



INTERNATIONAL SCHOOL FOR GEOSCIENCE RESOURCES (IS-Geo)
KOREA INSTITUTE OF GEOSCIENCE AND MINERAL RESOURCES (KIGAM)

PUBLIC CUSTOMIZED TRAINING COURSE ON
Modeling Geologic Sequestration of CO₂ with the STOMP-CO₂ Reservoir Simulator

The International School for Geoscience Resources of KIGAM presents a training course on **Modeling Geologic Sequestration of CO₂ with the STOMP-CO₂ Reservoir Simulator**. The course will take place in the Mirinae room of the International School for Geoscience Resources at KIGAM in Daejeon (Korea) from Oct. 31th to Nov. 3rd, 2023 and will include the following topics.

Date	Topics	Instructors
10.31. (TUE)	Day 1. Modeling Aqueous Saturated and Unsaturated Flow and Transport Topic 1. Introduction to Modeling with STOMP and STOMPX Topic 2. Aqueous Flow in Saturated and Unsaturated Porous Media Topic 3. Aqueous Flow to a Well in a Confined Multi-layer System	Dr. Mark White, P.E. (PNNL) Signe White, P.G., P.H.G.(Intera)
11.1. (WED)	Day 2. Modeling Carbon Sequestration in Deep Saline Formations Topic 1. Radial Flow of Supercritical CO ₂ from an Injection Well (GeoSeq #3) Topic 2. Contrasting Pressure- and Flow-Controlled CO ₂ Injection Wells Topic 3. CO ₂ Injection into a Hybrid Heterogeneous Domain	
11.2. (THU)	Day 3. Parallel Processing and Modeling Coupled Hydraulic and Geomechanical Processes Topic 1. Extended Domain: Contrasting Pressure- and Flow-Controlled CO ₂ Injection Wells Topic 2. Extended Domain: Multi-Well Pressure Interference Topic 3. Hydromechanical Responses with CO ₂ Injection	
11.3. (FRI)	Day 4. Modeling Coupled Hydraulic and Geochemical Processes Topic 1. Introduction to Geochemical Modeling with ECKEChem Topic 2. Mineral Trapping in a Glauconitic Sandstone Topic 3. Modeling CO ₂ Impacts to a Drinking Water Carbonate Aquifer - Laboratory Experiments to Field-Scale Forecasts	

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**Public Customized Training Course on
Modeling Geologic Sequestration of CO₂ with the STOMP-CO₂ Reservoir Simulator**

Date/Time	Program Description	Remarks
10.31 (Tue)	Modeling Aqueous Systems	
09:00-10:00	Overview of Subsurface Modeling	Dr. Mark White, P.E.
10:00-11:45	Modeling with STOMP and STOMPX	Signe White, P.G., P.H.
11:45-13:00	<i>Lunch</i>	
13:00-15:00	1D Aqueous Flow and Transport	Dr. Mark White, P.E.
15:00 - 17:00	2D Aqueous Flow and Transport	Signe White, P.G., P.H.
11.1 (Wed)	Modeling Carbon Sequestration	
09:00-10:00	Overview of CO ₂ Storage Modeling	Dr. Mark White, P.E.
10:00-11:45	Radial Flow of scCO ₂	Dr. Mark White, P.E.
11:45-13:00	<i>Lunch</i>	
13:00-15:00	Pressure/Flow Controlled Wells	Signe White, P.G., P.H.
15:00 - 17:00	Hybrid Heterogeneous Domain	Dr. Mark White, P.E.
11.2 (Thu)	Parallel Computing and Modeling Coupled Geomechanics	
09:00-10:00	Overview of Geomechanical Modeling	Dr. Mark White, P.E.
10:00-11:45	Extended Domain w/ Injection Well	Signe White, P.G., P.H.
11:45-13:00	<i>Lunch</i>	
13:00-15:00	Extended Domain Pressure Interference	Signe White, P.G., P.H.
15:00 - 17:00	Modeling Coupled Geomechanics	Dr. Mark White, P.E.
11.3 (Fri)	Modeling Carbon Mineralization	
09:00-10:00	Overview of Geochemical Modeling	Dr. Mark White, P.E.
10:00-11:45	Mineralization: Glauconitic Sandstone	Dr. Mark White, P.E.
11:45-13:00	<i>Lunch</i>	
13:00-15:00	Modeling Lab-scale Carbonate Aquifer	Signe White, P.G., P.H.
15:00 - 17:00	Modeling Field-scale Carbonate Aquifer	Dr. Mark White, P.E.

