Appendix A

Senate Bill 4 Language Mandating the Independent Scientific Study on Well Stimulation Treatments

The following is the language from Senate Bill 4 (Pavley, Statutes of 2013) that required the independent scientific study on well stimulation treatments, of which this volume comprises the first installment.

3160. (a) On or before January 1, 2015, the Secretary of the Natural Resources Agency shall cause to be conducted, and completed, an independent scientific study on well stimulation treatments, including, but not limited to, hydraulic fracturing and acid well stimulation treatments. The scientific study shall evaluate the hazards and risks and potential hazards and risks that well stimulation treatments pose to natural resources and public, occupational, and environmental health and safety. The scientific study shall do all of the following:

1. Follow the well-established standard protocols of the scientific profession, including, but not limited to, the use of recognized experts, peer review, and publication.

2. Identify areas with existing and potential conventional and unconventional oil and gas reserves where well stimulation treatments are likely to spur or enable oil and gas exploration and production.

3. (A) Evaluate all aspects and effects of well stimulation treatments, including, but not limited to, the well stimulation treatment, additive and water transportation to and from the well site, mixing and handling of the well stimulation treatment fluids and additives onsite, the use and potential for use of nontoxic additives and the use or reuse of treated or produced water in well stimulation treatment fluids, flowback fluids and handling, treatment, and disposal of flowback fluids and other materials, if any, generated by the treatment. Specifically, the potential for the use of recycled water in well stimulation treatments, including appropriate water quality requirements and available treatment technologies, shall be evaluated. Well stimulation treatments include, but are not limited to, hydraulic fracturing and acid well stimulation treatments.

   (B) Review and evaluate acid matrix stimulation treatments, including the range of acid volumes applied per treated foot and total acid volumes used in

treatments, types of acids, acid concentration, and other chemicals used in the treatments.

4. Consider, at a minimum, atmospheric emissions, including potential greenhouse gas emissions, the potential degradation of air quality, potential impacts on wildlife, native plants, and habitat, including habitat fragmentation, potential water and surface contamination, potential noise pollution, induced seismicity, and the ultimate disposition, transport, transformation, and toxicology of well stimulation treatments, including acid well stimulation fluids, hydraulic fracturing fluids, and waste hydraulic fracturing fluids and acid well stimulation in the environment.

5. Identify and evaluate the geologic features present in the vicinity of a well, including the well bore, that should be taken into consideration in the design of a proposed well stimulation treatment.

6. Include a hazard assessment and risk analysis addressing occupational and environmental exposures to well stimulation treatments, including hydraulic fracturing treatments, hydraulic fracturing treatment-related processes, acid well stimulation treatments, acid well stimulation treatment-related processes, and the corresponding impacts on public health and safety with the participation of the Office of Environmental Health Hazard Assessment.

7. Clearly identify where additional information is necessary to inform and improve the analyses.

Appendix B.

CCST Steering Committee Members

Full curricula vitae for Steering Committee members are available upon request. Please contact California Council on Science and Technology (916)-492-0996.

Jane Long, Ph.D.

Steering Committee Chair
Principal Associate Director at Large, Lawrence Livermore National Laboratory, Retired

Dr. Long recently retired from Lawrence Livermore National Laboratory, where she was the Principal Associate Director at Large, Fellow in the LLNL Center for Global Strategic Research and the Associate Director for Energy and Environment. She is currently a senior contributing scientist for the Environmental Defense Fund, Visiting Researcher at UC Berkeley, Co-chair of the Task Force on Geoengineering for the Bipartisan Policy Center and chairman of the California Council on Science and Technology's California's Energy Future committee. Her current work involves strategies for dealing with climate change including reinvention of the energy system, geoengineering and adaptation. Dr. Long was the Dean of the Mackay School of Mines, University of Nevada, Reno and Department Chair for the Energy Resources Technology and the Environmental Research Departments at Lawrence Berkeley National Lab. She holds a bachelor's degree in engineering from Brown University and Masters and PhD from U. C. Berkeley. Dr. Long is a fellow of the American Association for the Advancement of Science and was named Alum of the Year in 2012 by the Brown University School of Engineering. Dr. Long is an Associate of the National Academies of Science (NAS) and a Senior Fellow and council member of the California Council on Science and Technology (CCST) and the Breakthrough Institute. She serves on the board of directors for the Clean Air Task Force and the Center for Sustainable Shale Development.

Roger Aines, Ph.D.

Senior Scientist, Atmospheric, Earth, and Energy Division and Carbon Fuel Cycle Program Leader E Programs, Global Security, Lawrence Livermore National Laboratory

Roger Aines leads the development of carbon management technologies at Lawrence Livermore National Laboratory, working since 1984 in the U.S. national laboratory system. Dr. Aines's work has spanned nuclear waste disposal, environmental remediation, applying stochastic methods to inversion and data fusion, managing carbon emissions, and sequestration monitoring and verification methods. Aines takes an integrated view of the energy, climate, and environmental aspects of carbon-based fuel production and use. His current focus is on efficient ways to remove carbon dioxide from the atmosphere and safer methods for producing environmentally clean fuel. He holds 13 patents and has authored more than 100 publications. Aines holds a Bachelor of Arts degree in Chemistry from Carleton College, and Doctor of Philosophy in geochemistry from the California Institute of Technology.

Jens Birkholzer, Ph.D.

Deputy Director, Earth Sciences Division, Lawrence Berkeley National Laboratory

Dr. Birkholzer joined Lawrence Berkeley National Laboratory in 1994 as a post-doctoral fellow and has since been promoted to the second-highest scientist rank at this research facility. He currently serves as the deputy director of the Earth Sciences Division and as the program lead for the nuclear waste program, and also leads a research group working on environmental impacts related to geologic carbon sequestration and other subsurface activities. His area of expertise is subsurface hydrology with emphasis on understanding and modeling coupled fluid, gas, solute and heat transport in complex subsurface systems, such as heterogeneous sediments or fractured rock. His recent research was mostly in the context of risk/performance assessment, e.g., for geologic disposal of radioactive wastes and for geologic CO_2 storage. Dr. Birkholzer has authored about 90 peer-reviewed journal articles and book chapters, and has over 230 conference publications and abstracts.

Brian Cypher, Ph.D.

Associate Director, Endangered Species Recovery Program,
California State University, Stanislaus

Dr. Cypher received a PhD in Zoology from Southern Illinois University in 1991. Since 1990, he has been engaged in ecological research and conservation efforts on a variety of animal and plant species and their habitats. Much of this work has occurred in the San Joaquin Valley in central California and has involved extensive evaluations of the effects of hydrocarbon production and energy development on ecological processes and individual species. The information generated has been presented in numerous reports and publications, which have contributed to the development of conservation strategies and best-management practices that help mitigate environmental impacts from energy development activities.

Jim Dieterich, Ph.D.

Distinguished Professor of Geophysics, University of California, Riverside

Dr. Dieterich's research interests have to do with the mechanics of deformation processes, particularly as they relate to earthquake and volcanic phenomena. Areas of emphasis include development of governing relations for earthquake nucleation and earthquake occurrence; estimation of earthquake probabilities; fault constitutive properties; and coupled interactions between magmatic activity, faulting, and earthquakes. Current research includes (1) numerical simulation of earthquakes processes in interacting fault systems, (2) origins of earthquake clustering including foreshocks and aftershocks, (3) application of seismicity rate changes to infer stress changes in volcanic and tectonic environments, (4) laboratory investigation of fault constitutive properties and surface contact process.

Donald L. Gautier, Ph.D.

Consulting Petroleum Geologist, DonGautier L.L.C.

With a career spanning almost four decades, Dr. Donald L. Gautier is an internationally recognized leader and author in the theory and practice of petroleum resource analysis. As a principal architect of modern USGS assessment methodology, Gautier's accomplishments include leadership of the first comprehensive evaluation of undiscovered oil and gas resources north of the Arctic Circle, the first national assessment of United States petroleum resources to be fully documented in a digital environment, and the

first development of performance-based methodology for assessment of unconventional petroleum resources such as shale gas or light, tight oil. He was lead scientist for the San Joaquin Basin and Los Angeles Basin Resource Assessment projects. His recent work has focused on the analysis of growth of reserves in existing fields and on the development of probabilistic resource/cost functions. Gautier is the author of more than 200 technical publications, most of which concern the evaluation of undiscovered and undeveloped petroleum resources. He holds a Ph.D. in geology from the University of Colorado.

Peter H. Gleick, Ph.D.

President, Pacific Institute

Dr. Peter H. Gleick is an internationally recognized environmental scientist and co-founder of the Pacific Institute in Oakland, California. His research addresses the critical connections between water and human health, the hydrologic impacts of climate change, sustainable water use, privatization and globalization, and international security and conflicts over water resources. Dr. Gleick was named a MacArthur "genius" Fellow in October 2003 for his work on water, climate, and security. In 2006 Dr. Gleick was elected to the U.S. National Academy of Sciences, Washington, D.C. Dr. Gleick's work has redefined water from the realm of engineers to the world of social justice, sustainability, human rights, and integrated thinking. His influence on the field of water has been long and deep: he developed one of the earliest assessments of the impacts of climate change on water resources, defined and explored the links between water and international security and local conflict, and developed a comprehensive argument in favor of basic human needs for water and the human right to water—work that has been used by the UN and in human rights court cases. He pioneered the concept of the "soft path for water," developed the idea of "peak water," and has written about the need for a "local water movement." Dr. Gleick received a B.S. in Engineering and Applied Science from Yale University and an M.S. and Ph.D. from the Energy and Resources Group of the University of California, Berkeley. He serves on the boards of numerous journals and organizations, and is the author of many scientific papers and ten books, including Bottled & Sold: The Story Behind Our Obsession with Bottled Water and the biennial water report, The World's Water, published by Island Press (Washington, D.C.).

A. Daniel Hill, Ph.D.

Department Head, Professor and holder of the Noble Chair, Petroleum Engineering Department at Texas A&M University

Dr. A. D. Hill is Professor, holder of the Noble Endowed Chair, and Department Head of Petroleum Engineering at Texas A&M University. Previously, he taught for 22 years at The University of Texas at Austin after spending five years in industry. He holds a B. S. degree from Texas A&M University and M. S. and Ph. D. degrees from The University of Texas at Austin, all in chemical engineering. He is the author of the Society of Petroleum Engineering (SPE) monograph, Production Logging: Theoretical and Interpretive Elements, co-author of the textbook, Petroleum Production Systems (1st and 2nd editions), co-author of an SPE book, Multilateral Wells, and author of over 170 technical papers and five patents. He has been a Society of Petroleum Engineers (SPE) Distinguished Lecturer, has served on numerous SPE committees and was founding chairman of the Austin SPE Section. He was named a Distinguished Member of SPE in 1999 and received the SPE Production and Operations Award in 2008. In 2012, he was one of the two inaugural winners of the SPE Pipeline Award, which recognizes faculty, who have fostered petroleum engineering Ph.Ds. to enter academia. He currently serves on the SPE Editorial Review Committee, the SPE Global Training Committee, and the SPE Hydraulic Fracturing Technology Conference Program Committee. Professor Hill is an expert in the areas of production engineering, well completions, well stimulation, production logging, and complex well performance (horizontal and multilateral wells), and has presented lectures and courses and consulted on these topics throughout the world.

