace and Security Science Series C. Environmental Security, vol. 3, Springer, Dordrecht, The Netherlands, 318 p.

Technical Training Provided

Computer Modeling

Mauritanian Ministre du Petrole, de L' Energie et des mines scientists, Hydrogeology of Mauritania (1-day)	2012
Geological Survey of Brazil scientists, Airborne-electromagnetic inverse modeling and application of genetic programming (7-days)	2008
Geological Survey of Finland scientists, Reactive transport modeling (10-days)	2007
Servicio Nacional Estudious de Territoriales hydrologists, Peak flood frequency analysis and rainfall-runoff calibration for gaged/ungaged basins	2003
Servicio Nacional Estudious de Territoriales hydrologists, Modeling unsteady, confined and unconfined, modeling of coastal water flooding	2003
USGS hydrologists, Unconfined-water and debris-flow modeling	2003
USGS hydrologists, Rainfall-runoff model calibration	2003
USGS hydrologists, Nonlinear parameter estimation	2000

USGS hydrologists, Geostatistical analysis	1999
USGS hydrologists, Ecological risk modeling	1999
USGS hydrologists, Water-budget modeling and analysis	1999

Short Courses

Mining applications of seismic tomography (1-day)	1996
Numerical modeling of flow in the vadose zone (2-days)	1992
Seismic imaging for spatial imaging of mine-tailings (5-days)	1992
Digital signal processing (5-days)	1987

Other Technical Activities

Intern advisor to Akbar Eshfani, USGS Volunteer for Science	2010
Intern advisor to Morgan Erlich, USGS Volunteer for Science	2009
Advisor to Erin Wallin, USGS Visiting Scientist	2006-2008

Annual work plans, Upper Illinois River Basin, USGS, 110 pp. ($1.9M)	2001
Annual work plans, Upper Illinois River Basin, USGS, 102 pp. ($1.8M)	2000
Annual work plans, Upper Illinois River Basin, USGS, 193 pp. ($1.7M)	1999
nnual work plans, Upper Illinois River Basin, USGS, 65 pp. ($1.4M)	1998
Annual work plans, Upper Illinois River Basin, USGS, 23 pp. ($750K)	1997

Government Assistance

Australia, Geoscience Australia	2016
Brazil, Centro de Pesquisas Meteorológicas e Climáticas Aplicadas a Agricultura, University of Campinas	2013
Brazil, Geosciences Institute, University of Campinas	2012
Brazil, Empresa Brasileira de Pesquisa Agropecuária, Campinas	2012
Brazil, Centro de Pesquisas Meteorológicas e Climáticas Aplicadas a Agricultura, University of Campinas	2012
Kyrgyzstan, Hydrogeology and Water Economy Problems Laboratory	2007
Portugal, European research consortium	2008
Georgia, Seismic Monitoring Center and Ministry for Education and Science	2008
European Union, Mine Waste Directive task group member, Brussels	2007
Haiti, Geological Survey of Haiti	2006
Mauritania, Ministre du Petrole, de L' Energie et des Mines	2006
Romania, Romanian National Agency for Mineral Resources	2006
El Salvador, Servicio Nacional Estudious de Territoriales	2003

WebEx Seminars (oral and cybercast)

Quantitative mineral resource assessment software (new)	2011
Colorado Water Science Center seminar series	2002-2004
Watershed model calibration and predictive analysis	2002
Model calibration and predictive analysis for watershed models	2002
Simulation of urbanization and its effects on ecological integrity	2001
Stochastic framework for assessing effects of urbanization of water quality	2001

Web products

Variably-saturated flow and transport 2D software	2002

Water-quality data server, UIRB-NAWQA study unit 2000
(basis for USGS National Water Information Server NWIS-Web)

PROFESSIONAL ASSOCIATIONS

American Geophysical Union 1996-present
American Water Resources Association 2002-2004
Minnesota Ground Water Association 1990-2004
New Zealand Hydrological Society 2014-present
Society of Exploration Geophysicists 1986-1996

HONORS, AWARDS, RECOGNITION

University

Research assistantship, University of Minnesota, 1996
Fellowships, Chevron Petroleum: 1985, 1986
Research assistantships: University of Wisconsin: 1984, 1985

U.S. Bureau of Mines

PhD educational opportunity fellowship: 1994-1996
Paper-of-the-year award: 1990, 1992, 1994
Outstanding performance award: 1990, 1991, 1992, 1993, 1994, 1995
Superior performance award: 1986, 1987, 1988, 1989
On-the-spot award: 1990, 1991

U.S. Geological Survey

Exceptional performance award: 2009, 2010
Superior performance ward: 2006, 2007, 2008, 2011, 2012
Star award: 1998, 1999, 2000, 2001, 2005, 2006, 2007

Minnesota Governor

Certificate of commendation: 1991

SCIENTIFIC LEADERSHIP

Leadership at project, team, program, and Bureau levels: At the *project* level, I promoted and prioritized work; coordinated and prepared the scope of work and financial plans with annual budgets to ~$2.0M; determined project staffing needs and hired scientists with specialized experience; determined assignments, awards, and promotions; reviewed and ensured timely completion and quality of technical proposals, work plans, presentations, and reports; and evaluated employee performance. As a leader, I motivated scientific teams toward common goals. Leading teams was challenging because they often included scientists and support staff from multiple disciplines, multiple states, and organizations. To facilitate implementation of core activities, I guided and participated in project designs, data collection, analyses, and interpretation; promoted team workshops on scientific field data collection and modeling applications; identified, planned, promoted, and coordinated multi-state activities with cooperating companies, State and Federal agencies, National Synthesis Teams, and other related studies; devised and promoted new scientific approaches; and developed, participated and chaired reviews at science center,

headquarter, and stakeholder meetings. I was among the first chiefs to use web products in support of USGS Water Resource Discipline projects. Notable contributions included conceptualizing, funding, and directing the development of internal and external project management web pages for the Upper Illinois River Basin (UIRB) - National Water Quality Assessment (NAWQA) project. My direction and funding development of an internal web-based project management email/calendar and external web-based water quality data server were precursors to LOTUS notes and National Water Information System (NWIS). The programmers and software used in developing the UIRB web server were later used by headquarters in the NWIS development. One recent assignment was subtask chief for one of two large tasks funded by the Mineral Resources Program (MRP). This role emerged as a result of my direction and guidance in the reformulation of the project task. In addition to project leadership, I mentored visiting USGS scientists, and doctoral students at universities in the US and abroad.

At the *team* level, several new research projects were started under my direction with high national visibility and success. Some examples that were developed while I was chief of the UIRB NAWQA project included Nutrients and suspended solids in surface waters of the Upper Illinois River Basin; Influence of various water quality sampling strategies on load estimates for small streams; Ecological risk assessment in the Upper Illinois River Basin; and Urbanization influences on aquatic communities in northeastern Illinois streams. In addition to providing guidance on administrative and funding aspects of these projects, I provided scientific direction that helped make these projects successful. Findings from these research projects provided a basis and direction for modification of NAWQA program protocols that included strategies for frequency of surface water sampling and conducting urban land-use gradient (ULUG) studies. Findings from the ULUG study provided funding estimates and necessary protocols used in the program implementation of nine urban land-use gradient studies conducted across different metropolitan regions of the US. Another example of my team leadership included implementation of an alternative management paradigm for managing multi-state teams. This paradigm provided a means to manage cyclical NAWQA funding and reduce otherwise hardships in annual science center staffing. This strategy was adopted as a preferred means of managing teams in the NAWQA program. As a senior staff member of the Illinois and Colorado Water Science Centers, I provided technical program direction, long-range planning, and project reviews; and developed, coordinated, and promoted a WebEx seminar series.

At the *program* level, I worked across discipline barriers providing direction to various committees tasked with funding and planning scientific programs. This direction included the annual review and selection of technical proposals and long-range planning for the Health and Safety and Environmental Technology programs for the USBM. At the USGS, I provided input on long-range planning to the National Research Program for reactive unsaturated zone transport model development. Similarly, I provided input and direction on the development and long-range planning for a new NAWQA Agricultural Flow and Transport Synthesis Team. Other leadership examples included input on research grade evaluation panels for Ground Water Hydrology of the Water Resource Discipline, and Crustal Imaging and Characterization Team of the Geologic Discipline.

At the *bureau* level, I exercised intergovernmental leadership in the transfer of technical information and support of peace through science initiatives. In technical transfer, I provided information on findings of my research for which publications were new and guidelines otherwise nonexistent. This information transfer was in the form of committee involvement, seminars, workshops, and expert testimony that arose based on requests by management and scientists within the USBM, USGS, collaborating agencies, and industry personnel. For example, I provided technical direction on a special USBM committee charged with developing well-drilling guidelines to reduce Bureau liability for groundwater pollution. At the USGS, I provided technical seminars to management and scientists of the NAWQA Leadership and National Synthesis Teams, Office of Water Quality, and Office of Surface Water on topics, such as model calibration framework for assessing effects of urbanization on water quality, model calibration and simulation of urbanization and its effects on ecological integrity, and a new approach to watershed model

calibration and predictive analysis. The application of my regularized nonlinear inverse procedure was adopted as a standard for HSPF modeling in the USGS. I represented the Bureau as an expert witness on Colorado River water quality modeling in response to a Toughy request by Denver Water. An example of my interaction among bureaus included providing guidance to the Federal Emergency Management Agency on use of post-fire flood and debris flow modeling techniques which were used to reestablish new insurance rates. In other examples, I provided field training and model guidance to the US Department of Agriculture and National Institute of Occupational Safety and Health on how to evaluate solute leaching of agriculture chemicals in freezing (hydro-mechanical) ground and application of seismic tomography to mitigate rock bursts in deep metal mines. More recently, I provided updates and slides of my intergovernmental support to the International Program and Director of the USGS.

Leadership in the external scientific community

My scientific leadership outside the federal government is reflected in frequently serving as a reviewer of manuscripts for in-house publications and outside books and journals, participating in or leading committees (American Geophysical Union technical committee on Unsaturated zone for hydrology, 2004-2011); annual chairing of symposia at scientific meetings (American Geophysical Union, and European Geosciences Union); serving as an editorial board member (Global Security Affairs and Analysis, Science publishers, 2007-2008; and The Open Civil Engineering Journal, Bentham Science publishers, 2007-present); and serving as an adjunct professor (Department of Geophysics, Colorado School of Mines: 2006-2008; Department of Environmental Science, University of Colorado: 2004-2012; Department of Mathematics and Statistical Sciences, University of Colorado: 2012-present). As adjunct professor, I served on a number of graduate thesis committees and co-advised master and doctoral candidates.