※ The working language is English. This schedule is subject to change.

MARK WHITE

STAFF MECHANICAL ENGINEER

Earth Systems Sciences Division

Pacific Northwest National Laboratory

PROFESSIONAL OBJECTIVES

Seek solutions for sustainable energy and water resources through the development of technologies and analytical tools to evaluate their effectiveness and impacts. Recover the earth's environment via approaches that fit today and the tomorrow of future generations.

EDUCATION AND PROFESSIONAL REGISTRATION

- 1995-Current: PROFESSIONAL ENGINEER - Colorado State Board of Registration for Professional Engineers and Professional Land Surveyors.
- 1982-1986: DOCTOR OF PHILOSOPHY in MECHANICAL ENGINEERING - Colorado State University, Thesis: Partitioned Enclosure Free Convection with Real and Boussinesq Fluids.
- 1982: BOURSE CHATEAUBRIAND - Ecole Nationale Supérieure des Mines de Paris
- 1977-1981: MASTER OF SCIENCE in MECHANICAL ENGINEERING - Colorado State University, Thesis: Optimization of Numerical Parameters and Solution Procedures for a Mass Wall Glazing System.
- 1973-1977: BACHELOR OF SCIENCE in BIOPHYSICS - Pennsylvania State University, Senior Project: Protein Composition of Ascites Fluid from Laboratory Rats.

EMPLOYMENT HISTORY

- 2014-Current: STAFF MECHANICAL ENGINEER – Earth Systems Sciences Division, PNNL
- 1997-2002: ADJUNCT PROFESSOR - Mechanical Engineering Department, WSU Tri-Cities
- 1991-2014: SENIOR RESEARCH ENGINEER - Environmental Technology Division, PNNL
- 1988-1991: SENIOR RESEARCH ENGINEER - Applied Physics Center, PNNL
- 1986-1987: RESEARCH ENGINEER - Applied Physics Center, PNNL

PROFESSIONAL EXPERIENCE

More than thirty years of developing world-class multifluid, coupled-process numerical simulation capabilities for the Pacific Northwest National Laboratory by acquiring and managing internal and external project funding from national and foreign clients. Application areas for the developed software, coined STOMP, have included environmental restoration, environmental stewardship, carbon sequestration, conventional and unconventional fossil energy production, and geothermal systems. Most recent code advances involve coupled geomechanics, and embedded fracture, fault and borehole capabilities, a modeling approach that reduces the discretization required for simulating coupled fracture/matrix systems with active boreholes, typical of enhanced geothermal system reservoirs.