Larry Lake, Ph.D.

Professor, Department of Petroleum and Geosystems Engineering, University of Texas, Austin

Larry W. Lake is a professor of the Department of Petroleum and Geosystems Engineering at The University of Texas at Austin and director of the Center for Petroleum Asset Risk Management. He holds B.S.E and Ph.D. degrees in Chemical Engineering from Arizona State University and Rice University. Dr. Lake has published widely; he is the author or co-author of more than 100 technical papers, the editor of 3 bound volumes and author or co-author of four textbooks. He has been teaching at UT for 34 years before which he worked for Shell Development Company in Houston, Texas. He was chairman of the PGE department twice, from 1989 to 1997 and from 2008 to 2010. He formerly held the Shell Distinguished Chair and the W.A. (Tex) Moncrief, Jr. Centennial Endowed Chair in Petroleum Engineering. He currently holds the W.A. (Monty) Moncrief Centennial Chair in Petroleum Engineering. Dr. Lake has served on the Board of Directors for the

Society of Petroleum Engineers (SPE) as well as on several of its committees; he has twice been an SPE distinguished lecturer. Dr. Lake is a member of the US National Academy of Engineers and won the 1996 Anthony F. Lucas Gold Medal of the SPE. He won the 1999 Dad's Award for excellence in teaching undergraduates at The University of Texas and the 1999 Hocott Award in the College of Engineering for excellence in research. He also is a member of the 2001 Engineering Dream Team awarded by the Texas Society of Professional Engineers. He is an SPE Honorary Member.

Thomas E. McKone, Ph.D.

Deputy for Research Programs in the Energy Analysis and Environmental Impacts Department, Lawrence Berkeley National Laboratory (LBNL)

Thomas E. McKone, is a senior staff scientist and Deputy for Research Programs in the Energy Analysis and Environmental Impacts Department at the Lawrence Berkeley National Laboratory (LBNL) and Professor of Environmental Health Sciences at the University of California, Berkeley School of Public Health. At LBNL, he leads the Sustainable Energy Systems Group. His research focuses on the development, use, and evaluation of models and data for human-health and ecological risk assessments, as well as the health and environmental impacts of energy, industrial, and agricultural systems. Outside of Berkeley, he has served six years on the EPA Science Advisory Board, has been a member of more than a dozen National Academy of Sciences (NAS) committees including the Board on Environmental Studies and Toxicology, and has been on consultant committees for the Organization for Economic Cooperation and Development (OECD), the World Health Organization, the International Atomic Energy Agency, and the Food and Agriculture Organization. McKone is a Fellow of the Society of Risk Analysis and has received two major awards from the International Society of Exposure Analysis—one for lifetime achievement in exposure science research and one for research that has impacted major international and national environmental policies.

William A. Minner, P.E.

Petroleum Engineer, Minner Engineering, Inc.

Minner is an independent petroleum engineering consultant, with a primary focus on hydraulic fracture well stimulation technology and application. After receiving B.S. and M.S. degrees in mechanical engineering with a petroleum option from the University of California, Berkeley, Minner joined Unocal in 1980, and began to focus on hydraulic fracturing well stimulation in 1985. In 1995, he left Unocal to open an office for Pinnacle Technologies in Bakersfield. Pinnacle's focus was on the development and

commercialization of hydraulic fracture mapping technologies; Minner's role was in engineering consulting, using fracture diagnostics and mapping results to assist clients with hydraulic fracture engineering design, execution, and analysis. His engineering consulting role continued after the fracture mapping business was sold in 2008 and the company name was changed to StrataGen Engineering, and after February 2015, when he left StrataGen to venture out in the independent engineering consulting arena. Minner is a registered Petroleum Engineer in California, and received Society of Petroleum Engineers regional awards in 2011 and 2015 for his contribution to technical progress and interchange. He has authored or coauthored 21 industry technical papers on hydraulic fracturing.

Amy Myers Jaffe

Executive Director, Energy and Sustainability, University of California, Davis

Amy Myers Jaffe is a leading expert on global energy policy, geopolitical risk, and energy and sustainability. Jaffe serves as executive director for Energy and Sustainability at University of California, Davis with a joint appointment to the Graduate School of Management and Institute of Transportation Studies (ITS). At ITS-Davis, Jaffe heads the fossil fuel component of Next STEPS (Sustainable Transportation Energy Pathways). She is associate editor (North America) for the academic journal Energy Strategy Reviews. Prior to joining UC Davis, Jaffe served as director of the Energy Forum and Wallace S. Wilson Fellow in Energy Studies at Rice University's James A. Baker III Institute for Public Policy. Jaffe's research focuses on oil and natural gas geopolitics, strategic energy policy, corporate investment strategies in the energy sector, and energy economics. She was formerly senior editor and Middle East analyst for Petroleum Intelligence Weekly. Jaffe is widely published, including as co-author of Oil, Dollars, Debt and Crises: The Global Curse of Black Gold (Cambridge University Press, January 2010 with Mahmoud El-Gamal). She served as co-editor of Energy in the Caspian Region: Present and Future (Palgrave, 2002) and Natural Gas and Geopolitics: From 1970 to 2040 (Cambridge University Press, 2006). Jaffe was the honoree for Esquire's annual 100 Best and Brightest in the contribution to society category (2005) and Elle Magazine's Women for the Environment (2006) and holds the excellence in writing prize from the International Association for Energy Economics (1994).

Seth B. C Shonkoff, Ph.D., MPH

Executive Director, PSE Healthy Energy
Visiting Scholar, University of California, Berkeley
Affiliate, Lawrence Berkeley National Laboratory

Dr. Shonkoff is the executive director of the energy science and policy institute, PSE Healthy Energy. Dr. Shonkoff is also a visiting scholar in the Department of Environmental Science, Policy and Management at UC Berkeley, and an affiliate in the Environment Energy Technology Division at Lawrence Berkeley National Laboratory in Berkeley California. An environmental and public health scientist by training, he has more than 15 years of experience in water, air, climate, and population health research. Dr. Shonkoff completed his PhD in the Department of Environmental Science, Policy, and Management and his MPH in epidemiology in the School of Public Health from the University of California, Berkeley. He is a contributing author to the Human Health chapter of The Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5). He has worked and published on topics related to the intersection of energy, air pollution, water quality, climate, and human health from scientific and policy perspectives. Dr. Shonkoff's research also focuses on the development of the effectiveness of anthropogenic climate change mitigation policies that generate socioeconomic and health co-benefits. Dr. Shonkoff's current work focuses on the human health, environmental and climate dimensions of oil and gas development in the United States and abroad.

Dan Tormey, Ph. D., P.G.

Principal, ENVIRON International Corporation
Dan Tormey, Ph. D., P.G. Principal, Ramboll Environ Corporation

Dr. Daniel Tormey is an expert in energy and water and conducts environmental reviews for both government and industry. He works with the environmental aspects of all types of energy development, with an emphasis on oil and gas, including hydraulic fracturing and produced water management, pipelines, LNG terminals, refineries and retail facilities. Dr. Tormey was the principal investigator for the peer-reviewed, publicly available, Hydraulic Fracturing Study at the Baldwin Hills of southern California, on behalf of the County of Los Angeles and the field operator, PXP. He conducts projects in sediment transport, hydrology, water supply, water quality, and groundwater-surfacewater interaction. He has been project manager or technical lead for over two hundred projects requiring fate and transport analysis of chemicals in the environment. He has a Ph.D. in Geology and Geochemistry from MIT, and a B.S. in Civil Engineering and Geology from Stanford. He is a Principal at Ramboll Environ Corporation; was named by the National Academy of Sciences to the Science Advisory Board for Giant Sequoia National Monument; is a Distinguished Lecturer for the Society of Petroleum Engineers; is on the review committee

on behalf of IUCN for the UNESCO World Heritage Site List and member of the IUCN Geoscientist Specialist Group; is volcanologist for Cruz del Sur, an emergency response and contingency planning organization in Chile; was an Executive in Residence at California Polytechnic University San Luis Obispo; and is a Professional Geologist in California. He has worked throughout the USA, Australia, Indonesia, Italy, Chile, Ecuador, Colombia, Venezuela, Brazil, Senegal, South Africa, Armenia and the Republic of Georgia.

Samuel Traina, Ph.D.

Vice Chancellor of Research, University of California, Merced

Dr. Traina is the Vice Chancellor for Research and Economic Development at the University of California, Merced, where he holds the Falasco Chair in Earth Sciences and Geology. He serves as a Board Member of the California Council of Science and Technology. Prior to joining UC Merced in 2002 as a Founding Faculty member and the Founding Director of the Sierra Nevada Research Institute, Dr. Traina was a faculty member for 17 years at The Ohio State University, with concomitant appointments in the School of Natural Resources and the Environment, the Department of Earth Science and Geology, Civil and Environmental Engineering, Microbiology and Chemistry. He has served on the National Research Council's Standing Committee on Earth Resources. In 1997–1998, he held the Cox Visiting Professorship in the School of Earth Sciences at Stanford University. Dr. Traina's past and current research has dealt with the fate, transformation, and transport of contaminants in soils and natural waters, with an emphasis on radionuclides, heavy metals, and mining wastes. Dr. Traina holds a B.S. in soil resource management and a Ph.D. in soil chemistry. He is a fellow of the Soil Science Society of American and of the American Association for the Advancement of Science, as well as a recipient of the Clay Scientist Award of the Clay Minerals Society.

Laura Feinstein, Ph.D.

CCST Project Manager

Laura Feinstein serves as the project manager and author for CCST on this report, and CCST's previous report on well stimulation prepared for the Bureau of Land Management. She previously served as a CCST Science and Technology Policy Fellow with the California Senate Committee on Environmental Quality. She was the director of the GirlSource Technology and Leadership Program, where she developed and ran a program teaching computer and job skills to low-income young women. She also was a web/media developer and researcher with the Center for Defense Information, a think-tank focusing on security issues. She was awarded a CalFED Bay-Delta Science fellowship for scientific research on ecological problems facing the Bay-Delta watershed, and a California Native Plant Society research scholarship. She has a Ph.D. in Ecology from University of California, Davis.

Disclosure of Conflict of Interest: Prof. Dan Hill

In accordance with the practice of the California Council on Science and Technology (CCST), CCST makes best efforts to ensure that no individual appointed to serve on a committee has a conflict of interest that is relevant to the functions to be performed, unless such conflict is promptly and publicly disclosed and CCST determines that the conflict is unavoidable. A conflict of interest refers to an interest, ordinarily financial, of an individual that could be directly affected by the work of the committee. An objective determination is made for each provisionally appointed committee member regarding whether or not a conflict of interest exists, given the facts of the individual's financial and other interests, and the task being undertaken by the committee. A determination of a conflict of interest for an individual is not an assessment of that individual's actual behavior or character or ability to act objectively despite the conflicting interest.

We have concluded that for this committee to accomplish the tasks for which it was established, its membership must include among others, individuals with research and expertise in the area of acid treatments for petroleum wells who have studied oil and gas industry operations in the United States and are internationally recognized for this expertise. Acid treatment is of particular public concern in California and is the subject of regulation under SB4.