In the past decade, my role has broadened to include various international assignments, such as a State Department-sponsored modeling course (Budapest, 2005) as part of the Middle East Peace Process (18 scientists from 6 different ministries in the strife-ridden areas of Israel, Jordan, and Palestine); NATO-sponsored Advanced Research Workshops (Urban Groundwater Management and Sustainability, Baku Azerbaijan, 2004; Groundwater and Ecosystems in Canakkale, Turkey, 2005; and Climate change Effect on Water Supplies – Issues of National and Global Security, Izmir, Turkey, 2011), Chinese-sponsored International Symposium on Methodology in Hydrology (Nanjing, China, 2005), and various governmental sponsorships as visiting scientist (Brazil and Finland) and visiting professor (Brazil, China, El Salvador, Finland). As part of the NATO-sponsored Advanced Research Workshops, Chinese-sponsored International Symposium, and Brazilian 44th Geological Congress, I gave keynote talks and presided as chairman over special advanced modeling sessions. In the case of the 2011 NATO-sponsored Advanced Research Workshop, I accepted the role of co-convener (36 scientists from 18 countries) and co-editor of a book on Climate Change and its Effect on Water Resources – Issues of National and Global Security (NATO Science for Peace and Security Science Series).

I provided technical assistance to scientists in the countries of Brazil, El Salvador, Finland, Haiti, Kyrgyzstan, Mauritania, Romania, and Turkey; and special European Union committees. My involvement in these international activities resulted in various requests for me to serve as visiting Scientist (Geological Survey of Finland, Kuopio, Brazil, 2007; Geological Survey of Brazil, Fortaleza, Brazil, 2008**),** visiting professor (Universidad Centroamericana, El Salvador: 2003, 2004, 2005, 2006; Hohai University, Nanjing, China, 2005; Kuopio University, Kuopio, Finland, 2007; Universidade de Brasilia, Brasilia, Brazil, 2008; Universidade de Campinas, Campinas, Brazil, 2008, 2012), adjunct professor (Universidade de Campinas, Campinas, Brazil, 2008-present; Universidade de Brasilia, Brasilia, Brazil, 2008-present), and mentor visiting USGS scientists (Fabio Iwashita, University of Campinas, Brazil; Lucas Moreira (Fulbright Scholar), University of Brasilia, Brasilia, Brazil; and Can Ertekin, University of Çanakkale Onsekiz Mart University, Çanakkale, Turkey). As a visiting professor, I developed and taught

advanced modeling courses on special topics related to my research published while working at the USGS. My role as an adjunct professor allowed me to participate and preside on a number of graduate thesis committees and serve as co-advisor for Ph.D. students in Brazil (University of Brasilia, and University of Campinas) and Turkey (University of Çanakkale Onsekiz Mart University). In these university rolls, I guided student projects to be consistent with USGS science program themes and goals, and provided guidance in development of manuscripts, and assisted in the development of a hydrogeology curriculum (University of Brasilia). While I served as adjunct professor in San Salvador, I provided guidance to a senate committee charged with developing country-wide groundwater protection plans for aquifers in El Salvador.

RESEARCH ACHIEVEMENTS

From**:** July 1, 2015 To: present

Rainfall Recharge – GNS Theme: Research Programme; Funding: National Institute of Water and Atmospheric Research Waterscape programme. Aim: Understand effects of rainfall recharge uncertainty on New Zealand water budget.

Uncertainty Quantification - As project member, I am *responsible* to devise an approach for introducing conditional uncertainty into water budget models, and provide results as stochastic boundary condition to a numerical groundwater model, for which there are no published methods, approaches, or guidelines. My research *resulted* in the first assessment of conditional uncertainty for rainfall-recharge to the coastal Heretaunga Plains aquifer. Other plans include a set of guidelines for modeling rainfall recharge with conditional uncertainty; a conference abstract and international presentation. To date, my research *demonstrated* that quantile modeling of MCMC rainfall-recharge time series is useful to quantify conditional uncertainty for stochastic input to machine-learning network models. Case study area includes the Hawke's Bay region. Collaborators: Hawke's Bay Regional Council and GNS Science Strategic Development Fund.

Our Rising Tide – GNS Theme: Research Programme; Funding: Strategic Development Fund. Aim: Evaluate regional effects of climate-change induced sea-level rise in New Zealand.

Modeling seawater intrusion - As task leader, I am *responsible* to develop, calibrate, and apply a density-dependent groundwater flow and transport model to quantify the response and uncertainty of climate-change induced sea-level rise on landward intrusion of seawater in estuaries and the coastal Heretaunga Plains aquifer. To date, my research *resulted* in the first density-dependent groundwater flow and transport model for NZ. Other plans include a set of guidelines for coastal climate-change induced sea-level assessment for NZ; a proposal for future research; and a conference abstract and international presentation. Case study area includes the Heretaunga Plains groundwater basin of the Hawke's Bay region. Collaborators: Various GNS departments; and Hawke's Bay Regional Council.

Earthquake Hydrology – GNS Theme: Research Programme; Funding: Royal Society of New Zealand, Innovation and Employment. Aim: Understand the role of large earthquakes on aquifer dynamics.

Data Fusion and Knowledge Discovery - As project member, I am *responsible* to quantify relations among, identify optimal information subset in, and formulate predictions of changes in well pressure caused by ground acceleration, shaking, stress and related changes in the earth's crust due to M7.1 and M6.3 earthquakes at Canterbury in 2010 and 2011 for which there are no published methods, approaches, or guidelines. To date, my research *resulted* in the first systematic investigation in which artificial adaptive systems were used to evaluate and model earthquake hydrology. This research *demonstrated* the use of data mining and machine-learning techniques to identify key relations and input variables that

drive underground fluid movement during these major earthquakes and quantify their prediction uncertainty. The initial case study area is in the Christchurch region; however, this study region will be expanded to include 100 additional New Zealand earthquakes that will *result* in at a conference abstract, international presentation, and journal article. Collaborators: Environment Canterbury Regional Council and Envirolink.

Technical Assistance to the Government of Australia - Project chief: K. Lawrie; Theme: Water; Funding: Geoscience Australia. Groundwater is a major natural resource in the Murray-Darling Basin, Australia. The current and future management of this resource will impact on the economic viability of many of the Basin's regional communities. As task chief, I am *responsible* to test efficacy of the machine-learning paradigm to inform groundwater model for there are no published methods, approaches, or guidelines. My research is expected to *result in* development of a conceptual groundwater model and provide input to a multi-institutional World Bank proposal. The research will *demonstrate* how the data-fusion paradigm can be used for estimating hydrostratigraphic units from hydrogeophysical data.

Technical Assistance to the United States Government – Task chief: J. Tindall; Theme: Water; Funding (In-kind): GNS and Unsaturated Zone Project, National Research Program, USGS. The USGS is interested in understanding potential for transport of pollution through the unsaturated zone to regional aquifers. As an external project member, I am *responsible* to model the unsaturated-zone transport of: (1) bromide and δO^{18} in sand near Denver and for a comparison to pollution studies in the Ogalla Aquifer; (2) δO^{18}, atrazine, and dicamba through silt and loam soils overlying the High Plains aquifer for agricultural purposes and role of preferential flowpaths. To date, my research *resulted in* fitting convection-dispersion equations to model field measurements at each depth for the first objective. The second modeling objective for transport through dual permeability soils is underway, as is mentoring the task chief in applications of these models. This work will be used to *demonstrate* role of the unsaturated zone and preferential flow to control transport of agricultural chemicals.

From**:** July 1, 2014 To: present

Smart Aquifer Characterization – GNS Theme: Research Programme; Funding: New Zealand Ministry of Business, Innovation and Employment. Aim: Develop innovative methods for rapid and cost-effective characterisation of New Zealand's groundwater systems.

Geophysical Methods – Traditional methods for aquifer mapping and characterization are prohibitively time consuming, costly, and provide data at limited spatial and temporal resolution. As project member, I am *responsible* to develop and apply data-fusion and machine-leaning schemes to hydrogeophysical data for which there are no published methods or guidelines. To date, my research *demonstrated* that it is possible to fuse disparate, sparse, noisy, redundant, and scale-dependent airborne and borehole hydrogeologic data for mapping of heterogeneous alluvial physical and chemical aquifer properties in Ettrick and Strath- Taieri basins of the Otago region. This research *resulted* in new machine-learning software, domestic and international conference abstracts and presentations, and a journal article describing the near-real time mapping heterogeneous surficial aquifers. Case study areas include Otago region, New Zealand; and northeast Nebraska, USA. One GNS report and second journal article are in preparation. Collaborators: Otago Regional Council, NZ, Semeion Institute, IT, Geoscience Australia, AU, US Geological Survey, USA.

Satellite Remote Sensing – Large-scale fluxes of water across the subsurface-atmospheric interface are poorly known in New Zealand. Knowledge of this information is critical for holistic management of water-resources. As task leader, I am *responsible* to direct and participate in research on satellite-derived rainfall recharge across New Zealand (NZ); and perform research using machine-learning (ML) and

related techniques for spatiotemporal downscaling of the National Institute of Water virtual climate station network data, and real-time satellite classification of landscape soil and vegetal components, mineral prospecivity and geothermal resource mapping (rock alteration and geochemical) for which there are no published methods, approaches, or guidelines. To date, this research *demonstrated* it is possible to calculate and quantify uncertainty in national satellite-based rainfall recharge estimates; and that stochastic training of unsupervised ML network can identify landscape soil and vegetation components with up to 92% accuracy. To date, this task *resulted* in software, GNS report, proceedings paper, and journal submission describing the mathematics, techniques, and results. Case study areas include Southland region, New Zealand, and Minas Gerias Brazil. Collaborators: Environment Southland Regional Council, NZ; National Institute of Water (NIWA) and Atmospheric Research, NZ; and Empresa Brasileira de Pesquisa Agropecuária, Brazil.

Tracer Validation in Hydrogeology – GNS Theme: Research Programme; Funding: New Zealand Ministry of Business, Innovation and Employment. Aim: Improve groundwater models by conceptualization, calibration, and validation using hydrochemical, temperature and age tracer data.

Data fusion, Imputation, and Knowledge Discovery - As a task leader, I am *responsible* to perform research on development and application of computationally-intelligent schemes for which there are no published methods, approaches, or guidelines. My research will *result* in new software and papers describing data fusion, optimal subset selection of input information; and knowledge discovery to improve the conceptualization, calibration, and validation of groundwater models. To date, this research *demonstrated* it is possible to impute sparse hydrochemistry data sets, identify lithologic controls on surface-groundwater interaction; reduce uncertainty using optimal subsets; estimate hydrostratigraphic unit information for model conceptualization and optimal starting parameter values and spatial statistical constraints for inverse problem; and apply a hybrid optimization scheme to obviate calibration issues with local minima. This research *resulted* in one GNS report, several conference abstracts, local and international presentations, and one post-doctoral research fellow. Case study area includes the Southland region. Collaborators: Environment Southland region, NZ; Semeion Institute, IT; University of Brasilia; BR.

From**:** July 1, 2014 To: June 30, 2015

Geothermal Supermodels –GNS Theme: Research Programme; Funding: New Zealand Ministry of Business, Innovation and Employment. Aim: develop next generation integrated geothermal modeling tools, including a new flow simulator, geophysical and geochemical codes, and the linkages between them.