- Kutsienyo, E.J., Appold, M.S., White, M.D., Ampomah, W. 2023. "Field-Scale Reactive Transport Assessment of CO₂ storage in the Farnsworth Unit through Enhanced Oil Recovery Practices." *Greenhouse Gases: Science and Technology*. PNNL-SA-182432. doi:10.1002/ghg.2206.
- Kutsienyo, E.J., M.S. Appold, M.D. White, and W. Ampomah. 2021. "Numerical Modeling of CO₂ Sequestration within a Five - Spot Well Pattern in the Morrow B Sandstone of the Farnsworth Hydrocarbon Field: Comparison of the TOUGHREACT, STOMP - EOR, and GEM Simulators." *Energies*, 14,5337. doi:10.3390/en14175337.
- Fu P., M. Schoenball, J. Ajo-Franklin, C. Chai, M. Maceira, J. Morris, and H. Wu, et al. 2021. "Close Observation of Hydraulic Fracturing at EGS Collab Experiment 1: Fracture Trajectory, Microseismic Interpretations, and the Role of Natural Fractures." *Journal of Geophysical Research: Solid Earth* 126, no. 7:Article No. e2020JB020840. PNNL-SA-163986. doi:10.1029/2020JB020840
- Bao T., J.A. Burghardt, V. Gupta, and M.D. White. 2021. "Impact of time-dependent deformation on geomechanical risk for geologic carbon storage." Submitted to *International Journal of Rock Mechanics and Mining Sciences*. PNNL-SA-161528.
- Johnson T.C., J.A. Burghardt, C.E. Strickland, H.A. Knox, V.R. Vermeul, and M.D. White. 2021. "4D Proxy Imaging of Fracture Dilation and Stress Shadowing Using Electrical Resistivity Tomography During High Pressure Injections into a Crystalline Rock Formation." Submitted to *Journal of Geophysical Research: Solid Earth*. PNNL-SA-161624.
- White S.K., F.A. Spane, H.T. Schaef, Q. Miller, M.D. White, J.A. Horner, and B.P. McGrail. 2020. "Quantification of CO₂ Mineralization at the Wallula Basalt Pilot Project." *Environmental Science & Technology* 54, no. 22:14609-14616. PNNL-SA-151577. doi:10.1021/acs.est.0c05142
- White M.D., T.J. Kneafsey, Y. Seol, W.F. Waite, S. Uchida, J.S. Lin, and E.M. Myshakin, et al. 2020. "An international code comparison study on coupled thermal, hydrologic and geomechanical processes of natural gas hydrate-bearing sediments." *Marine and Petroleum Geology* 120. PNNL-SA-154536. doi:10.1016/j.marpetgeo.2020.104566
- Ju X., F. Liu, P. Fu, M.D. White, R.R. Settagst, and J. Morris. 2020. "Gas Production from Hot Water Circulation through Hydraulic Fractures in Methane Hydrate-Bearing Sediments: THC-Coupled Simulation of Production Mechanisms." *Energy and Fuels* 34, no. 4:4448-4465. PNNL-SA-152460. doi:10.1021/acs.energyfuels.0c00241
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- Mattson E.D., M.D. White, Y. Zhang, B.G. Johnston, and A.J. Hawkins. 2018. "Collab Fracture Characterization: Preliminary Results from the Modeling and Flow Testing of Experiment 1." *Transactions - Geothermal Resources Council* 42. PNNL-SA-137950.
- Dobson P.F., T.J. Kneafsey, J. Morris, A. Singh, M.D. Zoback, B. Roggenthen, and T.W. Doe, et al. 2018. "The EGS Collab Hydroshear Experiment at the Sanford Underground Research Facility – Siting
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Criteria and Evaluation of Candidate Sites." *Transactions - Geothermal Resources Council* 42. PNNL-SA-137953.

Kneafsey T.J., D.A. Blankenship, P.F. Dobson, H. Knox, T.C. Johnson, J. Ajo-Franklin, and P.C. Schwering, et al. 2018. "EGS Collab Project Experiment 1 Overview and Progress." *Transactions - Geothermal Resources Council* 42. PNNL-SA-137951.

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White, M.D., R.P. Esser, B.J. McPherson, R.S. Balch, N. Liu, P. Rose, L. Garcia, and W. Ampomah. 2017. "Interpretation of Tracer Experiments on Inverted Five-Spot Well-Patterns within the Western Half of the Farnsworth Unit Oil Field," *Energy Procedia* 114:7070-7095. 10.1016/j.egypro.2017.03.1849.

Boswell, R., Schoderbek, D., Collett, T.S., Ohtsuki, S., White, M.D., Anderson, B.J. 2017. "The Ignik Sikumi Field Experiment, Alaska North Slope: Design, Operations, and Implications for CO₂-CH₄ Exchange in Gas Hydrate Reservoirs." *Energy & Fuels*, 31(1):140-153. doi:10.1021/acs.energyfuels.6b01909.

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BOOK CHAPTERS

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TECHNICAL REPORTS

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Years of Experience: 37

Education:

- MS, 1989, Geology, Indiana University, Bloomington
- BS, 1986, Geology, Indiana University, Bloomington

Professional Registrations/Affiliations:

- Professional Geologist, WA, No. 1134
- Professional Hydrogeologist, WA, No. 1134
- Member, National Groundwater Association
- Member, American Geophysical Union (Hydrology Section)
- Member, Geological Society of America

Professional History:

2021 – Present	Senior Hydrogeologist – INTERA Incorporated, Richland, WA
1989 – 2021	Scientist, Research Scientist, and Senior Research Scientist – Pacific Northwest National Laboratory, Richland, WA
2000 – 2009	Adjunct Faculty – Columbia Basin College, Pasco, WA
1994 – 1996	Adjunct Faculty – Heritage College, Toppenish, WA
1986 – 1988	Associate Instructor – Indiana University Geology Department, Bloomington, IN

Software and Skills:

- Flow and Transport: STOMP-W, STOMP-CO₂, STOMP-GT, STOMP-EOR, eSTOMP, CFEST, MODFLOW, MT3DMS, PORFLOW, PORMC, CMG-GEM
- Computer Languages: FORTRAN, Perl, Python
- Geospatial, Geologic, and Visualization: Tecplot, Petrel, ArcMap, ArcGIS Pro
- Computing Environments: Mac, Linux, Windows, High Performance Computing



Signe White has over 3 decades of experience developing conceptual and numerical models for a wide range of subsurface applications at local and regional scales. In addition to vadose zone and groundwater flow and transport modeling, her experience includes reservoir modeling for geologic storage of carbon dioxide (CO₂) in deep saline and basalt reservoirs, enhanced oil recovery, enhanced geothermal systems, and noble gas transport in various geologic environments. She has worked on performance assessments (PA), total risk assessments, and has served as a subject matter expert and technical reviewer for National Environmental Policy Act (NEPA) analyses for the U.S. Department of Energy, National Nuclear Security Administration (NNSA). Ms. White has performed geospatial analyses of oil, gas, and methane hydrate resources in the Arctic Circle and modeled methane gas hydrate production from subsea reservoirs. While at Pacific Northwest National Laboratory (PNNL), Ms. White was a member of the software development team for the Subsurface Transport Over Multiple Phases (STOMP) simulator and the Velo knowledge management system, and she developed aquifer test analysis software. She was responsible for the design, creation, and maintenance of the STOMP, eSTOMP and E4D online user guides and websites. Ms. White served as a short course instructor for the STOMP simulator from 2007 to 2021, hosted by institutions such as the International School for Geoscience Resources of KIGAM (Korea Institute of Geoscience and Mineral Resources), the South Africa National Energy Development Institute (SANEDI), the US Environmental Protection Agency, INTERA, Battelle, and a number of universities worldwide. She has been active in various science education and outreach programs throughout her career. Ms. White has served as adjunct faculty at Heritage College where she taught hydrogeology, and at Columbia Basin College where she taught the evening introductory geology class for 9 years.

Project Experience

Simulations for Geologic CO₂ Storage Site Class VI Permit Application – Confidential Client. 2023. *Project Manager and Lead Modeler.* Carbon capture and storage (CCS) will need to play a critical role in meeting the emissions-reduction goals set by the United States and other countries around the globe. Net-zero carbon energy portfolios can only be achieved through the geologic storage of carbon at the gigaton scale. The U.S. Environmental Protection Agency (EPA) requires all CO₂ injection wells to be permitted under the Underground Injection Control (UIC) program, specifically as Class VI wells which require multi-phase modeling of the fate and transport of the injected CO₂ and delineation of the Area of Review (AoR). Simulations of CO₂ injection using the Subsurface Transport Over Multiple Phases – CO₂ (STOMP-CO₂) simulator were conducted in support of a Class VI permit application for a storage site identified by the client. Responsible for managing work and conducting numerical modeling of CO₂ injection and plume evolution.

Preliminary Scoping Simulations for Geologic CO₂ Storage Site Evaluation – Confidential Client. 2022-2023. *Project Manager and Modeler.* Identifying potential geologic storage reservoirs for secure storage of injected CO₂ is the first step in developing a CO₂ storage project. A conceptual model was developed based on publicly available data and simulations of CO₂ injection using the Subsurface Transport Over Multiple Phases – CO₂ (STOMP-CO₂) simulator were conducted to determine injectivity

and storage capacity for a site identified by the client. Responsible for managing work and conducting numerical modeling of CO₂ injection at the site.