To meet the need for this expertise and experience, Dr. Dan Hill is proposed for appointment to the committee, even though we have concluded that he has a conflict of interest because of investments he holds and research services provided by his employer.

As his biographical summary makes clear, Dr. Hill is a recognized expert in petroleum reservoir engineering with many publications to wit. He is also known as one of the world's key experts in acid treatment.

After an extensive search, we have been unable to find another individual with the equivalent combination of expertise in acid treatment as Dr. Hill, who does not have a similar conflict of interest. Therefore, we have concluded that this potential conflict is unavoidable.

Disclosure of Conflict of Interest: William Minner

In accordance with the practice of the California Council on Science and Technology (CCST), CCST makes best efforts to ensure that no individual appointed to serve on a committee has a conflict of interest that is relevant to the functions to be performed, unless such conflict is promptly and publicly disclosed and CCST determines that the conflict is unavoidable. A conflict of interest refers to an interest, ordinarily financial, of an individual that could be directly affected by the work of the committee. An objective determination is made for each provisionally appointed committee member regarding whether or not a conflict of interest exists given the facts of the individual's financial and other interests, and the task being undertaken by the committee. A determination of a conflict of interest for an individual is not an assessment of that individual's actual behavior or character or ability to act objectively despite the conflicting interest.

We have concluded that for this committee to accomplish the tasks for which it was established its membership must include, among others, individuals with direct experience in the area of well stimulation practice, specifically in California. Well stimulation is of particular public concern in California and is the subject of regulation under SB4. The practice in California is significantly different than in other states so we require someone with direct experience in the state.

To meet the need for this expertise and experience, William Minner is proposed for appointment to the committee even though we have concluded that he has a conflict of interest because of investments he holds and research services provided by his employer.

As his biographical summary makes clear, William Minner is a recognized expert in petroleum reservoir stimulation with a long history of practice in California as well as around the world. He is one of the most recognized experts in California well stimulation design and execution.

After an extensive search, we have been unable to find another individual with the equivalent combination of expertise as William Minner, who does not have a similar conflict of interest. Therefore, we have concluded that this potential conflict is unavoidable.

Appendix C.

Report Author Biosketches

- **Jens T. Birkholzer**, Lawrence Berkeley National Laboratory
- **Adam Brandt**, Stanford University
- **Laura C. Feinstein**, California Council on Science and Technology
- **Kyle Ferrar**, The Frac Tracker Alliance
- **William Foxall**, Lawrence Berkeley National Laboratory
- **Donald L. Gautier**, DonGautier L.L.C.
- **Ben K. Greenfield**, University of California Berkeley
- **Matthew G. Heberger**, Pacific Institute
- **James E. Houseworth**, Lawrence Berkeley National Laboratory
- **Michael L. B. Jerrett**, University of California, Los Angeles
- **Preston D. Jordan**, Lawrence Berkeley National Laboratory
- **Nathaniel J. Lindsey**, Lawrence Berkeley National Laboratory
- **Jane C. S. Long**, California Council on Science and Technology
- **Randy L. Maddalena**, Lawrence Berkeley National Laboratory
- **Thomas E. McKone**, Lawrence Berkeley National Laboratory
- **Scott E. Phillips**, California State University, Stanislaus
- **Seth B.C. Shonkoff**, PSE Healthy Energy
- **William T. Stringfellow**, Lawrence Berkeley National Laboratory
- **Craig Ulrich**, Lawrence Berkeley National Laboratory

Jens T. Birkholzer

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Education

1982-1985	University of Technology, Aachen. B.Sc. in Civil Engineering, 1985.
1985-1988	University of Technology, Aachen. M.Sc. in Water Resources, Hydraulic Engineering, Soil and Rock Mechanics, 1988.
1989-1994	University of Technology, Aachen. Ph.D. in Subsurface Hydrology, 1994.

Research and Professional Experience

Dr. Birkholzer joined LBNL in 1994 as a post-doctoral fellow and has since been promoted to the second-highest scientist rank at this research facility. He currently serves as the deputy director of the Earth Sciences Division and as the program lead for the nuclear waste program, and also leads a research group working on environmental impacts related to geologic carbon sequestration and other subsurface activities. His area of expertise is subsurface hydrology with emphasis on understanding and modeling coupled fluid, gas, solute and heat transport in complex subsurface systems, such as heterogeneous sediments or fractured rock. His recent research was mostly in the context of risk/performance assessment, e.g., for geologic disposal of radioactive wastes and for geologic CO_2 storage. Dr. Birkholzer has authored about 90 peer-reviewed journal articles and book chapters, and has over 230 conference publications and abstracts.

Current and past Positions

Since 2014	Deputy Director, Earth Sciences Division, Lawrence Berkeley National Laboratory (LBNL)
Since 2008	Program Lead, Nuclear Energy and Waste, Earth Sciences Division, LBNL
Since 2001	Staff Scientist and Group Leader, Earth Sciences Division, LBNL
1999 - 2001	Chief Engineer and Project Manager, Construction of the New International Airport in Dusseldorf, HOCHTIEF AG, Germany
1994 - 1998	Geological Scientist, Earth Sciences Division, LBNL

1989 - 1994	Research Associate (since 1993 Group Leader), Institute of Hydraulic Engineering and Water Resources Management (IWW), University of Technology, Aachen, Germany

Honors and Awards

2012	Director's Award for Exceptional Achievement (TOUGH codes), by LBNL
2007, 1997	Outstanding Performance Award, by LBNL
1995 - 1996	Postdoctoral fellowship granted by the Humboldt-Stiftung
1995	Friedrich-Wilhelm Award for Summa Cum Laude Ph.D. Thesis
1995	Borchers Award for Summa Cum Laude Ph.D. Thesis
1994 - 1995	Postdoctoral fellowship granted by the DAAD
1989	Research-fellowship granted by the DAAD
1989	Springorum Award for Summa Cum Laude M.Sc.
1989	Hünnebeck Award for best Master Thesis
since 1986	Studienstiftung des Deutschen Volkes

Adam Brandt

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Education

Ph.D. (2008), Energy and Resources, University of California, Berkeley

M.S. (2005), Energy and Resources, University of California, Berkeley

B.S. (2003), Environmental Studies (emphasis Physics), Highest Honors, University of California, Santa Barbara

Research and Professional Experience

Dr. Brandt is an Assistant Professor in the Department of Energy Resources Engineering, Stanford University. His research focuses on reducing the greenhouse gas impacts of energy production and consumption, with a focus on fossil energy systems. Research interests include life cycle assessment of petroleum production and natural gas extraction. A particular interest is in unconventional fossil fuel resources such as oil sands, oil shale and hydraulically fractured oil and gas resources. He also researches computational optimization of emissions mitigation technologies, such as carbon dioxide capture systems. Dr. Brandt received his Ph.D. from the Energy and Resources Group, UC Berkeley.

Current and Past Positions

2012- Present:	Assistant Professor, Department of Energy Resources Engineering, Stanford University
2009-2012:	Acting Assistant Professor, Department of Energy Resources Engineering, Stanford University
2007-2012:	Expert consultancy
2003-2008:	Graduate Student Researcher, University of California, Berkeley
2003-2008:	Teaching Assistant, University of California, Santa Barbara
2002:	Undergraduate research fellow, University of Southern California

2001: Development Intern, Boabab Valley Resource Reserve, Morogoro Region, Tanzania.

Honors and Awards

2006 Received Student Paper Award for paper "Testing Hubbert," 26th Annual Conference of the United States Association of Energy Economists.

2003 Outstanding Senior of 2003, Environmental Studies program, UC Santa Barbara.

2003 Highest Honors at graduation (top 2.5% of graduating students), UC Santa Barbara.

2001 UC President's Undergraduate Scholarship and Kirby-Jones Scholarship.

2000 Highest GPA in Sophomore class of the Educational Opportunity Program, a program for under-represented students and students whose parents did not attend college.

Laura C. Feinstein

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Education

1994-1998 University of California at Berkeley, Berkeley, CA.
B.A. in Anthropology, 1998.

2006-2012 University of California at Davis, Davis, CA. Ph.D. in Ecology, 2012.

Research and Professional Experience

Dr. Feinstein has worked for the California Council on Science and Technology (CCST) since January 2014. She previously served as a CCST Science and Technology Fellow with the California Senate Committee on Environmental Quality. Her graduate student research focused on the ecology and genetics of an invasive plant species in the San Francisco Bay's tidal wetlands. She has worked on a diverse array of ecological problems, including restoration of coastal marshes, biogeochemical cycles in redwood forests, and the genetics of adaptation. Laura has published and presented at numerous conferences on ecological genetics and tidal wetland plant communities.

Current and past Positions

Since 2014 Project Manager, Well Stimulation Technology in California, California Council on Science and Technology (CCST)

Since 2012 Postdoctoral researcher, restoration of San Francisco Bay tidal marshes, U.C. Davis

2012-2013 CCST Science and Technology Policy Fellow with the California Senate Committee on Environmental Quality

Honors and Awards

2007 CALFED Bay-Delta Science Fellow

2006 National Science Foundation Integrative Graduate Education and Research Traineeship on Invasive Species Research Award

2006 California Native Plant Society Research Award

Kyle Ferrar

Western Program Coordinator
The FracTracker Alliance
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Education

2004-2008	University of Pittsburgh, Pittsburgh, PA. B.S. in Biological Sciences, 2004.
2008-2010	University of Pittsburgh Graduate School of Public Health, Pittsburgh, PA. M.P.H. in Environmental and Occupational Health, 2010.
2010-Current	University of Pittsburgh Graduate School of Public Health, Pittsburgh, PA. Dr.P.H. Candidate in Environmental and Occupational Health.

Research and Professional Experience

Kyle Ferrar is the Western Program Coordinator at The FracTracker Alliance, a leading resource on oil and gas issues and a trusted asset to the concerned public. The FracTracker Alliance shares maps, data, and analyses to communicate impacts of the global oil and gas industry, and informs actions that positively shape our energy future. Ferrar's's expertise is in exposure assessment and risk analysis using community-based participatory research methods, with a focus on fossil fuel energy extraction and generation. His most recent work has included environmental justice assessments, community health assessments, and characterizations of waste streams from industrial and municipal wastewater treatment plants treating flowback and produced waters. Ferrar has authored and contributed to numerous peer-reviewed journal articles and conference publications.

Current and Past Positions

Since 2013	Western Program Coordinator, The FracTracker Alliance, Oakland, California
2007-2013	Staff Researcher, Center for Healthy Environments and Communities, Pittsburgh, Pennsylvania

William Foxall

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Education

1966-1969	Queen Mary College, University of London, UK. B.Sc. in Physics, 1969.
1974-1976	University of Washington, WA. M.S. in Geophysics, 1976.
1986-1992	University of California, Berkeley, CA. Ph.D. in Geophysics, 1992.