Develop Improved Modeling Tools - The aim of this task was to understand the effect of regional groundwater flow on the temperature distribution in a geothermal reservoir. As task leader, I was *responsible* to model self-potential response to coupled flows induced by primary potentials associated with flow of water, heat, and electrical resistivity for which there are no published software, methods, approaches, or guidelines. My research *resulted* in new software and supporting files to conduct explicitly-coupled forward and inverse modeling of electrokinetic response to either heat flow or groundwater flow. Application of this software *demonstrated* it is possible to model the spontaneous potential using temperature observations from the Monroe-Red Hill geothermal system. Joint inverse estimation and distribution of thermal conductivity, coupling coefficients, and electrical resistivity was possible using Tikhonov regularization. This task *resulted* in a GNS report, an international conference abstract and presentation, GNS report, and proceedings paper, unpublished software and files used to conduct this study are available for future work. This work attracted a post-doctoral research fellow who is working with me to implement a cross-gradient constraint to simultaneously estimate hydrogeophysical properties at the hydrothermal deposit. Case study area includes the Taupo Geothermal field, NZ, and

Monroe-Red Hill geothermal area, Utah, USA. My current research involves forward and inverse modeling of the electrokinetic response to coupled heat and groundwater flow.

From**:** October 1, 2012 To: June 30, 2014

Integrated Methods Development - USGS Theme: Energy and Minerals; Funding: Mineral Resources Program. *Geophysical Methods – Geophysical Theory and Software*.

Fusion of Disparate Data. Subtask chief: M.J. Friedel. The USGS and its Mineral Resources Program require new methods for the integration and interpretation of disparate data types in support of mineral resource assessments. As a project member, I was *responsible* to perform research on joint-inverse applications for improved subsurface imaging of geology for which there are no published methods, approaches, or guidelines. My research will *result* in software and papers describing the simultaneous integration, estimation, and uncertainty analysis multiple data sets, e.g. geophysical, geologic, and hydrogeologic data, using joint inverse and hybrid techniques. To date, two journal papers were written describing novel joint inverse modeling approaches for improved imaging and quantification of uncertainty in subsurface structures. An accompanying open file report is being written for general use that describes the scripts, input files, and available joint-inverse software. To date, this research *demonstrated* that (1) the prediction of observation samples can be used to map the objective function surface and quantify the statistical distribution of likely model parameters (image), and (2) the addition of a cross-gradient constraint to a gradient solver can be used to integrate disparate data (seismic receiver function, seismic dispersion, magnetotelluric) for improved imaging of lateral and vertical structure (velocity and resistivity). My research involved hybrid modeling in which joint numerical and soft-computing techniques are combined to fuse big data for improved earth imaging.

Technical Assistance to the U.S. Army - USGS Theme: Core Science Systems; Funding: Engineer Research Development Center, U.S. Army.

Detection of Improvised Explosive Devices. Improvised explosive devices (IEDs) are constructed and deployed in ways other than conventional military action. Reducing risks through the remote location of IEDs is a goal of the Army for which there are no published methods, approaches, or guidelines. As task chief, I was *responsible* to coordinate members and perform research for locating IEDs using remotely measured data. This research is important because traditional processing schemes are plagued by large, disparate, sparse, and uncertain data sets. Preliminary research *resulted* in a paper describing a new hybrid-modeling scheme in which space-borne hyperspectral data were used to discriminate soils and vegetation in Brazil. A second paper is being written that compares and contrasts alternative machine-learning schemes for enhanced discrimination of soils and vegetation. This research *demonstrated* that machine-learning algorithms trained with stochastic data sets can be used to classify soils and vegetation in the difficult tropical environment using noisy satellite data. Future plans are to remotely identify changes in soil conditions using numerically simulated sensor responses, and devise a statistical methodology to quantify uncertainty in site classifications. This research provided the US military with technology for reducing fatalities of soldiers engaged in combat worldwide.

From**:** October 1, 2012 To: September 30, 2013

*Geophysical Remote Sensing – "The Chameleon.***"** The military collects and stores various types of spatiotemporal geophysical data worldwide. The Army wants to expand use of these data in meeting various task requirements for which there are no published methods, approaches, or guidelines. As task chief, I was *responsible* to coordinate members and perform research leading to near real-time airborne geophysical imaging. Until now, this goal was considered intractable because of challenges associated with large, disparate, and scale-dependent data. Preliminary research *resulted* in presentations and journal

article (in review) describing a new hybrid modeling scheme in which airborne electromagnetic data were used to perform near real-time imaging of resistivity structure in a glacial aquifer. To date, this research *demonstrated* that remote EM measurements could be input to a classifier trained using measurements and inverted geophysical structure to reduce the time from acquisition to interpretation (from months to hours). This approach was tested in collaboration with Brazilian researchers for application to data collected using ground resistivity, and sensors mounted on drones and satellites. A second paper was written in which a hybrid data-integration scheme is used for computing near real-time hydrostratigraphy.

From**:** October 1, 2011 To: September 30, 2013

Reliability of Geophysical Instrument Response to Unexploded Ordnance. The risks associated with cleanup of military land provide impetus for research on locating buried unexploded ordnance (UXO). The army wants to reduce hazards associated with false alarms when using commercial equipment for which there are no published methods, approaches, or guidelines. As task chief, I was *responsible* to perform research on the reliability of geophysical instrument response to UXO. My research *resulted* in presentations and a USGS report describing the statistical reliability of experiments conducted using time-domain electromagnetic and total field magnetometer systems, and the effects of environmental factors on system reliability. Using a nonparametric statistical approach *demonstrated* that at least one test associated with each experiment differed among the group and for all instruments. Pair-wise comparison among median test values revealed statistically similar (and dissimilar) field tests for each experiment. Application of data-mining techniques revealed the relative importance of environmental factors. These findings are important and relevant for the remediation of land containing UXO in the US and countries worldwide.

From**:** October 1, 2011 To: September 30, 2012

Hydrogeologic Framework for Glacial Aquifers - USGS Theme: Water; Funding: State of Nebraska.

Estimation of Subsurface Attributes Using Hydrogeologic and Geophysical Measurements. Groundwater models are used to answer management questions regarding quantity and quality of water. Because models are uncertain and hydrogeologic data spatially-limited, investigators often rely on a model improvement strategy based on the independent evaluation of geophysical data. As task chief, I was *responsible to* devise an alternative model improvement strategy in which disparate data could be integrated simultaneously for which there are no published methods, approaches, or guidelines. My research *resulted in* presentations and a draft journal article describing a novel hybrid modeling scheme in which spatiotemporal hydrogeologic and geophysical information are simultaneously integrated to compute a conceptual hydrstratigraphic model. The application and testing *demonstrated* ability to integrate borehole, airborne, and satellite measurements; simultaneously estimate continuous hydrogeologic properties with reduced uncertainty; and estimate continuous spatial distribution of hydrostratigraphic units for numerical model building. This new approach can be applied to improve numerical models for understanding groundwater-resources worldwide.

From**:** October 1, 2009 To: September 30, 2012

Advanced Modeling of Nonlinear Problems in Earth Science - Project Chief: M.J. Friedel; USGS Theme: various; Funding: various international agencies. Despite progress made in numerical inverse modeling, their ill-posedness and nonlinearity promotes computational challenges associated with convergence, nonuniqueness, and uncertainty. As project chief, I was *responsible* to devise and implement novel modeling strategies for solving nonlinear problems associated with USGS themes for which there are no published methods, approaches, or guidelines. My research *resulted in* presentations and journal papers describing the formulation and testing of new methods that were developed together

with visiting scientists (below). This research *demonstrated* that new modeling approaches did not need to rely on the stationarity condition, can incorporate scaling, strike a balance between practicality and exactitude, and reduce uncertainty.

Hillslope Hydrology (Task 1; USGS Theme: Water; Funding: Fundação de Amparo à Pesquisa do Estado de São Paulo, Brazil). As task chief, I was *responsible* to interpret relations between hillslope weathering and shallow ground-water quality in the Paraná basin, Brazil. This research *resulted in* devising a data mining-GIS approach for interpreting hillslope chemical weathering that is described the along with guidelines and applications in coauthored presentations, university courses, and a journal publication. The research *demonstrated* that weathering processes reached a steady-state condition at the regional scale; whereas the local-scale chemical concentrations were related to redox conditions along the vertical curvature of the hillslope.

Spatial Physical Properties (Task 2; USGS Theme: Water; Funding: Fundação de Amparo à Pesquisa do Estado de São Paulo, Brazil). As task chief, I was *responsible* to estimate properties from spatially-limited sampling at different scales: soils in the Vargem de Caldas basin, Minas Gerais, Brazil, and groundwater properties in the Serra-Geral fractured basalt aquifer, Paraná, Brazil. This research *resulted* in devising a stochastic-data mining approach to estimate spatially-distributed properties that is described along with guidelines and applications in coauthored presentations, university courses, and two journal publications. This research *demonstrated* that despite spatially-limited measurements, continuous distributions could be estimated for soil properties based on their nonlinear relations to regional morphometric features, and hydrogeologic properties; and dependent variables could be estimated based on their nonlinear relations to airborne electromagnetic measurements. This approach was generalized to provide optimal starting values and geostatistical constraints for groundwater and any numerical inverse problems characterized by spatially-limited field data.

Geophysical Imaging of Deep Structures (Task 3, USGS Theme: Core Science Systems, Energy and Minerals, and Water; Funding: Fulbright Scholar Program). As task chief, I was *responsible to* improve imaging of deep sedimentary and mantle (Moho) discontinuities in the Paraná basin, southeastern Brazil. This research *resulted in* devising new approaches for assessing uncertainty during the joint inversion of seismic data and seismic and electrical (disparate) data that is described along with guidelines and applications in coauthored international presentations, university courses and seminars, and two journal articles. This research *demonstrated* the ability to quantify improvements in the joint inversion of seismic receiver function and surface-wave dispersion data with reduced uncertainty when imaging the core-mantle boundary; and the possibility to improve imaging of lateral and vertical heterogeneities when jointly inverting seismic and magnetotelluric data. The algorithm can be applied to integrate multiple geophysical and geophysical-hydrogeologic data types for solving problems in minerals and energy.

Climate Change (Task 4; USGS Theme: Climate and Land Use Change, and Water; Funding: Fundação de Amparo à Pesquisa do Estado de São Paulo, Brazil). As task chief, I was *responsible to* improve current reconstructions and forecasts of climate-change variables across various scales. My research *resulted in* devising a novel approach to perform simultaneous reconstructions and forecasts of spatiotemporal climate-change variables. The research *demonstrated* applicability of using: (1) a soft computing approach to reconstruct temperature, precipitation, and drought over the period of 0-2000 across the southwest and south-central US, global regions between 30 degrees of latitude, hemispheres, and earth scales; and (2) a hybrid approach to forecast conditional likelihood for annual climate-change in the southwestern United States. Because the new forecasting approach can be applied at any spatiotemporal scale, it can be further extended to local and global reconstructions where self-similarity exists. I described these approaches, guidelines and applications in coauthored international presentations, university courses and seminars, and two journal articles. These results have broad economic, political, and social implications worldwide. Also, I was invited to participate in convening a NATO workshop, edit a book on climate change relating

to national and global security, and participate on a scientific workgroup involving researchers from the Brazilian Agricultural Institute, University of São Paulo, Brazilian National Institute for Space Research, University of Campinas, and Desert Research Institute. Since the 2012 invitation, I am a contributing researcher on the largest climate-change project in Brazil (http://www.cpa.unicamp.br/alcscens/).