Research and Professional Experience

Dr. Foxall has led induced seismicity research activities in the Earth Sciences Division Lawrence Berkeley National Laboratory since 2013. His expertise is in seismic source physics and wave propagation, seismic hazard analysis, and measurement and inversion of deformation in the Earth. Dr. Foxall's most recent work has been on physics-based simulation approaches to seismic hazard assessment for induced seismicity related to CO_2 sequestration, and analysis of induced seismicity related to enhanced geothermal systems and unconventional oil and gas recovery. Other recent work was on inversion of ground surface deformation for imaging fluid flow in CO_2, oil and geothermal reservoirs, and for characterization of underground facilities. He has also conducted research into joint inversion of seismic and acoustic data for determination of explosive yield. Dr. Foxall has authored and coauthored more than 30 peer-reviewed journal articles and conference publications.

Current and Past Positions

Since 2013	Senior Geological Scientist, Earth Sciences Division, Lawrence Berkeley National Laboratory (LBNL)
1996 – 2013	Physicist, Lawrence Livermore National Laboratory (LLNL)
1996 – 1999	Visiting Research Geophysicist, University of California, Berkeley
1995 – 1996	Staff Scientist, Lawrence Berkeley National Laboratory
1992 – 1995	Postdoctoral Fellow, Lawrence Berkeley National Laboratory
1986 – 1992	Graduate Student Research Assistant, Lawrence Berkeley National Laboratory

1983 – 1992 Seismological Consultant

1976 – 1983 Seismologist, Woodward-Clyde Consultants, San Francisco, CA

Honors and Awards

1974 Fulbright Scholarship

Donald L. Gautier

Consulting Geologist
University of Adelaide (Adjunct Professor); U.S. Geological Survey (Scientist Emeritus)

Research: During a career spanning almost four decades, Gautier has conducted basic and applied research to address problems of petroleum geology and resource analysis. An extensive publication record and a global reputation for excellence in speaking, writing and teaching document this body of work.

His research has contributed to significant advancements, which include: (1) the first comprehensive evaluation of undiscovered oil and gas resources north of the Arctic Circle (Gautier and others, 2009; Gautier and others, 2011), (2) the first assessment of United States petroleum resources to be fully documented in a digital environment (Gautier and others, 1995a; Gautier and others, 1995b), (3) quantification of the relationship between porosity and time-temperature exposure in quartz-rich sandstones (Schmoker and Gautier, 1988; Gautier and Schmoker, 1989), and (4) the linkage of authigenic mineral precipitation in fine-grained sediments to the microbial geochemistry of early diagenetic environments (Gautier, 1982; Gautier and Claypool, 1984).

Recent work has focused on the quantitative evaluation of unconventional resources, the analysis of reserve growth in existing fields, and the development of probabilistic resource/cost analysis techniques to support interdisciplinary resource decisions.

Teaching: For the last ten years, Gautier's teaching has emphasized intensive graduate or professional-level training for university, government, and industrial groups. Courses and workshops have addressed the geology of unconventional resources, resource evaluation, quantitative assessment methodology, and geopolitical and economic issues related to the global distribution and quality of petroleum resources. Recent course offerings have included: Geology and Assessment of Unconventional Reservoirs, Play Assessment Methodology, and Integration of Resource Geology and Microeconomics

Outreach and Public Service: Lots of Gautier's time goes to providing information and guidance to governmental and non-profit organizations such as the California Division of Oil, Gas, and Geothermal Resources, California Council on Science and Technology, Central Intelligence Agency, EuroGeoSurveys, United States Coast Guard, U.S. Department of State, Energy Information Administration, International Energy Agency, Geological Survey of Denmark and Greenland, National Intelligence Council, The Nature Conservancy, Norwegian Petroleum Directorate, Massachusetts Institute of Technology, University of California, and the World Bank.

Professional societies seek him out as a meeting convener, technical session chair, short course teacher, expert panelist and speaker. He has enjoyed contributing his expertise to the World Petroleum Congress, the International Geological Congress, the American

Association of Petroleum Geologists, the European Association of Geoscientists and Engineers, the Geological Society of London, and many other organizations.

The international press and scientific journalists regard Gautier as a trusted source of objective information on issues of global petroleum resources and their development. He routinely grants print, radio, and television interviews to organizations such as the BBC, CBC, CNN, National Geographic, the New York Times, PBS, Der Spiegel, Science Magazine, and the Wall Street Journal.

Ben K. Greenfield

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Education

1989-1993	Brown University, Providence, RI. B.A. in Biology, 1993.
1997-2000	University of Wisconsin, Madison, WI. M.S. in Zoology, 2000.
2011-Present	University of California, Berkeley, CA. Ph.D. in Environmental Health Sciences, In Progress.

Research and Professional Experience

Ben Greenfield is an environmental scientist, with a research focus on contaminant trends in space and time, and implications for policy and risk assessment. As a M.S. student at University of Wisconsin-Madison and a scientist at the San Francisco Estuary Institute, he developed expertise in characterizing legacy contamination (e.g., mercury, PCBs, pesticides, polycyclic aromatic hydrocarbons) in fish and aquatic sediment, and the interpretation of monitoring data for environmental management and regulation. He is currently pursuing a Ph.D. in Environmental Health Sciences at University of California, Berkeley, focused on the application of statistical and mechanistic models to the source-receptor-outcome relationship between environmental pollution exposure and human disease. Mr. Greenfield has coauthored 28 peer-reviewed journal articles.

Current and Past Positions

Since 2011	Doctoral Student, Environmental Health Sciences, University of California, Berkeley
2003 – 2011	Environmental Scientist, San Francisco Estuary Institute, Oakland, CA
2000 – 2003	Environmental Analyst, San Francisco Estuary Institute, Oakland, CA

Honors and Awards

2013 IGERT Systems Approach to Green Energy Traineeship, National Science Foundation and UC Berkeley

2011 STAR Fellowship, US Environmental Protection Agency

1999 STAR Fellowship, US Environmental Protection A

Matthew G. Heberger

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http://www.pacinst.org/

Education

1992–1996	Cornell University, Ithaca, New York. B.S. in Agricultural and Biological Engineering, 1996.
2001–2003	Tufts University, Medford, Massachusetts. M.S. in Water Resources Engineering, 2003.

Research and Professional Experience

Mr. Heberger has been a research associate in the Water Program of the Pacific Institute since 2007. He is a water resource engineer and hydrologist specializing in hydraulic, hydrologic, and water quality analyses and modeling, the nexus between water and energy, and impacts of climate change on water resources. Prior to joining the institute, Mr. Heberger worked as a consulting engineer at the consulting firm of Camp, Dresser, and McKee (CDM), where he was responsible for building and calibrating rainfall-runoff, hydraulic and water quality models for major waterways across the US.

Current and Past Positions

Since 2007	Research Associate, Pacific Institute, Oakland, California
2003 – 2007	Water Resources Engineer, Camp Dresser & McKee, Cambridge, Massachusetts
2001 – 2003	Research Assistant, Department of Civil and Environmental Engineering, Tufts University, Medford, Massachusetts
1999 – 2001	Coordinator, International Network on Participatory Irrigation Management, Washington, DC
1996 – 1998	Water and Sanitation Extension Agent, United States Peace Corps, Mali, West Africa

Honors and Awards

2007 Registered Professional Engineer, Commonwealth of Massachusetts

2004 Certified Floodplain Manager, Association of State Floodplain Managers

James E. Houseworth

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Education

1973-1977	California Institute of Technology, Pasadena, CA. B.S. in Environmental Engineering, 1977.
1977-1978	California Institute of Technology, Pasadena, CA. M.S. in Environmental Engineering, 1978.
1979-1984	California Institute of Technology, Pasadena, CA. Ph.D. in Environmental Engineering, 1984.

Research and Professional Experience

Dr. Houseworth has been a program manager in the Earth Sciences Division of Lawrence Berkeley National Laboratory (LBNL) since 2000. His expertise is in single and multiphase flow and solute transport in porous and fractured geologic media, and he has worked on applications to petroleum recovery, nuclear waste disposal, and geologic CO_2 sequestration. His most recent work has centered on nuclear waste disposal in argillaceous rock, CO_2/brine leakage from geologic storage reservoirs, and risk assessments of petroleum recovery operations. Dr. Houseworth has authored over 30 peer-reviewed journal articles and conference publications.

Current and Past Positions

Since 2000	Program Manager, Earth Sciences Division, Lawrence Berkeley National Laboratory (LBNL)
1997 – 2000	Technical Systems Manager II, Duke Engineering and Services, Las Vegas, Nevada
1992 – 1997	Senior Staff Consultant, INTERA Inc., Las Vegas, Nevada
1984 – 1992	Research Engineer, Chevron Oil Field Research Company, La Habra, California
1979 – 1980	Engineer, Bechtel Inc., San Francisco, California

Honors and Awards

2012	Director's Award for Exceptional Achievement (TOUGH codes), by LBNL
2007, 2006	Outstanding Performance Award, by LBNL
1984	Ph.D. thesis - Richard Bruce Chapman Memorial Award

Michael L.B. Jerrett

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Education

1986 Trent University, B.Sc. in Environmental Science

1988 University of Toronto, M.A. in Political Science/Environmental Studies

1996 University of Toronto, Ph.D. in Geography

Research and Professional Experience

Dr. Michael Jerrett is an internationally recognized expert in Geographic Information Science for Exposure Assessment and Spatial Epidemiology. He is professor and chair of the Department of Environmental Health Sciences in the Fielding School of Public Health at UCLA. Dr. Jerrett earned his PhD in Geography from the University of Toronto (Canada). For the past 15 years, Dr. Jerrett has researched how to characterize population exposures to air pollution and built environmental variables, how to understand the social distribution of these exposures among different groups (e.g., poor vs. wealthy), and how to assess the health effects from environmental exposures. Over the decade, Dr. Jerrett has also studied the contribution of the built and natural environment to physical activity, behavior and obesity. In 2009, the United States National Academy of Science appointed Dr. Jerrett to the Committee on "Future of Human and Environmental Exposure Science in the 21st Century." The committee recently concluded its task with the publication of a report entitled "Exposure Science in the 21st Century: A Vision and a Strategy." In 2013, the U.S. Environmental Protection Agency appointed Dr. Jerrett to the Clean Air Scientific Advisory Sub-Committee for Nitrogen Oxides. In 2014, Dr. Jerrett was named to the Thomson Reuters List of Highly Cited Researchers, indicating he is in the top 1% of all authors in the fields of Environment/Ecology in terms of citation by other researchers.

Current and Past Positions

Environmental Planner, Land Use Planning Unit, Env. Planning Section,

Approvals Branch, Ontario Ministry of the Environment

Postdoctoral Fellow, Geography and Geology Department, McMaster University

Assistant Professor, Geography Department, San Diego State University

Associate Professor (promoted from Assistant in 2002), School of Geography and Geology, and Health Studies Program, McMaster University

2003-2006 Associate Professor, Preventive Medicine Department, Keck School of Medicine, University of Southern California

2006-Present Associate Professor, Division of Environmental Health Sciences, School of Public Health, University of California, Berkeley

2008-Present Director, Doctor of Public Health Program, School of Public Health, University of California, Berkeley

2012-Present Chair and Full Professor, University of California, Berkeley

Honors and Awards

1995 Teaching Postdoctoral Fellowship, Tri-Council Research, MIEH, McMaster University.

1998 Nystrom Award Competition Finalist, Association of American Geographers (USA).

2003 Dangermond Endowed Speaker in Geographic Information Science, Environmental Systems Research Institute, Redlands, CA and University of California, Santa Barbara

2009 National Academy of Science Member of the Committee on "Future of Exposure Assessment in the 21st Century"

Preston D. Jordan

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Education

1982-1987	University of California, Berkeley, B.A., Geology, 1988
1996-1997	University of California, Berkeley, M.S. in Eng. Sci., Geotechnical Engineering, 1997

Licenses

California Professional Geologist (since 1998)

California Certified Hydrogeologist (since 2007)

California Certified Engineering Geologist (since 2012)

Research Interests

Mr. Jordan has been a geologist in the Earth Sciences Division at Lawrence Berkeley National Laboratory (LBNL) since 1990. In addition to his work on the current report, he has advised the California State Water Resources Control Board regarding guidelines for monitoring groundwater at well stimulation sites. Previously, he was the principal investigator of a scientific assessment of onshore oil well stimulation in California for the Bureau of Land Management state office. Prior to his work on well stimulation, he researched the risk of geologic carbon storage, with a focus on assessing leakage risk. His work on a risk assessment of one of the few industrial-scale geologic carbon storage projects in the world led the operator to reduce the injection pressure. Mr. Jordan has co-authored over 15 peer-reviewed journal articles and conference papers.

Professional Experience

Since 1990	Staff Research Associate currently (after five promotions), Earth Science Division, Lawrence Berkeley National Laboratory
1988-1989	Staff Geologist, Harlan Tait Associates, San Francisco
1988	Field Geologist, Department of Geology and Geophysics, University of California, Berkeley

1987 Assistant Field Geologist, Department of Geology and Geophysics, University of California, Berkeley

Honors and Awards

2010 Outstanding Performance Award, by LBNL

1987 USGS/NAGT program nominee, by University of California, Berkeley

Nathaniel J. Lindsey

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Education

2006-2010	University of Rochester, Rochester, NY. B.S. in Alternative Energy and Sustainable Engineering, 2010.
2011-2013	University of Edinburgh, Edinburgh, Scotland. M.Sc. in Geophysics, 2013
2015-	University of California at Berkeley, Berkeley, CA. Ph.D. in Geophysics

Research and Professional Experience

Mr. Lindsey is a geophysicist in the Earth Sciences Division at Lawrence Berkeley National Laboratory (LBNL). His research seeks to improve seismic methods that characterize earthquake hazard, and apply seismic and electromagnetic geophysics to image the high-temperature hydrothermal fluid processes within geothermal energy reservoirs. Recently, his work has centered on induced seismicity related to enhanced geothermal systems in the western US, and 3-D magnetotelluric (MT) numerical simulation of geothermal systems in Iceland, East Africa, New Zealand, and the United States.

Current and Past Positions

Since 2012	Research Associate, Earth Sciences Division, Lawrence Berkeley National Laboratory (LBNL)
2011 – 2012	US-UK Fulbright Scholar, School of GeoSciences, University of Edinburgh
2010 – 2011	Researcher, Department of Seismology, Geology, & Tectonophysics, Lamont-Doherty Earth Observatory, Columbia University
2010	NSF Research Experience for Undergraduates (REU) Intern, Summer of Applied Geophysical Experience Program, Los Alamos National Laboratory
2010	NSF REU Intern, Department of Physics, University of Rochester
2009	Summer Undergraduate Laboratory Intern, Earth Sciences Division, LBNL
2008	NSF REU Intern, Department of Chemistry, University of Rochester

Honors and Awards

2015 Graduate Research Fellowship, National Science Foundation

2014 Best Presentation Award, Geothermal Resources Council Annual Meeting

2011 Fulbright Scholarship (UK)

2010 Dean's Prize for Undergraduate Research, University of Rochester

2009 Outstanding Commitment to Action, Clinton Global Initiative University

Dr. Jane C. S. Long

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Dr. Long currently focuses on strategic approaches to the climate change problem. She has led efforts to define energy systems with radical emission cuts that can feasibly be built by mid- century. In recognition that the outcomes of climate change might become extremely severe, she leads a national effort to begin research on intentional modification of the climate: geoengineering. Dr. Long also works to bring a factual basis to the debate about hydraulic fracturing and to develop standards for safe practice.

Dr. Long recently retired from Lawrence Livermore National Laboratory as Principal Associate Director at Large. Her leadership was focused on insuring that energy research was coordinated with climate research and the directorate she led was not merely describing the climate problem, but developing solutions to this problem. Outside of the Lab, she was co-chair of the Task Force on Geoengineering for the Bipartisan Policy Center that issued a report recommending that the U.S. begin research on this topic. She led the effort to propose concrete steps the government can take to start research that will be featured in an upcoming "Comment" piece in Nature. These steps recommend governance appropriate for this controversial topic, including review of scientific and social merit, risk assessment, transparency and vested interests management and legal constructs.

She is chairman of the California Council on Science and Technology's California's Energy Future committee, which produced a series of reports designed to show if and how California could reduce emissions by 80% by 2050. These reports contained a methodology—a four-step process—for thinking about this problem that has had influence well beyond the California borders. Many advocates or plans for a new energy system do not take feasibility into account and they often use questionable accounting in counting emissions. The methodology contained in these reports explicitly assesses feasibility and presents an accounting framework for ensuring emission reductions are all counted and counted once. Dr. Long wrote the summary report in language understandable by policy makers; this report is cited frequently, and she has presented the material in many places throughout the country.

She is now on the board of the Center for Sustainable Shale Gas Development in Pennsylvania, which is an organization formed to provide voluntary environmental certification for hydraulic fracturing operators. On this board, she has worked to help develop a standard for wastewater treatment and disposal, perhaps the most difficult environmental problem associated with hydraulic fracturing. She is the lead for a legislatively mandated study of hydraulic fracturing in the state of California. This multimillion dollar assessment includes a large team of scientists. In this role, she has served as the bridge between science and policy—by working with scientists to tailor

highly technical assessments to the public concerns, and to both communicate issues not usually discussed but which are important, and identify issues often discussed, but which in reality are not important.

As the Dean of the Mackay School of Mines, Dr. Long started the Director of the Great Basin Center for Geothermal Energy and through her initiative, the state instituted the Task Force on Renewable Energy and Energy Conservation, which was the first time Nevada had a state body devoted to promoting these technologies. She also initiated the Mining Life-Cycle Center designed to act like an extension service in promoting sustainable practice to the mining industry. Dr. Long also worked at Lawrence Berkeley National Laboratory leading teams to clean up environmental contamination, develop geothermal energy, and store nuclear waste.

Randy L. Maddalena

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Education

1992 University of California, Davis, B.S. Environmental Toxicology

1998 University of California, Davis, Ph.D. Agricultural and Environmental Chemistry

Research and Professional Experience

Dr. Maddalena's research focus at LBNL is on environmental fate and transport processes and multi-pathway exposure assessment for organic chemicals combining modeling, bench scale experimentation and field observational studies applying a range of environmental analytical chemistry techniques. His recent research has focused on characterizing indoor pollutant emission sources from a range of activities and materials, identifying sources of indoor pollutants in FEMA trailers, characterizing exposure concentrations of insecticides on passenger aircraft, developing sampling and modeling tools for assessing indoor exposures to semi-volatile organic compounds, characterizing sulfur gas emission from Chinese drywall, and quantifying particle emission from Mongolian space heating stoves. Other research projects focus primarily on indoor air quality measurements and the development of environmental sampling and analytical chemistry methods to support research on the fate and exposure characterization for a range of pollutants.

Current and Past Positions

Since 1998 Research Scientist, Lawrence Berkeley Lab, Environmental Energy Technology Division, Berkeley, CA

1996 – 1998 Graduate Student Research Associate, Energy and Environment Division, Ernest Orlando Lawrence Berkeley National Laboratory, University of California, Berkeley, CA 94720

1992 – 1997 Post Graduate Researcher, Risk Science Program, Department of Environmental Toxicology, University of California, Davis CA 95616

1992 – 1992 Staff Toxicologist, EMCON Associates, Sacramento, CA 95834

1988 – 1992 General Building Contractor, Groveland California, 95694

1980 – 1988 General Building Contractor, Palmer Alaska, 99645

Honors and Awards

The Honors Society of Phi Kappa Phi (1992-) by election of the Chapter at University of California, Davis; Graduate Student Representative, Graduate Group in Agricultural and Environmental Chemistry, University of California, Davis (June 1995-June 1996)

Thomas E. McKone

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Education

University of St. Thomas, St. Paul MN. B.A. in Chemistry, 1974.

University of California, Los Angeles, CA. M.S. in Nuclear Engineering,1977.

University of California, Los Angeles, CA. Ph.D. in Nuclear Engineering, 1981.

Research and Professional Experience

Dr. McKone, is a senior staff scientist and Deputy for Research Programs in the Energy Analysis and Environmental Impacts Division at the Lawrence Berkeley National Laboratory (LBNL) and Professor of Environmental Health Sciences at the University of California, Berkeley School of Public Health. At LNBL he leads the Sustainable Energy Systems Group. His research focuses on the development, use, and evaluation of models and data for human-health and ecological risk assessments and the health and environmental impacts of energy, industrial, and agricultural systems. Outside of Berkeley, he has served six years on the EPA Science Advisory Board, has been a member of more than a dozen National Academy of Sciences (NAS) committees including the Board on Environmental Studies and Toxicology, and has been on consultant committees for the Organization for Economic Cooperation and Development (OECD), the World Health Organization, the International Atomic Energy Agency, and the Food and Agriculture Organization.

Research and Professional Experience (Recent)

Since 2011	Senior Scientist; Group Leader, Sustainable Energy Systems Group; and Deputy for Research Programs, Energy Analysis and Environmental Impacts Division, LBNL.
2000 – 2011	Senior Scientist; Group Leader, Environmental Chemistry Exposure and Risk Group; and Deputy Department Head, Indoor Environment Department, LBNL.
1996 – 2000	Staff Scientist and Group Leader, Exposure and Risk Analysis Group, Environmental Energy Technologies Division, LBNL.

Since 1996	Professor and Research Scientist, School of Public Health, University of California, Berkeley.

Honors and Awards

McKone is a Fellow of the Society of Risk Analysis and has received two major awards from the International Society of Exposure Analysis—one for lifetime achievement in exposure science research and one for research that has impacted major international and national environmental policies.

Scott E. Phillips

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Education

1989 – 1993 California State University, Fresno, Fresno, CA. B.A. in Geography, 1993.

1993 – 1997 California State University, Fresno, Fresno, CA. M.A. in Geography, 1997.

2007 – 2013 UC Davis, Geography Graduate Group

Research and Professional Experience

Scott Phillips has been a geographic information systems analyst for the Endangered Species Recovery program at California State University, Stanislaus since 1996. His work mostly centers on measuring and mapping of habitat quality for special-status species in human-impacted environments of the San Joaquin Valley of California.