From**:** October 1, 2011 To: September 30, 2012

Technical Assistance to the Government of Mauritania - USGS Theme: Energy and Minerals, and Water; Funding: World Bank.

Hydrogeologic Expert. This was a restart of an earlier study placed on hold because of a coup de tat. The new Mauritania government wanted to complete evaluation of mineral-resource potential to promote their mining sector in the world market. As task chief, I was *responsible* to provide hydrologic expertise on this international and multi-disciplinary team. My research *resulted in* presentations and reports (English and French) on the water resources of Mauritania, a hydrogeologic map of Mauritania (1:100,000), and training of Mauritanian scientists on advanced groundwater modeling. The research *demonstrated* that existing hydrogeologic and geophysical data could be integrated and used to identify three hydrogeologic units for groundwater exploitation in support of future mineral-resource and public drinking-water supply development activities.

From**:** October 1, 2006 To: September 30, 2012

Development of Mineral Environmental Assessment Methodologies - USGS Themes: Energy and Minerals, Ecosystems; Funding: Mineral Resources Program.

Alternate Modeling Paradigms and Methods to Evaluate Uncertainty. Land managers, regulators, and decision makers want to understand the environmental risks associated with mining known and undiscovered mineral resources. As subtask chief, I was *responsible* to evaluate the effects of natural and anthropogenic stresses on water-quality in existing and proposed mining watersheds. My research *resulted in* presentations (national and international, conference and workshop), abstracts, and journal articles describing new approaches for modeling complex systems for which there are no published methods, approaches, or guidelines; a partnership with scientists at the Geological Survey of Finland to address fate of mining contaminants in bog-dominated cold-regions; and the teaching of two groundwater modeling courses at university of Kuopio. My research *demonstrated* the ability to quantify uncertainty in scale-dependent and multi-component reactive groundwater systems, determine the significance of climate and hydrology in the formation of natural acid-rock drainage in mineralized watersheds, predict the response of coupled watershed processes under climate change, predict the water-quality response across a hydrothermal alteration-mining gradient, predict the mineral-resource effects on aquatic ecosystems, predict the predominant type of basin hydrothermal alteration and presence or absence of mining activity, and that it is possible to differentiate among the continuum between inputs of background and mine-related acidity and metals.

From: October 1, 2008 To: September 30, 2011

Quantitative Global Mineral Resource Assessment - USGS Theme: Energy and Minerals; Funding: Mineral Resources Program (MRP).

Stochastic Mineral-Resource Software (Task Chief: 25%-50% per year). Quantitative mineral-resource assessments provide government and industry decision makers with information about the likelihood of undiscovered mineral endowments. As task chief, I was *responsible* to coordinate members and perform research activities related to software and methods development for mineral prospectivity in undiscovered

terrain. My research *resulted in* a stochastic simulator with new functionality for use as an Excel add-in; a new data-driven economic filter suitable for application to copper porphyry and other mineral resource assessments worldwide; and statistical methods (traditional, multivariate, geostatistical estimation and simulation) to summarize population and spatial patterns in data sets, improve deposit density descriptions, identify and correct sample heterogeneity and impute missing data in USGS grade and tonnage models; these developments are described in a guidance memorandum, presentations (management, AGU Union, USGS modeling, and keynote international), USGS manuscripts, and a journal article. This research *demonstrated* the importance for MRP modelers to correct and improve quantitative resources estimates by assigning appropriate number of Monte Carlo trials, incorporating correlation among tract metals and among tract deposits, ensuring homogeneity of grade and tonnage models, estimating true values of zeros in grade and tonnage models, fitting and hypothesis testing of grade and tonnage models, applying economic constraints, and aggregating pre- and post- tract assessment resource estimates.

From: October 1, 2010 To: September 30, 2011
From: October 1, 2007 To: September 30, 2008

All Time Electromagnetic System - USGS Theme: Core Science Systems; Funding: Strategic Environmental Research and Development Program, Department of Army**.**

UXO Discrimination. Unexploded ordnances (UXO) pose an ongoing worldwide problem for military agencies that are transferring training ranges or munitions disposal areas to civilian control. An important U.S. military goal is to reduce hazards by improving geophysical technology to locate UXO. As a project member, I was *responsible* to perform research that improved detection and discrimination of buried UXO using measurements from a prototype USGS electromagnetic system. My research *resulted in* the development and application of new and novel processing schemes for identifying UXO, additional funding from the Army, national and international conference presentations, and a journal article. The work *demonstrated* the importance of applying a regularization scheme to the numerical inverse algorithm for improved target discrimination (from 60% to about 75%). The soft computing approach further enhanced target discrimination and facilitated the simultaneous estimation of depth, orientation, and weight of UXOs. Combining these approaches in a statistical hybrid framework increased the discrimination accuracy to about 95%.

From: December 1, 2008 To: December 30, 2011

Technical Assistance to the Republic of Kyrgyzstan – Project chief: M.J. Friedel; USGS Theme: Water; Funding: U.S. Civilian Research & Development Foundation (CRDF).

Mitigation of Groundwater Flooding in the Bishkek Region of Kyrgyzstan. Southeast Asia is undergoing climate change. A goal of the Kyrgyzstan government is to mitigate risks associated with climate-induced groundwater flooding. In response to a request by the Director, Kyrgyz Scientific Institute of Irrigation (KSII), I formulated and coauthored this study. As a project chief, I was *responsible* to perform research activities that included development and testing of models for which there are no published methods, approaches, or guidelines; provide groundwater training; and participate in scientific exchange visits. My research *resulted in* the development of nonstationary analytical equations for studying infiltration and vertical drainage in arid intermountain valleys, development and calibration of a numerical groundwater flow model of the Bishkek region, a visit to KSII by me to train research staff on advanced groundwater flow modeling, and a US field trip that I lead for visiting KSII scientists, and a draft journal article on vertical drainage calculations. These results, guidelines and applications, were described in presentations at NATO workshops and a final report to CRDF. This work *demonstrated* that lowering of ground-water

levels in the northern Bishkek region was possible using strategies involving reduced irrigation water losses in the recharge zone, horizontal agricultural drainage, and vertical wells at selected regions. Tradeoffs among strategies are associated with time, capital and operational expenses, and potential usage or disposal of produced water.

From: October 1, 2008 To: September 30, 2010

Unsaturated Zone Project – USGS Theme: Water; Funding: National Research Program, WRD, USGS.

Water and Solute Transport in Macroporous Soils (Task chief: J. Tindall, USGS Theme: Water; Funding: in-kind). Given the uncertainty in climate change and numerical complexities associated with simulating energy balance at the earth-atmosphere interface and subsurface fluxes, the development and application of appropriately coupled numerical models are limited, and calibration and prediction guidelines nonexistent. As a project member, I was *responsible* to develop new software and provide project mentorship. My research *resulted in* the first USGS inverse application of a variably-saturated dual permeability flow and transport model using PEST protocols (DUALPi), mentoring the task chief in inverse applications of this new model, and mentoring a graduate student in laboratory measurement and analysis of coupled and hysteretic phenomenon. This work *demonstrated* that numerical inversion of dual-domain flow and transport equations was possible for studying climate-induced movement of subsurface moisture and solutes.

From: October 1, 2006 To: September 30, 2009

Assessment of Wildfire Related Hazards on Human and Ecological Communities: A Demonstration Project in the Front Range of Colorado Fire Science - USGS Theme: Natural Hazards; Funding: USGS Bureau Leadership Council.

Shallow Landslides and Debris Flows - Natural Hazards Resulting from Wildfire in Forested Regions. Residents of Grand County, Colorado are threatened by natural hazards such as wildfire, flooding, and debris flows. An important goal of local, State, and Federal authorities was to understand the risks of post-wildfire effects in these mountainous terrains. As task chief, I was *responsible* to model nonlinear post-wildfire hazards and their uncertainty for which there were no published methods, approaches, or guidelines. My research *resulted in* devising novel approaches to quantify nonlinear relations between pre- and post-fire variables and hydrologic mechanisms and responses, evolve nonlinear predictive debris-flow equations, quantify nonlinear predictive uncertainty in debris-flow equations, determine the likelihood of wildfire-induced hydrologic response (debris flow, flooding, mud flow, or no response) and initiation mechanism (runoff, landslide, runoff and landslide, none), and forecast effects of climate change on post-fire hazards. This work was described in presentations and two journal articles; and it *demonstrated* that data-driven modeling can be used in forecasting real-time post-fire hazards, and long-term post-recovery processes and effects of climate-change scenarios. Also, genetic programming can be used to evolve nonlinear post-fire debris-flow equations with less prediction uncertainty than the single traditional equation. Both modeling approaches can be applied to nonlinear multivariate problems in all fields of study.

From**:** October 1, 2006 To: September 30, 2008

Technical Assistance to the Government of Mauritania - USGS Themes: Energy and Minerals, and Water; Funding: World Bank. The Mauritania government wanted to promote its mining sector in the world market. In response to the international request for assistance, I coauthored the original proposal and participated in negotiations that lead to the $1.5M contract. As task chief, I was *responsible* to provide hydrologic expertise in support of the national mineral-resource assessment. My research *resulted*

in an inventory and review of existing hydrogeologic data, a preliminary country-wide hydrostratigraphic map, a country-wide environmental stratification and water-quality monitoring design, and a groundwater model calibration strategy, where were described in four USGS manuscripts. The work *demonstrated* the importance of using airborne geophysical data to define the two groundwater basins. In the porous basin, there is uniform vertical recharge and localized discharge coincident with groundwater pumping at Nouakchott inducing saline groundwater flow from the Atlantic Ocean, inter-basin exchange of fresh groundwater. In the fractured rock basin, there are local recharge areas and groundwater flows across country boundaries. The Senegal River serves as a source and sink of fresh groundwater to both basins. Combining hydrogeologic unit maps with drilling productivity, groundwater-quality, and geophysical interpretations identified three water-resource development targets for future exploitation.

Technical Assistance to the Government of Finland - USGS Themes: Energy and Minerals, and Water; Funding: Geological Survey of Finland. The Finish government wanted to provide information to Federal land managers, regulators, and other decision makers for understanding environmental issues associated with mining known and undiscovered mineral-resource occurrences. As task chief, I was *responsible* to conduct research that quantified effects of natural and anthropogenic stresses on water-quality in existing and proposed mining watersheds for which there are no published methods, approaches, or guidelines. My research *resulted in* quantifying the efficacy of reactive barriers to mitigate mine-waste problems; and developing and teaching new courses at University of Kuopio: multi-component reactive transport modeling, and ecological risk assessment for mining environments. My findings formed the basis for presentations, course material, and a manuscript. The research *demonstrated* the various options and their efficacy for mitigating potential pollution by acidity and metals.

From: October 1, 2005 To: September 30, 2007

Technical Assistance to the Government of Romania – Project chief: M.J. Friedel, USGS Themes: Energy and Minerals, and Water; Funding: World Bank. More than 2,000 years of mining in Romania has contributed to the deterioration of facilities with on-going and catastrophic pollution of the environment. In response to this international request for assistance, I formulated the proposal and participated in negotiations that lead to a $900K contract. As project chief, I was *responsible* to lead and participate on the multi-disciplinary and international team of experts (USGS and US Army Corps. of Engineers, USA; SRK, South Africa; ENINVEST, Romania). My participation *resulted in* a Tisa Basin tailings and waste dump inventory and risk prioritization, a written engineering and environmental guidelines for tailings and waste dump facility management, a reconnaissance study of water quality in the mining affected Aries River basin, a sediment transport model of the mining-affected Aries River basin, and a transport model of reactive chemistry in the tailings. Findings from this study formed the basis for a final report provided to the World Bank. This work *demonstrated* to World Bank officials that the Romanian government was taking steps in the clean-up and mitigation of environmental pollution. Given this prerequisite, Romania was allowed to join the European Union in 2007.

National Maps - Source/Process Studies of Selected Contaminants Associated with Mineral Deposits - USGS Themes: Energy and Minerals, and Water; Funding: Mineral Resources Program. U.S. mining and processing of resources to satisfy energy and raw material requirements has disrupted land use and drainage patterns, contaminated soil and water resources, and affected biodiversity and ecology. The aim of this study was to understand the environmental impact of historical mining activity at the national scale. As task chief, I was *responsible* to perform research activities that included development and testing of models for which there are no published methods, approaches, or guidelines. My research *resulted in* devising a national stochastic framework for evaluating and interpreting the scope of the abandoned mine land problem. The work *demonstrated* the benefits of using a random stratified basin integration process. The new framework formed the basis for several tasks in a new USGS project: Development of Mineral Environmental Assessment Methodologies.

From: October 1, 2005 To: September 30, 2006

Tensor Magnetic Gradient System - USGS Themes: Core Science Systems; Funding: Strategic Environmental Research and Development Program, U.S. Department of Army. One approach to identifying buried unexploded ordnance (UXO) was based on near real-time acquisition and processing of magnetic gradients. Because of the earth's large magnetic field, difference in orientation of magnetic heads, and rotation during data acquisition, the near real-time identification of a UXO required development and implementation of a numerical inverse algorithm. As project member, I was *responsible* to develop a modeling approach for identifying UXO based on measurements from the USGS prototype tensor magnetic gradient system (TMGS) for which there were no published methods, approaches, or guidelines. My research *resulted in* development of a numerical inverse algorithm for application to the TMGS, guidelines, and recommendations for improving the methodology. This work *demonstrated* that UXO location could be improved using the estimated nonlinear model coefficients for computing the tensor magnetic field measurements, estimated angles for tensor rotation of all magnetometers, and estimated the difference between known and adjusted set of magnetic field values. This study also identified systematic noise and provided a recommendation improve UXO by jointly inverting TMGS and all-time electromagnetic system data which became the basis for a new proposal.

Technical Assistance to the Government of Haiti - USGS Themes: Natural Hazards, Water; Funding: U.S. Agency for International Development (USAID). Haitian residents are threatened by natural hazards. Hurricanes are prominent among these natural hazards, but the monsoon rains also pose an increased risk of catastrophic flooding and landslides because of denuded mountainous terrains that exaggerate the hydrologic response. As project chief, I was *responsible* to devise a model-based flood warning system for Haiti for which there were no published methods, approaches, or guidelines. My research *resulted in* devising a novel three-part predictive methodology, summary report, presentation, and training to USAID and Haitian government. The work *demonstrated* the possibility of extending conventional inverse theory to ungaged basins in which conservative (worst-case) precipitation-flood inundation nomograms could be used as a flood-warning tool. The Haitian government is still using this flood-warning tool for determining when to evacuate villages in selected basins bordering the Dominican Republic.

Evaluation of Directional Borehole Radar and High Frequency Sounder - USGS Themes: Core Science Systems, and Water; Funding: U.S. Environmental Protection Agency. The USGS developed a high-frequency sounder for acquiring measurements in response to pollution by toxic chemicals. Interpretation of the geophysical response was difficult without appropriate geophysical software and interpretation methods. As project member, I was *responsible* to assist in the development of relevant processing and interpretation methods, and guidelines for imaging low dense non-aqueous phase liquids. My research *resulted in* a new tomographic algorithm for radar imaging in-situ changes of electrical conductivity and permittivity following a contaminant spill, a regularized layered-earth inverse scheme was devised and implemented for lateral imaging using the high-frequency sounder which were written-up and presented as part of a Ph.D. dissertation that I was a co-advisor. This work *demonstrated* that the standard deviation of estimated parameters (on a per-pixel basis) could provide probability maps of contamination in the region between boreholes.

Handcart Gulch - Source/Process Studies of Selected Contaminants Associated with Mineral Deposits - USGS Themes: Energy and Minerals; Funding: Mineral Resources Program. U.S. mining and processing of resources has disrupted land use and drainage patterns, contaminated soil and water resources, and affected biodiversity and ecology in Handcart Gulch. As task chief, I was *responsible* to mentor project members on: water and sediment sampling, analyses, and interpretation of geochemistry and isotopes, coupled inverse modeling with emphasis on model calibration by joint inversion of mass

and energy data, and computing predictive uncertainty for more accurate interpretation of contaminant transport at an abandoned mine land site.

Unsaturated Zone Project –USGS Theme: Water; Funding: National Research Program, WRD, USGS.

Biodegradation of PAHs and PCBs (Task chief: J Tindall, USGS Theme: Water; Funding: in-kind). The traditional split-sample validation of unsaturated zone models was considered weak for various reasons. As project member, I was *responsible* to formulate and apply an alternative approach to validate our recently published numerical biodegradation model. My research *resulted in* formulating a strong validation test based on a novel inverse approach. The work *demonstrated* the ability to estimate the limits of nonlinear predictive uncertainty. The application of this new approach was described in a journal article and led to an invitation to teach related courses at Hohai University, Nanjing, China.

From: October 1, 2004 To: September 30, 2005

Post-Wildfire Flood Potential in Willow and Mitchell Creek Watersheds - USGS Themes: Natural Hazards, and Water; Funding: Federal Emergency Management Agency. The post-wildfire effects in mountainous terrains of Colorado are likely to exaggerate the hydrologic response with subsequent risk of flooding and debris flows. I was sought as a technical expert by management of the Federal Emergency Management Agency (FEMA) and USGS Colorado Water Science Center Director. As project member, I was *responsible* to mentor the project chief on using modeling methodologies and guidelines that I previously developed and were adopted by FEMA. My participation *resulted in* using these modeling methodologies to predict the timing and spatial extent of flooding in burned mountainous watersheds and across unconfined and urbanized alluvial fans of Glenwood Springs, CO. The work *demonstrated* it was possible to determine the wildfire-induced flood plain boundaries for reestablishing FEMA insurance rates.

Unsaturated Zone Project – USGS Theme: Water; Funding: National Research Program, WRD, USGS.

Enhanced Remediation of Toluene in the Vadose Zone (Task chief: James Tindall; USGS Themes: Water; Funding: In-kind). In situ bioremediation of hazardous material can play an important role in environmental restoration of superfund sites, oil spills, leaky underground storage tanks, and commercial, industrial, and agricultural operations. As project member, I was *responsible* to devise a method for interpreting his laboratory and field measurements of $C0_2$ and toluene biodegradation. At the time of this study, there were no published approaches, methods, or guidelines to assist this effort. My research *resulted in* a development and application of a gas flux diffusion model that was described in a journal article. The work *demonstrated* the importance of quantifying the partitioning, direction, and rates of gas flux movement for a comprehensive understanding of in-situ vadose-zone biodegradation. The methodology we developed in this project was later used to remediate coastal wetlands (up to 30,000+ acres at last count) beginning Fall 2010 due to the BP Oil Spill in the Gulf of Mexico.

From: October 1, 2003 To: September 30, 2004

Technical Hydrologic Assistance to the Government of El Salvador - USGS Themes: Natural Hazards, and Water; Funding: U.S. Agency for International Development. The El Salvadoran government received an international loan to develop a new seaport for increased capacity and competitiveness in the global market. The likelihood for recurring monsoon storms and hurricanes, however, raised concern about potential flooding of the proposed seaport. As task chief, I was *responsible* to evaluate the likelihood for flooding the proposed seaport under extreme hydrologic events. At the time of this study, there were no published approaches, methods, or guidelines to assist this effort. My research *resulted in* devising a novel two-step regionalization procedure to predict probable flooding in coastal

ungauged basins. The new modeling approach resulted in special international assignments, international keynote presentation, and two international journal articles one of which was a special edition. This work *demonstrated* the efficacy of using dissimilarity equations among tributary basins (as soft prior information) to estimate parsimonious model parameter structure. The estimated joint set of parameter values formed the basis from which probable peak-flow discharge limits were estimated revealing increasing prediction uncertainty with basin size. In the downstream alluvial plain, model application of the estimated minimum/maximum peak-flow hydrographs facilitated simulation of probable 100-year flood-flow depths in confined canyons and across unconfined coastal alluvial plains. The regionalization procedure provides a tool for hydrologic risk assessment and flood protection planning for coastal basins worldwide.

Improvements to Conceptual Wildfire-Induced Flood Models - USGS Themes: Natural Hazards, and Water; Funding: Venture Capital Fund, USGS Director. Basin attributes used in flood modeling are commonly based on parameters derived from 30-m digital elevation models. As task chief, I was *responsible* to evaluate if higher resolution satellite information could improve wildfire-induced flood models. Because of its national importance, interdisciplinary collaboration, lack of guidelines, and my recent advances in simulating wildfire effects on flooding, I was sought as a technical expert to devise an approach for comparing the efficacy of using different satellite information types in improving conceptual wildfire-induced flood models. My research *resulted in* developing a novel approach to quantify the differences that spatial resolution (5-m IFSAR and 30-m DEM) had on estimated rainfall-runoff model parameter values. A USGS summary report was written and submitted to the Venture Capital coordinator. This work *demonstrated* that estimated parameter values could achieve quantifiable improvements.

Development of Predictive Equations using Knowledge Discovery Techniques - USGS Themes: Core Science Systems, and Energy and Minerals; Funding: National Institute of Occupational Safety and Health. The underground extraction of ore redistributes stress that often leads to rock bursts. As project member, I was *responsible* to develop an approach to predict critical stress from remotely measured geophysical data. My research *resulted in* successfully applying an evolutionary algorithm to discover equations for predicting critical stress from seismic tomographic data. The work *demonstrated* that the magnitude of mining stress could be estimated based on seismic tomographic velocity measurements.