Current and Past Positions

Since 2003 GIS Manager, CSU Stanislaus – Endangered Species Recovery Program

Since 2015 Professor of Geography, Merced College

2010 – 2015 Adjunct Professor of Geography, Merced College

1996 – 2003 GIS Analyst, CSU Stanislaus – Endangered Species Recovery Program

Seth B. C. Shonkoff

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Education

1999 – 2003	Skidmore College, Saratoga Springs, NY. B.A. in Environmental Science, 2003.
2007 – 2008	University of California, Berkeley, Berkeley, CA. M.P.H. in Epidemiology, 2008.
2006 – 2012	University of California, Berkeley, Berkeley, CA. Ph.D. in Environmental Science, Policy, and Management, 2012.

Research and Professional Experience

Dr. Shonkoff is the executive director of the energy science and policy institute, PSE Healthy Energy. Dr. Shonkoff is also a visiting scholar in the Department of Environmental Science, Policy and Management at UC Berkeley, and an affiliate in the Environment Energy Technology Division at Lawrence Berkeley National Laboratory in Berkeley California. An environmental and public health scientist by training, he has more than 15 years of experience in water, air, climate, and population health research. Dr. Shonkoff completed his Ph.D. in the Department of Environmental Science, Policy, and Management and his MPH in epidemiology in the School of Public Health from the University of California, Berkeley. He is a contributing author to the human health chapter of The Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5). He has worked and published on topics related to the intersection of energy, air pollution, water quality, climate, and human health from scientific and policy perspectives. Dr. Shonkoff's research also focuses on the development of the effectiveness of anthropogenic climate change mitigation policies that generate socioeconomic and health co-benefits. Dr. Shonkoff's current work focuses on the human health, environmental and climate dimensions of oil and gas development in the United States and abroad.

Current and Past Positions

Since 2012	Executive Director, PSE Healthy Energy, Oakland, CA

Since 2012	Visiting Scholar, Department of Environmental Science, Policy and Management, University of California, Berkeley, Berkeley, CA
Since 2014	Affiliate, Environment Energy and Technology Division, Lawrence Berkeley National Laboratory, Berkeley, CA
2006 – 2012	Climate and Environmental Public Health Graduate Student Researcher, University of California, Berkeley
2010 – 2010	Program Associate, Berkeley Air Monitoring Group, Berkeley, CA
2003 – 2006	Environmental Analyst, San Francisco Estuary Institute, Richmond, CA

Honors and Awards

Since 2014	Leader, Emerging Leaders Fund, Claneil Foundation, PA
Fall 2012	Outstanding Graduate Student Instructor Award, University of California, Berkeley

William T. Stringfellow, Ph.D.

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Education

1990-1994 Ph.D., Environmental Sciences and Engineering (supporting program: Microbial Physiology and Genetics), University of North Carolina at Chapel Hill.

1982-1984 M.S., Microbiology (minor: Aquatic Ecology), Virginia Polytechnic Institute and State University, 1984.

1976-1980 B.S., Environmental Health, University of Georgia, 1980.

Research and Professional Experience

William T. Stringfellow is a Professor and Director of the Ecological Engineering Research Program in the School of Engineering and Computer Science at the University of the Pacific. He has a joint appointment as a Research Engineer at Lawrence Berkeley National Laboratory where he is the Director of the Environmental Measurements Laboratory. Dr. Stringfellow is an expert in water quality and industrial waste management. His recent research includes evaluations of the sustainability of biomass energy facilities treating agricultural wastes and investigating the water quality impacts of the Gulf of Mexico oil spill. He is currently investigating the use of water treatment chemicals in the energy industry, with an emphasis on understanding the environmental impacts of biocides. Dr. Stringfellow has over 30 publications in the field of water quality and industrial waste management.

Current and Past Positions

2004 to present: University of the Pacific, Ecological Engineering Research Program, School of Engineering and Computer Science, Stockton, CA, Director, EERP and Professor

2003 to present: Lawrence Berkeley National Laboratory, Environmental Measurements Laboratory, Earth Sciences Division, Berkeley, CA, Director, EML

1996 to present: Lawrence Berkeley National Laboratory, Earth Sciences Division, Berkeley, CA, Environmental Engineer

1988 to 1989: Institut Pasteur, Departement d'Ecologie, Paris, France, Stagiaire (Visiting Researcher)

1983 to 1988: Sybron Chemicals, Inc., Salem Research Facility, Salem, Virginia, Senior Research Microbiologist

1980 to 1981: Ecology and Environment, Inc., Decatur, Georgia, Hazardous Waste Site Investigator

Awards

Outstanding Mentor Award, Lawrence Berkeley National Laboratory, 2001

Outstanding Mentor Award, Department of Energy, 2002

Craig Ulrich

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Education

1996-2000	Northwest Missouri State University, Maryville, MO; B.S. in Geology, 2005.
2002-2005	Rutgers the State University of New Jersey, Newark, NJ; M.S. in Environmental Geology, 2005.

Research and Professional Experience

Mr. Ulrich has been a geophysicist in the Earth Sciences Division of Lawrence Berkeley National Laboratory (LBNL) since 2010. His expertise is in near-surface geophysics with an emphasis in environmental studies of remediation, hydrology and climate change. His most recent work has centered on fresh- and salt-water mixing in coastal environments, understanding climate feedbacks in an arctic setting, and geologic CO_2 sequestration.

Current and Past Positions

Since 2010	Scientific Engineering Associate, Earth Sciences Division, Lawrence Berkeley National Laboratory (LBNL)
2006 – 2010	Geophysics Project Manager, Enviroscan, Lancaster, Pennsylvania
2005 – 2006	Geologist, Environmental Waste Management Associates, Parsippany, New Jersey
2003 – 2005	Geologist/Project Manager, Atlantic Environmental Solutions, Hoboken, New Jersey
2003 – 2006	Owner/Geophysicist, Nearsurface Geophysical Consultants, LLC, Jersey City, New Jersey

Appendix D.

Glossary

Acid fracturing – a form of hydraulic fracture stimulation of a formation performed by injecting the acid over the parting pressure of the rock and using the acid to etch channels in the fracture face.

Androgens – steroid hormones that promote the development and maintenance of male characteristics of the body.

Anti-androgens – a substance that can prevent the full expression of androgen.

Anti-estrogens – a substance that can prevent the full expression of estrogen.

Aquifer – a zone of saturated rock or soil through which water can easily move.

Bactericide – a product that kills bacteria in the water or on the surface of the pipe.

Basement faults – faults that occur in the undifferentiated assemblage of rock underlying the oldest stratified rocks in any region.

Basement rock – the undifferentiated assemblage of rock underlying the oldest stratified rocks in any region.

Bedding planes – surfaces that separate sedimentary layers in a rock. The beds are distinguished from each other by grain size and composition, such as in shale and sandstone. Subtle changes, such as beds richer in iron oxide, help distinguish bedding. Most beds are deposited essentially horizontally.

Biogenic methane – methane produced as a direct consequence of bacterial activity.

Biomarkers – complex molecular fossils used to correlate crude oil and petroleum source rocks, provide information on the type of organic matter, and characterize the thermal maturity.

Borehole cuttings – the small chips and fines generated by drilling through a formation with a drill bit. Most of the cuttings are removed from the drilling mud as the fluid pass through the solids control equipment (e.g., shakers, screens, cyclones, etc.,) at the surface.

Brittle – a rock characteristic that implies mechanical failure in the form of a fracture created with little or no plastic deformation.

BTEX (benzene, toluene, ethylbenzene, and xylene) – volatile aromatic compounds typically found in petroleum products such as gasoline and diesel fuel.

Buffer – a chemical used to maintain the pH of a solution within a limited range.

Cations – positively charged ions.

Chemical Abstracts Service (CAS) number – a unique numeric identifier, designates only one substance, has no chemical significance, and is a link to a wealth of information about a specific chemical substance within the CAS registry.

Chimneys – vertically oriented geological structures that may be circular or subcircular in planform if associated with faults, or may be more dispersed laterally if not associated with faults. Chimneys form from gas migration processes and are often found in association with mud volcanoes.

Class II wells – used for injection/disposal of fluids associated with oil and natural gas production. Most of the injected fluid is salt water (brine), which is brought to the surface in the process of producing (extracting) oil and gas. In addition, brine and other fluids are injected to enhance (improve) oil and gas production.

Clay stabilizer – a chemical additive used to prevent clay destabilization that results in clay migration or swelling caused by a reaction to an aqueous fluid.

Conductor casing – generally, the first string of casing in a well. It may be lowered into a hole drilled into the formations near the surface and cemented in place, or it may be driven into the ground by a special pile driver. Its purpose is to prevent the soft formations near the surface from caving in and to conduct drilling mud from the bottom of the hole to the surface when drilling starts.

Conventional reservoir – reservoirs that may be produced commercially without altering the reservoir permeability or associated hydrocarbon viscosity.

Corrosion inhibitor – a chemical or mixture of chemicals that prevents or reduces corrosion.

Coulomb criterion – a criterion for rock failure as a function of the normal and shear stress conditions.

Cross-link gel fracturing fluid – is generally an aqueous fluid containing a gelling agent like guar or xanthan and a crosslinker. It has even greater viscosity than a gel fracturing fluid.

Crosslinker – A substance that promotes or regulates intermolecular covalent bonding between polymer chains, linking them together to create a larger structure.

Diagenetic –physical and chemical changes that affect sedimentary deposits during burial and may culminate in lithification, i.e., turning sediment into solid rock.

Diagenetic trap – a trap formed as a result of diagenetic alteration of rocks within a sedimentary basin, resulting in decreased permeability.

Diatomite – a fine, soft, siliceous sedimentary rock composed chiefly of the silica-rich remains of diatoms.

Dip – A measure of the angle between the flat horizon and the slope of a sedimentary layer, fault plane, metamorphic foliation, or other geologic structure.

Directional drilling – drilling the wellbore in a planned angle of deviation or trajectory other than vertical.

Dissolved Organic Carbon (DOC) – mass of organic carbon from a measured water sample that is dissolved or colloidal that can pass through a filter, typically a 0.4 to 0.7 micron filter

Dolomites – carbonate rocks made up of dolomite ($CaMg(CaCO_3)_2$).

Downdip – located down the dip of a sloping planar surface.

Drilling mud – the fluid (water, oil or gas based) circulated through the wellbore during rotary drilling and workover operations that is used to establish well control, transport cuttings to the surface, provide fluid loss control, lubricate the string and cool the bottom hole assembly.

Ductile – a rock characteristic that implies mechanical failure in the form of a fracture created with a large amount of plastic deformation.

Earthquake magnitude – a measure of the amount of energy released during an earthquake, such as the Richter scale.

Effective stress – the total stress minus the pore pressure.

Endocrine-disrupting compounds – chemicals that may interfere with the body's endocrine system and produce adverse developmental, reproductive, neurological, and immune effects in both humans and wildlife.

EPA maximum contaminant level (MCL) – threshold concentration of a contaminant above which water is not suitable for drinking.

Epicenter – a point, directly above the true center of disturbance at the Earth's surface, from which the shock waves of an earthquake apparently radiate.

Estrogens – steroid hormones that promote the development and maintenance of female characteristics of the body.

Evaporative emissions – hydrocarbons released into the atmosphere through evaporation from equipment or storage facilities.

Fault – a fracture in the Earth in which one side has moved relative to the other.

Flaring – the combustion of unwanted gases produced by an oil well.

Flowback – fracturing fluid, perhaps mixed with formation water and traces of hydrocarbon, that flows back to the surface after the completion of hydraulic fracturing.

Foaming agent – a material that facilitates formation of foam.

Formation – a body of rock of considerable extent with distinctive characteristics that allow geologists to map, describe, and name it.

Fracture aperture – the distance between fracture faces.

Fracture height – the vertical extent of a fracture.

Fracture length – the horizontal extent of a fracture.

Fracture propagation – enlargement or extension of a crack in a solid material.

Friction reducer – a material, usually a polymer, that reduces the friction of flowing fluid in a conduit.

Fugitive emissions – emissions of gases or vapors due to leaks and other unintended or irregular releases.

Gel fracturing fluid –generally an aqueous fluid containing a gelling agent like guar or xanthan. It has an enhanced viscosity relative to slickwater fracturing fluids.

Globally Harmonized System of Classification and Labeling of Chemicals (GHS) – a worldwide initiative to promote standard criteria for classifying chemicals according to their health, physical and environmental hazards.

Greenhouse gas emissions (GHG) – emissions of gases such as CO_2 and methane that trap heat in the atmosphere.

Horizontal drilling – a well drilled in a manner to reach an angle of 90 degrees relative to a level plane at its departure point at the surface. In practice, the horizontal section of most horizontal wells varies by several degrees.

Hybrid fracturing – hydraulic fracturing that utilizes more than one type of fracturing fluid for a given stage.

Hydraulic diffusivity coefficient – the ratio of the hydraulic conductivity to the volume of water that a unit volume of saturated soil or rock releases from storage per unit decline in hydraulic head. It is a parameter that combines transmission characteristics and the storage properties of a porous medium.

Hydraulic fracturing – an operation in which a specially blended liquid is pumped down a well and into a formation under pressure high enough to cause the formation to crack open, forming passages through which oil can flow into the wellbore.

Hydrostatic pressure – the pore pressure that results from the static weight of pore fluid above the point of interest.

Induced seismicity – earthquakes caused by human activities.

Intercalated turbiditic sandstones – sandstones deposited from a turbidity current (an underwater current flowing downslope owing to the weight of sediment it carries) that are alternately layered between other rock types.

Intermediate casing – the casing set in a well after the surface casing but before production casing to keep the hole from caving and to seal off formations.

Iron control agent – a chemical that controls the precipitation of iron from solution.

Kelly – the heavy square or hexagonal steel member suspended from the swivel through the rotary table and connected to the topmost joint of drill pipe to turn the drill stem as the rotary table turns.

Kerogen – solid, insoluble organic material in shale and other sedimentary rock that yields oil and/or gas upon heating.

Lithology – the physical characteristics (e.g., mineral content, grain size, texture and color) of a rock or stratigraphic unit.

Matrix acidizing – use of a mineral acid (typically hydrochloric acid (HCl) or HCl in combination with hydrofluoric acid (HF)) or an organic acid (typically acetic or formic) to remove damage or stimulate the permeability of a formation.

Maturation – the chemical transformation of kerogen into petroleum fluids.

Median lethal dose (LD_{50}) – the dose required to kill half the members of a tested population after a specified test duration.

Microearthquakes – an earthquake of low intensity with a magnitude of 2 or less on the Richter scale.

Microscanner log – a geophysical measurement record from a downhole instrument that consists of four orthogonal imaging pads containing microelectrodes in direct contact with the borehole wall. It is used for mapping of bedding planes, fractures, faults, foliations, and other formation structures and dip determination.

Microseismic monitoring – a method of tracking a fracture by listening for the sounds of shear fracturing in the formation during the hydraulic fracturing process.

Migrated oil – oil that has moved from source rock to reservoir rock.

Miocene – the geologic time ranging from about 23 to 5.3 million years ago.

MODFLOW – the USGS's three-dimensional (3D) finite-difference groundwater model.

Multi-stage hydraulic fracturing – hydraulic fracturing conducted repeatedly in isolated segments along the length of the well's production interval.

Nanoparticles – a microscopic particle of matter that is measured on the nanoscale, usually less than 100 nanometers.

Normal stress – the internal forces per unit area that are exerted in a material object and are also perpendicular to the selected area.

Oil window - the temperature and pressure ranges under which the organic matter in organic-rich sedimentary rocks is transformed into petroleum fluids.

Opening mode fractures – a fracture that opens in response to tensile stress, i.e., a stress that acts to pull a material object apart.

Organic shales – organic-rich shales.

Overburden – the rock layers lying above a point of interest in the subsurface.

Oxides of nitrogen (NO_x) – consist of nitric oxide (NO), nitrogen dioxide (NO_2) and nitrous oxide (N_2O).

Ozone precursors – chemical compounds (such as carbon monoxide, methane, non-methane hydrocarbons, and nitrogen oxides) that, in the presence of solar radiation, react with other chemical compounds to form ozone.

Particulate matter (PM) and $PM_{2.5}$ – a complex mixture of extremely small particles and liquid droplets. $PM_{2.5}$ consist of particles less than 2.5 microns in diameter.

Permeability – the ability of a rock or other material to allow fluid flow through its interconnected spaces.

pH adjuster – chemical agents to reduce, or to increase, the acidity of a solution.

Phosphatic shales – phosphate-rich shales.

Pipes – vertically oriented geologic structures commonly circular or subcircular in planform that may have formed as a result of hydrothermal activity, overpressure, or dissolution processes.

Play – hydrocarbon reservoirs within the same region that have common sourcing and trapping mechanisms.

Pore pressure – the normal stress exerted by pore fluids on the porous medium.

Poromechanical effects – phenomena that occur in porous materials whose mechanical behavior is significantly influenced by the pore fluid.

Portland cement – a general class of hydraulic cements (cements that can harden under water) usually made by burning a mixture of limestone and clay in a kiln and pulverizing into a powder.

Precipitate – a solid substance formed from a liquid solution during a chemical process.

Produced water – water, ranging from fresh to salty, produced with the hydrocarbons as a result of pressure drawdown and flow through the petroleum reservoir.

Production casing – the last string of casing set in a well that straddles and isolates the producing interval, inside of which is usually suspended a tubing string.

Production liner – similar to casing pipe but does not extend back to the ground surface. Liners may or may not be cemented.

Propagation of water front – the movement of a constant water saturation level through a porous medium.

Proppant – well sorted and consistently sized sand or man-made materials that are injected with the fracturing fluid to hold the fracture faces apart after pressure is released.

Quaternary fault – a fault that formed sometime between the present and about 2.6 million years ago.

Radiogenic material – material produced by radioactive decay.

Redox conditions – a quantitative description of the environment in question with respect to be oxidizing or reducing.

Reservoir – a subsurface accumulation of hydrocarbon fluids that resides in rock pores and fractures.

Scale inhibitor – a chemical that prevents scale from forming in scale mineral saturated produced waters.

Sedimentary basin – a depression in the Earth's surface that collects sediment.

Seismic hazard – a phenomenon such as ground shaking, fault rupture, or soil liquefaction that is generated by an earthquake.

Seismic moment – a measure of the size of an earthquake based on the area of fault rupture, the average amount of slip, and the force that was required to overcome the friction sticking the rocks together that were offset by faulting.

Seismometer – an instrument for measuring the direction, intensity, and duration of earthquakes by measuring the actual movement of the ground.

Seismometer array – numerous seismometers placed at discrete points in a well-defined configuration.

Semi-volatile organic compounds (SVOC) – organic compound which has a boiling point higher than water and which may vaporize when exposed to temperatures above room temperature.

Shale – sedimentary rock derived from mud and commonly finely laminated (bedded). Particles in shale are commonly clay minerals mixed with tiny grains of quartz eroded from pre-existing rocks.

Shear failure – brittle or ductile damage that results from shear stress of sufficient magnitude.

Shear stress – the internal forces per unit area that are exerted in a material object and are also tangential to the selected area.

Siliceous – a rock rich in a silica phase, such as opal, cristobalite, or quartz.

Siliceous shales – silica-rich shales.

Slickwater fracturing fluid - a water-based fracturing fluid with only a very small amount of a polymer added to give friction reduction benefit.

Solvent - a substance that will dissolve a solid. In the oil field, oil based solvents may range from xylene for asphaltenes and sludges, to kerosene and diesel/xylene mixtures for paraffins.

Source rock – a rock rich in organic matter from the original sediment deposition that can generate petroleum fluids under certain temperature and pressure conditions.

Specific conductance - the measure of a material to conduct an electric current.

Stable isotopes – two or more forms of a chemical element having different numbers of neutrons that do not have any measurable radioactive decay.

Static fractures – fractures that are not changing over time.

Steam cycling – a form of steam injection in which injection and production take place in the same well, which is accomplished by alternating steam injection with oil production.

Steam injection – a thermally enhanced oil recovery method in which steam is forced into the reservoir by applying pressure; the thermal energy of the steam heats the reservoir, which reduces the viscosity of heavy oil (usually the target of thermal oil recovery methods).

Storage coefficient – the volume of water released from storage per unit surface area of a confined aquifer per unit decline in hydraulic head.

Stratigraphic trap – a trap formed as a result of variations in porosity and permeability of the stratigraphic sequence.

Stratigraphic zone – a body of strata that is distinguished on the basis of lithology, fossil content, age, or other rock property.

Stress – the internal forces per unit area that are exerted in a material object.

Strike – a geometrical characteristic of a planar geologic surface defined by the line of intersection between the geologic surface and a horizontal plane.

Structural features – geologic features that result from tectonic, diapiric, gravitational and compactional processes.

Structural trap – a trap formed as a result of faulting or folding of the rock.

Supercritical CO_2 – a fluid state of carbon dioxide which displays characteristics of both liquid and gas that occurs at conditions above its critical temperature and critical pressure.

Surface casing – the casing following the conductor casing in a well that protects fresh water aquifers from contact with fluids moving through the well. It is always cemented across the water zone and the cement usually extends to the surface.

Surfactant – a chemical that is attracted to the surface of a fluid and modifies the properties such as surface tension.

Tectonic features – features that are a result of forces or conditions within the Earth that cause movements of the crust.

Tectonic stress – stress that results from forces or conditions within the Earth that cause movements of the crust.

Televiewer log – a record of the amplitude of high-frequency acoustic pulses reflected by the borehole wall; provides location and orientation of bedding, fractures, and cavities.

Thermogenic methane – methane created by the thermal decomposition of buried organic material.

Tiltmeter – an instrument used to measure slight changes in the inclination of the Earth's surface resulting from subsidence or uplift, usually in connection with volcanology and earthquake seismology.

Total dissolved solids (TDS) – total amount of all inorganic and organic substances – including minerals, salts, metals, cations or anions – that are dissolved within a volume of water.

Total Organic Carbon (TOC) – total mass of organic carbon from a measured sample.

Total Suspended Solids (TSS) - total mass retained on a filter per unit volume of water, typically a 0.4 to 0.7 micron filter.

Toxicity – the degree to which a substance can harm humans or other living organisms.