From: October 1, 2002 To: September 30, 2004

Stochastic Optimization of Reservoir Operations for Water-Quality Benefits – Project chief: M.J. Friedel, USGS Theme: Water; Funding: Denver Water. Understanding the timing of reservoir pumping and returns on quantity and quality in of the Colorado River is of interest to local, State, and Federal water users. As project chief, I was *responsible* to determine if the reservoir could withdraw or return water without changing salinity of the river. At the time of this study, there were no published approaches, methods, or guidelines to assist this effort. My research *resulted in* devising the first evolutionary modeling scheme to optimize reservoir scheduling while minimizing salinity under stochastic conditions. This work *demonstrated* that it was possible to determine optimal days for withdrawing water from and returning reservoir water to the Colorado River so that concentrations of salinity would be minimized. This approach represents a departure from traditional thinking and it is of paramount importance in Western states experiencing drought and climate change. This approach has general applicability to the management of reservoirs worldwide. This novel optimization approach was adopted by Colorado's largest Water Management Districts for routine application to proposed and existing reservoirs.

Stochastic Modeling of the Effects that Sulphur Gulch Reservoir may have on Colorado River Quantity and Quality Near Grand Junction, CO – Project chief: M.J. Friedel, USGS Theme: Water; Funding: Northern Colorado Water Conservancy District and Denver Water. At the time of this project,

Colorado already experienced a period of drought lasting several years. To mitigate the effects of persistent drought conditions, Denver Water and other Colorado water management agencies wanted to increase storage capacity by building reservoirs on tributary streams to the Colorado River. As project chief, I was *responsible* to determine what effects that operating a single reservoir would have on the quantity and quality of Colorado River water. Prior to this study, forecasting operational effects of a proposed reservoir under uncertain hydrologic conditions was an unsolved problem. My research *resulted in* a published fact sheet and report describing the development and application of a stochastic model that included drought, system uncertainties, and variability in daily flow and carryover storage. Findings from this study were used as testimony by Denver Water in Federal Water Court. The work *demonstrated* that there was sufficient flow available in the Colorado River to refill the proposed Sulphur Gulch reservoir to capacity each year, and the probable annual median change in salinity caused by operating the proposed reservoir was less than the measurement error for salinity at the diversion points.

Post-Wildfire Technical Assistance to the United States Federal Emergency Management Agency - USGS Themes: Natural Hazards, Water; Funding: Federal Emergency Management Agency (FEMA). In the summer of 2002, wildfires burned the Hayman, Coal Seam, and Missionary Ridge drainage basins of Colorado. The FEMA wanted to determine flood-plain boundaries and where debris would occur, but this was not possible using traditional methods because streamflow data for most tributary subbasins were not available. As task chief, I was *responsible* to predict the probable location and amount of wildfire-induced debris flows. Prior to this study, predicting the effects of wildfires on flood and debris flow was limited to anecdotal observations and empirical approaches. My research *resulted in* a new modeling approach and guidelines that were adopted by FEMA for assessing flood and debris flow hazards and associated insurance rates. I described these results in presentations, USGS Report, and USGS training. This work *demonstrated* that a novel two-step numerical modeling approach could be used to predict recurrent flood-plain boundaries and likelihood for debris flows in all of the ungauged basins.

Model Calibration and Predictive Analysis of Vadose Zone Models - Project Chief: M.J. Friedel, USGS Theme: Water; Funding: Toxics Program, WRD, USGS. The success of vadose zone models to provide reliable predictions depend largely on the calibration process. Because the calibration process involves constraint measurements with limited information content, predictions made using these models are nonunique and uncertain. As project chief, I was *responsible to* develop an approach for reducing uncertainty in groundwater recharge prediction. My research *resulted in* extending conventional inverse theory in which a set of three governing partial differential equations were explicitly coupled and used together with a new regularization scheme for iterative updating of soft prior information. The work *demonstrated* that cross-over effects in jointly coupled moisture, heat, and solute information were mutually beneficial in reducing the prediction uncertainty in groundwater recharge estimates. Prior to giving seminar, workshop, university lectures, international keynote presentations, and publication in American Geophysical Union proceedings, NATO Advanced Studies Institute and Journal of Hydrology, calibration guidelines did not exist and prediction uncertainty was not computed. This work resulted in invited requests to convene international research session and membership to an important national hydrology committee.

From: October 1, 2002 To: September 30, 2003

Preferential Flow and Transport in the High Plains Aquifer - USGS Theme: Water; Funding: National Water Quality Assessment program, USGS. Groundwater sampling of the High Plains Aquifer detected elevated nitrate and pesticide concentrations, posing a health concern for 2 million people in eight States. As task chief, I was *responsible* to evaluate the plausibility of groundwater contamination by preferential flow mechanisms. My research *resulted in* devising a joint inverse approach using water, heat, and solute data to evaluate the hypothesis that contamination occurred through well bore leakage. This work *demonstrated* that at least some estimated model parameter combinations could promote

leakage through the wellbore gravel pack. The results of this modeling study were incorporated in a NAWQA summary report, and it has been used as course materials presented at various international universities.

From: October 1, 2001 To: September 30, 2002

South Platte River Basin Study Unit, National Water Quality Assessment – USGS Themes: Water; Funding: National Water Quality Assessment (NWQA) program, WRD, USGS. As a former NAWQA chief, I was asked to mentor the new SPLT project chief and serve as a task chief for the agricultural land use survey.

Agricultural Land-Use Survey. Understanding effect of drought on dry-land wheat farming and potential contamination of shallow unconfined aquifers was important issue to the National Water Quality Assessment (NAWQA) program. As task chief, I was *responsible* to devise the first stratified environmental sampling framework for this hydrogeologic setting. My research *resulted in* establishing a well network that formed the basis for which ~$250K was committed for installation and sampling of groundwater over a 2 year period. The work *demonstrated* the utility of a random stratified process to design monitoring networks. I used this new approach to devise surface and groundwater monitoring designs for World Bank studies in the Mauritania and Romania, and gave conference presentations on the effects of Salinity and drought effects on water quality.

Simulating Water and Solute Transport in Variably Saturated Macroporous Soils. Macropores can influence preferential flow and transport of agricultural chemicals and partitioning of energy at the earth's surface. As task chief, I was *responsible* to develop and apply a model for simulating flow and transport in macroporous soils. My research *resulted in* the incorporation of PEST protocols into the dual-permeability vadose-zone transport model (DUALP, developed by Dr. J. Nieber et al., University of Minnesota). The work *demonstrated* efficacy of the DUALPi code (unpublished) for calibrating a dual-domain finite-element method for simulating water and nutrient movement at the laboratory and field scales.

From: October 1, 1997 To: June 30, 2001

Upper Illinois River Basin Study Unit, National Water Quality Assessment Program – Project Chief: M.J. Friedel**,** USGS Theme: Water; Funding: National Water Quality Assessment program, USGS. In 1991, the U.S. Congress established the National Water-Quality Assessment (NAWQA) program of the USGS. The program goal was to evaluate water-quality in primary metropolitan basins across the US. As project chief, I was *responsible* for all aspects of administrative and scientific leadership for the Upper Illinois River Basin Study Unit (Wisconsin, Illinois, and Indiana). I hired and managed a multi-state, multi-disciplinary, scientific team; prepared work and financial plans with annual budgets to $2M; chaired annual liaison meetings; coordinated multi-state project activities with cooperating State and Federal agencies, and National NAWQA Synthesis Team and other study units; identified, planned, promoted, and maintained water-resource investigations with local, State, and Federal agencies; devised new approaches and coordinated and scheduled project activities including cooperating agencies; developed and participated in Science Center and headquarter reviews. In addition to core activities, I performed team workshops for various ecological and water-quality modeling applications. My oversight and participation *resulted in* determining the occurrence and distribution of, and trends in, quantity and water quality. This included random stratified monitoring designs; well drilling, installation, development, and slug tests/analyses; ecological, ground- and surface-water sampling, analyses, and interpretation including CFCs and dissolved gases; and unsaturated zone equipment installation, calibration, and monitoring. Several new research projects were started with high national visibility and success, some of which formed new national sampling strategies for urban land-use gradient, source water

risk, nutrients and solids, and load estimates. The work *demonstrated* timely completion and quality of workplans, technical presentations and scientific reports.

From: October 1, 1998 To: September 30, 2001

Urban Land-Use Gradient Study. Project Chief: M.J. Friedel**,** USGS Theme: Water; Funding: National Water Quality Assessment program, USGS. Water supplies for most people in the U.S. are derived from surface- and ground-water sources in urban basins. Prior to this study, the NAWQA program had no protocols for sampling and interpreting urban ecosystems. As project chief, I was *responsible* to direct and participate in development of a sampling methodology for quantifying relations among water-quality and aquatic communities. This work *resulted in* the first urban land use study for which data and interpretations were published. The protocol was adopted and used by the NAWQA program for sampling other metropolitan regions. Some data were used in the development of a stochastic model to forecast urbanization effects on ecological integrity, and an inverse modeling approach to support sampling and interpretation at ungauged sites. In addition to attracting a graduate student, opening new research area for TMDL, and predicting ecological integrity, this work led to an invited NATO sponsored keynote address and journal publication. This work *demonstrated* the importance of sampling across a spatiotemporal gradient to identify relations among urbanization effects and water chemistry, biology, and ecology; the forecast degradation of ecological integrity in tributary basins occurred at differential rates and with a probable distribution of likely outcomes; and the importance to balance model complexity and predictive uncertainty to avoid bias.

From: October 1, 1998 To: September 30, 1999

Variably-Saturated Transport in 2-Dimensions - VST2D. Project Chief: M.J. Friedel**,** USGS Theme: Water, Funding: Toxics Program, WRD, USGS. At the regional scale, vadose-zone processes are recognized for controlling short-term dynamics in hydrology and long-term water balance of hydrologic basins. At the time of this study, numerical vadose zone models simulated either water-heat or water-solute transport. As project chief, I was *responsible* to develop a numerical model for simulating water-heat-solute transport through the vadose zone. My research *resulted in* the development, verification, and publishing of first USGS vadose zone model for simulating coupled water-heat-solute transport in variably-saturated settings. This numerical model was described in presentations, USGS and journal publications, and led to membership in scientific committees. This study *demonstrated* that vadose zone theory could be extended to simultaneously solve an explicitly coupled set of governing nonlinear equations for water, heat, and solute transport.

From: October 1, 1997 To: September 30, 1998

Source-Water Risk Assessment in the Upper Illinois River Basin. Project Chief: M.J. Friedel**,** USGS Theme: Water; Funding: National Water Quality Assessment program, USGS. As part of the NAWQA retrospective analysis, program management became aware of numerous basin uncertainties in each study unit. As project chief, I was *responsible* to evaluate the possibility of using existing information to perform source-water drinking assessments. My research *resulted in* the creation of a large hydrogeologic database obtained from 40,000 well construction records. The work *demonstrated* that by using a combination of statistics, geostatistics, and mixing theory within a Monte Carlo framework, the probable concentrations, fluxes, and loads moving into and out of aquifers could be assessed for selected counties within a study unit. This work resulted in guidance presented to the NAWQA National Leadership Team**.**

CONSULTING GEOPHYSICIST and HYDROGEOLOGIST, St. Paul, MN 55044

From: October 1, 1996 To: September 30, 1996

Remediation of Radioactive Waste – Project Chief: M.J. Friedel, Funding: U.S. Department of Energy. The Department of Energy wanted to remediate low-level radioactive waste sites. I was *responsible* to devise a modeling approach to assess in-situ leach strategies for remediating radioactive waste sites. My research *resulted in* proposal, funding, and final report. This work *demonstrated* the benefits of using a nonlinear programming approach for evaluating alternative leaching configurations.

Vadose Zone Leaching of Agricultural Chemicals - Project Chief: M.J. Friedel, Funding: Agricultural Research Service (ARS), U.S. Department of Agriculture. The ARS wanted to understand study the dynamics of vadose zone leaching of agricultural chemicals. As project chief, I was *responsible* to simulate the solute leaching process under various conditions. My research *resulted in* a publication describing development and application of the first one-dimensional coupled water-heat-solute vadose zone transport model for simulating leaching of agricultural chemicals. In addition to coupled transport in porous media, I extended and published transport equations to include the freeze and thawing process (hydro-mechanical). This 1D model served as the basis for a two-dimensional model (VST2D) that was developed and published later.

Tomographic Imaging of Deep Underground Metal Mines – Project chief: M.J. Friedel, Funding: National Institute of Safety and Health (NIOSH). The extraction of ore underground often results in the redistribution of stresses that lead to catastrophic consequences and death. To improve miner safety, the NIOSH wanted to evaluate the efficacy of using remote geophysical imaging. As project chief, I was *responsible* for all aspects of study related to in-mine seismic tomographic imaging. My research *resulted in* a journal article describing spatiotemporal mapping of stress-induced velocity changes at the Sunshine silver mine, Kellogg, ID. I also developed and presented a short course on mining applications of seismic tomography at the Society of Exploration Geophysicists annual meeting. This work *demonstrated* the usefulness active 3-D seismic tomographic imaging for monitoring redistribution of stress and damage in underground mines.

From: October 1, 1991 To: September 30, 1995

Characterization and Remediation of Acid Mine Drainage From a Metal Mine Waste Impoundment – Project chief: M.J. Friedel, Funding: Advanced Mining Program, U.S. Bureau of Mines. Metal mining throughout the world has left a legacy of acid-mine drainage. As project chief, I was *responsible* to manage and lead a multidisciplinary team that developed technology and guidelines for remedial designs of mine tailings and waste impoundments. My research *resulted in* the characterization of unsaturated zone physical and chemical (liquid and solid phase) properties using spatial statistical and geophysical techniques; delineated boundaries and internal character of mine wastes, water table, and contaminant plumes, buried valley-fill aquifer and structure using various geophysical techniques (seismic, EM, magnetic, DC resistivity); coupled water-heat transport modeling to understand unsaturated-saturated flow, and geochemical and transport modeling including evolution of water chemistry, mixing, speciation, and reactions. This work resulted in Bureau committee appointments, presentations, short courses; conference proceedings and USBM publications.
From: October 1, 1990 To: September 30, 1995

In Situ Leach Mining of Unsaturated Chalcocite Ore – Project chief: M.J. Friedel, Funding: Advanced Mining Program, U.S. Bureau of Mines (USBM). Program management of the USBM wanted to develop approaches for characterizing chalcocite ore. As project chief, I was *responsible* to manage and lead a multidisciplinary team that developed technology and guidelines for characterizing Chalcocite deposits. My research *resulted in* new technology and guidelines for characterization and design of in situ leaching of fractured unsaturated Chalcocite deposit. In addition to management, I personally performed field testing (pump, packer, and tracer), sampling (water and rock) and analysis; deterministic modeling

(geochemical and transport modeling including evolution of water chemistry, mixing, speciation, and leach reactions along fractures); stochastic modeling to account for scale-dependence and fracture flow; inverse modeling to estimate spatial hydraulic properties. This work resulted in international and USA conference and university presentations; short course; international and USA conference proceedings, USBM, and journal publications.

From: October 1, 1989 To: September 30, 1994

Geomechanical and Geophysical Technology for Evaluating Rock Masses for In Situ Mining – Project chief: M.J. Friedel, Funding: Advanced Mining Program, U.S. Bureau of Mines. The USBM wanted to improve modeling in situ leach mining of fractured deposits. As project chief, I was *responsible* to manage and lead a multidisciplinary team that developed technology and guidelines for characterization of rock masses before, during, and after in situ mining. My research *resulted in* new technology and guidelines that were described in conference and university presentations; and conference proceedings, USBM, and journal publications. I personally evaluated fracture properties through hydromechanical modeling; uncertainty of spatial and temporal changes in hydraulic conductivity estimates; and spatial imaging using tomographic techniques. This work *demonstrated* the ability to quantify mechanical and storage properties of fractures during high-pressure injection testing, and imaging of fracture zones and solution movement using surface (CSAMT, TEM, ellipticity) and borehole methods (radio, radar, and seismic).

From: October 1, 1986 To: September 30, 1995

Assessment of Damage and Integrity of Mine Structures – Project chief: M.J. Friedel, Funding: Health and Safety Program, U.S. Bureau of Mines. The mining industry wanted to understand the spatiotemporal dynamics of stressed mine structures. As project chief, I was *responsible* to manage and lead a multidisciplinary team to study the damage and integrity of mine structures. My research *resulted in* the development of new methodologies including techniques, acquisition and interpretation software to identify high stress and damaged regions, and quantify peak stress in underground mines (hard and soft rock). I personally developed technologies for determining peak geostress using acoustic emission; assessing integrity of mine pillars and ribs using surface wave dispersion; real-time imaging of coal seam using machine cutter vibrations; and mine-wide imaging of rockmass failure and in-situ stress by active/passive traveltime/attenuation tomography and blast-induced particle motion. This work resulted in international and USA conference and short course presentations; international and USA conference, government, and journal publications. This work *demonstrated* the ability to remotely monitor the spatiotemporal dynamics of stress/damage during underground mining.

From: October 1, 1989 To: September 30, 1993

Cavity Detection Using Geophysical Methods – Project chief: M.J. Friedel, Funding: Abandoned Mine Land Program, U.S. Bureau of Mines. The USBM wanted to improve the ability to locate and characterize conditions of mine-related subsurface openings. As project chief, I was *responsible* to manage and lead a multidisciplinary team in the geophysical detection and assessment of underground cavities. My research *resulted in* evaluating surface and borehole geophysical technology and developing guidelines for mapping abandoned underground openings and imaging internal structure and attendant features. This work *demonstrated* the efficacy of surface resistivity (dipole-dipole, Schlumberger) and microgravity; and borehole backscattering, diffraction, and attenuation; cross-borehole radiowave attenuation and seismic traveltime tomography, and guided seismic wave tomography. This work resulted in conference presentations; proceedings and USBM publications.

From: May, 1984 To: June, 1986

Geophysical Studies – Project chief: Dr. R.E. Taylor, University of Wisconsin, Milwaukee, Wisconsin. As project chief, I was *responsible* to manage and lead field personnel in conducting and interpreting ground and borehole geophysical studies. My research *resulted in* interpretive geophysical reports supporting various environmental investigations. The work *demonstrated* the efficacy of geophysical studies (e.g. seismic refraction and reflection, DC electrical and VLF resistivity, and electromagnetic) to characterize proposed waste sites and delineate leachate plumes at existing landfills.

Research Assistant – Project chief: M.J. Friedel, Funding: Department of GeoSciences, University of Wisconsin; Milwaukee, Wisconsin. As research assistant, I was *responsible* for conducting mechanical property tests on sea ice for EXXON, and evaluate the magnitude of particle motion associated with VIBROSEIS exploration activities for CONOCO. My research *resulted in* completing mechanical property tests on sea ice samples, and development of VIBROSEIS modeling software and associated particle motion nomograms. This work *demonstrated* relevancy of strength characteristics for designing the hulls of ships traveling in the Arctic Ocean, and that the magnitude of particle motion could not affect pregnancies; this information was used as defense in civil court by CONOCO.

Hydrologic technician - Funding: Layne Geoscience, Milwaukee, Wisconsin. As hydrologic technician, I assisted in conducting and interpreting aquifer pump testing.

PROFESSIONAL ACHIEVEMENTS

Recent Accomplishments (Selected)

Discovery Science

Background – According to the National Science Foundation, answers to future problems in geoscience will require the fusion of both multidisciplinary data and traditional models. However, the fusion of multiple data variables (big data) is computationally challenging because they tend to be disparate, coupled, heterogeneous, noisy, nonlinear, redundant, scale-dependent, sparse, spatially-limited, and uncertain. Research in devising methods for intelligent fusion and analysis of big data represents state-of-the-art in geoscientific computing.
Role- I established the scientific basis, extended theory, and developed and implemented relevant computational intelligent schemes to solve previously unanswered research questions associated with six USGS themes: *Climate and Land-use Change, Core Science Systems, Ecosystems, Energy and Minerals, Natural Hazards,* and *Water*. My work aims to extract and use knowledge at the interface of big geoscience data sets, data mining, machine learning, multivariate statistics, and optimization. This work resulted in presentations, papers and continues as USGS and international collaborative research.
Results – My research involving computationally-intelligent data fusion solved previously intractable problems in the following six USGS themes. *Climate and Land-use Change*: (1) I identified scale-dependent teleconnections among climate variables and El Niño-Southern Oscillation (ENSO) events (pres., pub.), (2) I extended modern annual tropical Pacific land-air-sea temperature data to the millennial scale (pres., pub.), (3) I estimated the number of annual global ENSO events over the past 2,000 years (pres.), (4) I identified that climate variables have long-memory process (pres.) and performed a 50-year climate forecast for southern and southwestern United States (pres.; pub. in review), and (5) I predicted the likelihood of certain landscape characteristics in Brazil from space-borne satellite data (pres.**,** pub.). *Core Science Systems* (pres.): (1) I determined depth, orientation, weight, and type of buried munitions and explosives of concern (pres.; pub.); and (2) I predicted the magnitude of earthquakes for a region of china (unpublished), (3) I estimated uncertainty in lithospheric boundaries determined using a joint seismic inversion (pres., pub.), I improved resolution of lithospheric boundaries using joint inversion of receiver function, surface wave dispersion and magnetotelluric (pres., pub. in