Trace metals – metals that do not affect chemical or physical properties of the system as a whole to any significant extent, and have ideal solution behavior characteristic of very high dilution.

Trap – a configuration of geologic layers and/or structures that has a very low permeability and is suitable for blocking the upward movement of buoyant hydrocarbons.

Turbidity – the measure of relative clarity of a liquid. It is an optical characteristic of water and is an expression of the amount of light that is scattered by material in the water when a light is shined through the water sample.

Unconventional reservoir – oil and gas resources whose porosity, permeability, fluid trapping mechanism, or other characteristics differ from conventional sandstone and carbonate reservoirs, such as shale gas, shale oil, heavy and viscous oil, gas hydrates, tight gas, and coal-bed methane resources.

Updip – located up the dip of a sloping planar surface.

Viscosity – a measurement of a fluid's internal resistance to flow, expressed as the ratio of shear stress to shear rate.

Vitrinite – a type of woody kerogen that is used to measure source rock maturity.

Vitrinite reflectance – a measure of source rock maturity based on the reflectance of vitrinite, measured as % Ro. The onset of oil generation typically occurs at around Ro = 0.6%, with gas formation occurring when Ro = 1.2 %.

Volatile organic compounds (VOC) – organic chemicals whose composition makes it possible for them to evaporate under normal indoor atmospheric conditions of temperature and pressure.

Water flooding – purposely injecting water below and/or into the reservoir to drive the oil towards the producing wellbore.

Well completion – the activities and methods of preparing a well for the production of oil and gas or for other purposes, such as injection; the method by which one or more flow paths for hydrocarbons are established between the reservoir and the surface.

Well stimulation technology – refers to well stimulation methods of hydraulic fracturing, acid fracturing, and matrix acidizing.

Zonal isolation – the exclusion of fluids such as water or gas in one zone from mixing with fluids in another zone along pathways outside of a well casing, accomplished through cement that seals the rock to the casing.

Appendix E.

Review of Information Sources

For this report, authors of the report reviewed many sources of public information, including some that are not easily accessible to all citizens, such as fee-based scientific journals. If a member of the public wishes to view a document referenced in the report, they may visit California Council on Science and Technology at 1130 K Street, Suite 280, Sacramento, CA 95814-3965. We cannot duplicate or electronically transmit copyright documents. Please make arrangements in advance by contacting CCST at (916) 492-0996.

CCST issued a request for public submissions of literature by July 15, 2014. All literature submitted by the deadline is listed below in the Bibliography of Submitted Literature. Our scientists reviewed the submissions and cited a given reference in the report if it met all three of the following criteria:

1. Fit into one of the five categories of admissible literature (described in a-e below).
    a. Published, peer-reviewed scientific papers.
    b. Government data and reports.
    c. Academic studies that are reviewed through a university process, textbooks, and papers from technical conferences.
    d. Studies generated by non-government organizations that are based on data, and draw traceable conclusions clearly supported by the data.
    e. Voluntary reporting from industry. This data is cited with the caveat that, as voluntary, there is no quality control on the accuracy or completeness of the data.
2. Was relevant to the scope of the report.
3. Added substantive information to the report.

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Appendix F.

California Council on Science and Technology Study Process

The reports of the California Council on Science and Technology (CCST) are viewed as being valuable and credible because of the institution's reputation for providing independent, objective, and nonpartisan advice with high standards of scientific and technical quality. Checks and balances are applied at every step in the study process to protect the integrity of the reports and to maintain public confidence in them.

Study Process Overview—Ensuring Independent, Objective Advice

For over 25 years, CCST has been advising California on issues of science and technology by leveraging exceptional talent and expertise.

CCST can enlist the state's foremost scientists, engineers, health professionals, and other experts to address the scientific and technical aspects of society's most pressing problems.

CCST studies are funded by state agencies, foundations and other private sponsors. CCST provides independent advice; external sponsors have no control over the conduct of a study once the statement of task and budget are finalized. Study committees gather information from many sources in public and private meetings, but they carry out their deliberations in private in order to avoid political, special interest, and sponsor influence.

Stage 1: Defining the Study

Before the committee selection process begins, CCST staff and members work with sponsors to determine the specific set of questions to be addressed by the study in a formal "statement of task," as well as the duration and cost of the study. The statement of task defines and bounds the scope of the study, and it serves as the basis for determining the expertise and the balance of perspectives needed on the committee.

The statement of task, work plan, and budget must be approved by CCST's Board chair. This review often results in changes to the proposed task and work plan. On occasion, it results in turning down studies that CCST believes are inappropriately framed or not within its purview.

Stage 2: Committee Selection and Approval

Selection of appropriate committee members, individually and collectively, is essential for the success of a study. All committee members serve as individual experts, not as representatives of organizations or interest groups. Each member is expected to contribute to the project on the basis of his or her own expertise and good judgment. A committee is not finally approved until a thorough balance and conflict-of-interest discussion is held, and any issues raised in that discussion are investigated and addressed. Members of a committee are anonymous until this process is completed.

Careful steps are taken to convene committees that meet the following criteria:

An appropriate range of expertise for the task. The committee must include experts with the specific expertise and experience needed to address the study's statement of task. A major strength of CCST is the ability to bring together recognized experts from diverse disciplines and backgrounds who might not otherwise collaborate. These diverse groups are encouraged to conceive new ways of thinking about a problem.

A balance of perspectives. Having the right expertise is not sufficient for success. It is also essential to evaluate the overall composition of the committee in terms of different experiences and perspectives. The goal is to ensure that the relevant points of view are, in CCST's judgment, reasonably balanced so that the committee can carry out its charge objectively and credibly.

Screened for conflicts of interest. All provisional committee members are screened in writing and in a confidential group discussion about possible conflicts of interest. For this purpose, a "conflict of interest" means any financial or other interest which conflicts with the service of the individual because it could significantly impair the individual's objectivity or could create an unfair competitive advantage for any person or organization. The term "conflict of interest" means something more than individual bias. There must be an interest, ordinarily financial, which could be directly affected by the work of the committee. Except for those rare situations in which CCST determines that a conflict of interest is unavoidable, and promptly and publicly disclose the conflict of interest, no individual can be appointed to serve (or continue to serve) on a committee of the institution used in the development of reports if the individual has a conflict of interest that is relevant to the functions to be performed.

Point of View is different from Conflict of Interest. A point of view or bias is not necessarily a conflict of interest. Committee members are expected to have points of view, and CCST attempts to balance these points of view in a way deemed appropriate for the task. Committee members are asked to consider respectfully the viewpoints of other members, to reflect their own views rather than be a representative of any organization, and to base their scientific findings and conclusions on the evidence. Each committee member has the right to issue a dissenting opinion to the report if he or she disagrees with the consensus of the other members.

Other considerations. Membership in CCST and previous involvement in CCST studies are taken into account in committee selection. The inclusion of women, minorities, and young professionals are additional considerations.

Specific steps in the committee selection and approval process are as follows:

Staff solicit an extensive number of suggestions for potential committee members from a wide range of sources, then recommend a slate of nominees. Nominees are reviewed and approved at several levels within CCST. A provisional slate is then approved by CCST's Board. The provisional committee members complete background information and conflict-of-interest disclosure forms. The committee balance and conflict-of-interest discussion is held at the first committee meeting. Any conflicts of interest or issues of committee balance and expertise are investigated; changes to the committee are proposed and finalized. Committee is formally approved. Committee members continue to be screened for conflict of interest throughout the life of the committee.

Stage 3: Committee Meetings, Information Gathering, Deliberations, and Drafting the Report

Study committees typically gather information through:

1. Meetings
2. Submission of information by outside parties
3. Reviews of the scientific literature, and
4. Investigations by the committee members and staff.

In all cases, efforts are made to solicit input from individuals who have been directly involved in, or who have special knowledge of, the problem under consideration.

The committee deliberates in meetings closed to the public in order to develop draft findings and recommendations free from outside influences. The public is provided with brief summaries of these meetings that include the list of committee members present. All analyses and drafts of the report remain confidential.

Stage 4: Report Review

As a final check on the quality and objectivity of the study, all CCST reports—whether products of studies, summaries of workshop proceedings, or other documents—must undergo a rigorous, independent external review by experts whose comments are provided anonymously to the committee members. CCST recruits independent experts with a range of views and perspectives to review and comment on the draft report prepared by the committee.

The review process is structured to ensure that each report addresses its approved study charge and does not go beyond it, that the findings are supported by the scientific evidence and arguments presented, that the exposition and organization are effective, and that the report is impartial and objective.

Each committee must respond to, but need not agree with, reviewer comments in a detailed "response to review" that is examined by one or two independent report review "monitors" responsible for ensuring that the report review criteria have been satisfied. While feedback from the peer reviewers and report monitors is reflected in the report, neither group approved the final report before publication. The steering committee and CCST take sole responsibility for the content of the report. After all committee members and appropriate CCST officials have signed off on the final report, it is transmitted to the sponsor of the study and is released to the public. Sponsors are not given an opportunity to suggest changes in reports. All reviewer comments remain confidential. The names and affiliations of the report reviewers are made public when the report is released.

The report steering committee wishes to thank the oversight committee and the peer reviewers for many thoughtful comments that improved this manuscript.

Appendix G

Expert Oversight and Review

Oversight Committee:

Bruce Darling, National Academy of Sciences and National Research Council

Paul Jennings, California Institute of Technology

Robert F. Sawyer, University of California Berkeley

Report Monitors:

Maxine Savitz, Honeywell, Int. (Retired)

Robert F. Sawyer, University of California Berkeley

Expert Reviewers:

David Allen, University of Texas at Austin

Ari Bernstein, Harvard T.H. Chan School of Public Health, Boston Children's Hospital

Ziyad Duron, Harvey Mudd College

Graham Fogg, University of California, Davis

Gary Hughes, California Polytechnic State University, San Luis Obispo

Tissa Illangaskare, Colorado School of Mines

Thom Kato, Lawrence Livermore National Laboratory

George E. King, George E. King Engineering

Lisa McKenzie, University of Colorado

Peter McMahon, U.S. Geological Survey, Colorado Water Science Center

Mason Medizade, Cal Poly State University, San Luis Obispo

Charles Menzie, Exponent Inc.

Larry Saslaw, Bureau of Land Management, Retired

Appendix H

Unit Conversion Table

1	Oil Barrel	=	0.158987	Cubic Meters (m^3)
1	Cubic Foot (ft^3)	=	0.02831685	Cubic Meters (m^3)
1	Cubic Mile (mi^3)	=	4.16818	Cubic Kilometers (km^3)
1	Foot (ft)	=	0.3048	Meters (m)
1	Inch (in)	=	2.54	Centimeters (cm)
1	Gallon (gal)	=	0.00378541	Cubic Meters (m^3)
1	Acre-foot	=	1,233.4	Cubic Meters (m^3)
1	Miles (mi.)	=	1.609344	Kilometers (km)
1	Square Mile (mi^2)	=	2.589988	Square Kilometers (km^2)
1	Nautical Mile	=	1.852	Kilometers (km)
1	Millidarcy (md)	=	9.87×10^{-16}	Square meters (m^2)
1	Pound per Square Inch (psi)	=	6.89476×10^{-6}	Gigapascals (GPa)