review). *Ecosystems:* (1) I predicted mineral-resource effects on aquatic ecosystems (pres; draft pub.). *Energy and Minerals* (pres.): (1) I identified multivariate relations among global deposit and mining characteristics (pres.**,** pub**.** program guidance memo), (2) I identified heterogeneity in various grade and tonnage models (pres.**,** pub**.** program guidance memo), (3) I imputed missing data in grade and tonnage models (pres.**,** pub**.** program guidance memo), (4) I estimated true values of zeros in grade and tonnage models (pres.**,** pub**.** program guidance memo), (5) I estimated the density of various types of porphyry copper deposits (pres.**,** pub**.** program guidance memo), (5) I determined the economic feasibility of mining undiscovered porphyry copper deposits in British Columbia-Yukon territories (pres., pub.), (6) I predicted background and mine-related acidity and metals in river basins (pres., pub. in review). *Natural Hazards:* (1) I forecasted climate-change effects on the hydrology and geomorphology across post-fire landscapes in western U.S (pres.**;** pubs.), (2) I provided a set of nonlinear debris-flow equations and quantified their uncertainty (pres., pub.), and (3) I modeled hydrometeorological hazards for coastal cities of São Paulo, Brazil (pres., draft pub.). *Water:* (1) I estimated soil physical properties and quantified correlation structure across the Pocos de caldes basin Brazil (pres., pub.); (2) I estimated hydrogeologic properties and characterized hydrostratigraphy across the transboundary South American Serra Geral-Guarani aquifer system (pres., draft pub.); (3) I predicted the hillslope chemical weathering processes across Paraná state, Brazil (pres., pub.), (4) I forecasted climate-change effects on ground-water recharge (pres.; pub.), (5) I predicted well yield in the semi-arid climate and fractured crystalline rocks of northeastern Brazil (pres., pub.); (6) I demonstrated how to estimate starting parameter values and geostatistical constraints for applications to spatially-limited numerical inverse problems (pub.**),** (7) I performed near-real time airborne imaging of a heterogeneous surficial aquifer (pres.; draft pub.), (8) I computed continuous hydrostratigraphy for conceptual groundwater models by integrating geophysical-hydrogeologic data-integration scheme (draft pub.), (9) I devised scaling equations for ground-water recharge measurements (draft pub.), (10) I predicted climate-change effects on ground water recharge in the Midwestern United States (pres., draft pub.), and I evaluated significance of climate and hydrology in the formation of natural acid-rock drainage (pres.).

Impact – The application of computational intelligence is new to the USGS. This body of work demonstrates efficacy of intelligent data fusion and analysis that transcends USGS themes. This approach is significant because it provides an alternative modeling paradigm to solve previously unanswered big data problems that plague traditional methods. My shift in thinking toward computational intelligence resulted in invitations for me to co-convene and give a Keynote address at NATO advanced research workshops (Climate Change and its Effect on Water Resources – Issues of National and Global Security, 2011; and Socio-economic and Technological Aspects of Environmental Security, 2012); edit a NATO sponsored climate-change book (pub.**),** serve as an associate editor of the new Journal of Water and Energy Security (http://journalofwatersecurity.com/), convene a AGU Union Session on Computational Intelligence in Earth and Space Systems (pres.), and mentor as visiting USGS scientists and two Fulbright Scholars (Drs. Iwashita and Moreira). Outside the USGS, I had requests by Brazilian agencies (Agricultural Institute, Climate and Meteorological Institute, Dept. Environment and Society, and Geological Survey) for research collaboration, technical assistance, and teaching of university courses (University of Campinas, and University of Brasilia), and participate in a 2013 State Department sponsored US-Italy scientific exchange between Center for Computational and Mathematical Biology (http://ccmb.ucdenver.edu/), University of Colorado, Denver, CO and Semeion Research Center of Sciences of Communication (http://www.semeion.it/), Rome, Italy. Ongoing computational intelligence research collaboration with Brazil scientists involves climate-change applications to agriculture (http://www.cpa.unicamp.br/alcscens/) and natural hazards.

Given space limitations, examples of intelligent data fusion are provided only for my work under the climate and land-use change theme. *Climate and Land-use Change:* (1) The first study demonstrates that it is possible to integrate and simultaneously analyze relations of scale-dependent (local to global and modern to ancient time) climate variables. (2) The second study provided a 2,000 year temperature and precipitation series at an annual frequency for trend analysis and future use in calibrating global circulation (numerical) models. The application of quantile regression to these data provides alternative

interpretation in trends whose uncertainty can be quantified annually as empirical density functions. Quantile trends reveal that the ENSO phenomenon operates over a continuum of temporal and spatial scales. This finding suggests that any forcing influencing the frequency or intensity of climate change will increase the likelihood for drought hazards placing national and global security at risk. (3) The third study provides data from which it was possible to quantify the persistence of annual warm season El Niño, Neutral, and La Niña events over the past two millennia, and identify delays in global teleconnections and distribution of cooling and warming periods. These findings have broad economic, political, and social implications with respect to developing water resource policies. (4) The fourth study demonstrates the self-similar nature of reconstructed climate variables. This finding of long-memory processes suggests the possibility to forecast temperature and precipitation. (5) The fifth study provides the first nonlinear short-term (<50 years) forecast of annual precipitation and temperature at local and regional scales across southwestern US. This information provides water managers with the necessary resolution in climate variables to formulate water-resource and security planning. This application can be extended to provide additional resolution at local to global scales. (6) The sixth study demonstrates it is possible to predict landscape characteristics from Hyperspectral satellite data without the use of traditional multiple linear regression equations beset by poor resolution. This approach is generalized for climate applications in collaboration with researchers at the Brazilian agricultural research institute (Empresa Brasileira de Pesquisa Agropecuária) and university research institute (Centro de Pesquisas Meteorológicas e Climáticas Aplicadas a Agricultura).

SKILLS

Data fusion/mining (disparate, multivariate, nonlinear, sparse, spatiotemporal)
Database and queries (Access, SQL; Hadoop)
Dimension-reduction techniques (linear and non-linear)
Ecological field methods and Modeling (commercial and research)
Geophysical field methods and modeling (*Electrical and electromagnetic*: controlled source audiomagnetotellurics, electrical, time and frequency domain electromagnetic, gravity, DC resistivity, ground penetrating radar, induction, induced polarization, magnetic, magnetotelluric, radiometric, radio wave, spontaneous potential, very low frequency; *Potential fields*: gravity & magnetics; *Seismic*: particle motion, refraction, reflection, surface wave; *Seismology*: earthquake, source (natural and artificial), receiver function, surface wave dispersion; *Radometrics*)
Geophysical applications (*Configurations*: airborne, borehole, cross-hole, ground, tomographic; *Studies*: engineering, environmental, geothermal, groundwater, minerals, seismology, vadose)
Geospatial modeling (ArcGIS, geostatistics)
Geothermal field methods and modeling (commercial and research)
Groundwater field methods and modeling (water, heat, solute/reactive; coupled; forward/inverse; deterministic/stochastic; commercial and research)
Hybrid modeling (machine-learning with numerical and statistical models)
Integrated assessments (climate, ecological, ecosystem, hazards, land use, minerals, water)
Machine learning (classification, prediction, supervised/unsupervised, ensemble)
Numerical model development (coupled/nonlinear; finite-element/difference, stochastic PDEs)
Optimization methods (annealing, gradient, joint, metaheuristic, linear programming, MCMC)
Predictive model building and uncertainty quantification (statistical, data mining, hybrid)
Programming experience (C++, Fortran, VBA)
Scripting experience (Linux, Matlab, Python, R)
Python (NumPy, Pandas, Scikit-learn; machine-learning: gradient-boosting, random forest)
Reduced order methods (linear and nonlinear)
Remote sensing (landscape classification, large scale fluxes)
Regression (linear/nonlinear, quantile, symbolic, Bayesian)
Spatiotemporal modeling (downscaling, estimation)

Statistical modeling (clustering, spatial/time-series; estimation, forecasting, simulation)
Statistical software (Crystal Ball, GSLIB, R, Minitab)
Unsaturated zone field methods and Modeling (commercial and research)
Written and oral communication skills (presentations, proposals, journal articles)
Working experience with stakeholders and leading multi-disciplinary international teams
Years of experience mentoring students, post-docs, and visiting scientists

REFERENCES

Dr. Dean Anderson, Research Hydrologist, deander@usgs.gov
National Research Program, US Geological Survey/University of Colorado-Denver
Phone: +1-303-236-5691, https://profile.usgs.gov/deander
Relationship: collaborator greenhouse gas fluxes; field methods and modeling

Dr. Paolo Massimo Buscema, Professor, m.buscema@semeion.it
Semeion Institute, Rome, Italy
Mathematical & Statistical Sciences, University of Colorado, Denver, CO USA,
Phone: +1-303-236-5691, http://www.semeion.it/semeion/index.php/en/
Relationship: collaboration machine-learning and evolutionary algorithms

Dr. Robert Holmes, Research Hydrologist, rholmes@usgs.gov
Office of Surface Water, US Geological Survey
Phone: +1-573-308-3581, https://profile.usgs.gov/bholmes
Relationship: supervisor, water science center management team; long range planning

Dr. James Tindall, Research Hydrologist/Professor, drjamestindall@gmail.com, jtindall@usgs.gov
National Research Program, US Geological Survey
Department of Geography and Environmental Sciences, University of Colorado
Denver, CO. USA, Phone: +1-303-522-0250, https://profile.usgs.gov/jtindall
Relationship: collaboration development and application preferential flow and transport models

Dr. Weldon Lodwick, Professor, Weldon.Lodwick@cu.denver.edu
Mathematical & Statistical Sciences, University of Colorado, Denver, CO USA,
Phone: +1-720-891-8452, http://math.ucdenver.edu/~wlodwick/
Relationship: collaboration machine-learning, PDEs and uncertainty

Dr. David Lopes de Castro, Professor, david@geologia.ufrn.br
Universidade Federal do Rio Grande do Norte, Departamento de Geologia, BR
Phone: +(84) 32153808
Relationship: collaboration joint inverse problems

Dr. Lucas Moreira, Professor, lucas.paes.moreira@gmail.com, lucas.moreira@ifb.edu.br
Federal Institute of Education, Science and Technology of Brasilia, Electromechanics Group
QNM 40, Special Area #1, Taguatinga, Federal District, Brazil 72.146-000
Telefone: (61) 33404055
Relationship: collaboration joint inverse problems

Dr. John Nieber, Professor, nieber@umn.edu
Biosystems and Agricultural Engineering
University of Minnesota 1390 Eckles Avenue, St. Paul, MN 55108-6005
Phone: +1-612-625-6724

Relationship: collaboration groundwater and vadose zone finite-element model development

Relationship: collaboration development and application coupled flow and transport models

Dr. Erin Wallin, Research Geophysicist, ewallin08@gmail.com
Center for Study of Active Volcanoes (formerly), University of Hawaii at Hilo, HA, USA
US Department of Army, Corps of Engineers
Phone: +1-402-296-3905
Relationship: collaboration tomographic and joint inverse problems

Dr. Raymond Johnson, Senior geochemist/ Hydrogeologist, raymondhjohnson@gmail.com,
Navarro Research and Engineering, Inc. (formerly US Geological Survey)
Contractor to the U.S. Department of Energy,
Office of Legacy Management, 2597 Legacy Way, Grand Junction, CO 81503-1789
+1- 970-248-6468 (office), +1- 303-359-6990 (cell), www.navarro-inc.com
Relationship: collaboration groundwater modeling and uncertainty quantification