Annual 200 Area Pump & Treat Report Calculations - U.S. Department of Energy – Central Plateau Cleanup Company, Hanford Site, Hanford, WA. 2021 – Present. *Modeler.* The Hanford Site is a U.S. Department of Energy installation used for production of nuclear materials from 1943 until 1989 when Hanford’s mission was changed to environmental restoration. Primary responsibilities are to perform numerical modeling using MODFLOW (groundwater flow) and MT3DMS (contaminant transport) and associated calculations to evaluate existing groundwater pump-and-treat (P&T) remedies in place at the Hanford Site 200-ZP-1 and 200-UP-1 Groundwater Operable Units (OUs). Calculations supporting this evaluation include estimating the extent of hydraulic containment developed by the P&T remedies, evaluating the status of flow-path control in the downgradient areas of the P&T remedies, and comparing actual and simulated historical mass recovery, and projections of anticipated future mass recovery under assumed future extraction and injection rates.

Simulation of Carbon Dioxide Injection and Pre- and Post-Injection Hydrologic Testing at the Wallula Basalt Pilot Project - U.S. Department of Energy - Wallula Basalt Pilot Demonstration, Wallula, WA. 2018 – 2021. *Lead Modeler.* A pilot injection of 1000 metric tons of supercritical CO₂ (scCO₂) was completed in several deep isolated basalt zones near Wallula, Washington in 2013. Rock core samples extracted from the injection zone two years after the end of CO₂ injection revealed carbonate mineralization consistent with laboratory experiments. A re-analysis of the 2012 pre-injection and 2015 post-injection hydrologic testing that capitalized on the difference in fluid properties between scCO₂ and water was conducted to assess changes in near-field, wellbore and reservoir conditions that were apparent approximately two years following the end of injection. Numerical simulations of the hydrologic tests along with the scCO₂ injection using STOMP-CO2 showed that properly designed hydrologic tests could be used as a new monitoring tool to quantitatively estimate how much of the injected scCO₂ was mineralized, without modeling reactive transport. Simulation results indicated that approximately 60% of the injected scCO₂ was mineralized within two years. Responsible for all modeling conducted for this study and preparation of the *Environmental Science and Technology* journal publication.

Underground Nuclear Explosion Signatures Experiment - National Nuclear Security Administration, Nevada National Security Site, North Las Vegas, NV. 2019 – 2021. *Lead Modeler.* Measurement of radioactive gas seepage from an underground nuclear explosion (UNE) is one of the primary methods to confirm whether an event was nuclear in nature. Measurements taken at three sites near three historic underground nuclear test locations at the Nevada National Security Site (NNSS) showed highly elevated levels of ³⁹Ar in subsurface air decades after the test events, demonstrating that ³⁹Ar, which can be reliably detected at the surface or in the shallow subsurface, has the potential to be a long-term signature of a UNE. Simulations of post-explosion gas migration in fractured and non-fractured porous media were conducted using Subsurface Transport Over Multiple Phases – GeoThermal (STOMP-GT) to estimate the persistence of ³⁹Ar in the subsurface environment following an explosion. Simulation results showed that ³⁹Ar plumes persisted in the subsurface for over 30 years in all geologic environments that were simulated, establishing potential detectability years to decades after the originating event. Responsible for conceptual model development and numerical simulation of gas transport in a variety of geologic environments.

Evaluation of National Risk Assessment Partnership Integrated Assessment Model for Carbon Storage at Three Carbon Storage Assurance Facility Enterprise (CarbonSAFE) Sites - U.S. Department of Energy, OH and MI. 2017 – 2020. *Modeler.* The National Risk Assessment Partnership Integrated Assessment Model for Carbon Storage (NRAP-IAM-CS) toolset was developed for quantitative risk assessment of the geologic sequestration of CO₂. The NRAP-IAM-CS toolset was used to estimate the project risk area and the impact of leakage through legacy wells to overlying drinking waters at three Carbon Storage Assurance Facility Enterprise (CarbonSAFE) project sites: two saline reservoir storage sites evaluated as part of a Central Appalachian Basin project in Ohio, and one St. Peter Sandstone saline reservoir storage site evaluated as part of a project in Michigan. Risks were shown to be very low at all three candidate sites. Responsible for evaluating the NRAP-IAM-CS toolset and preparing manuscript for publication in the *International Journal of Greenhouse Gas Control*.

Geothermal Technologies Office Code Comparison Study, U.S. Department of Energy. Richland, WA. 2015 – 2016. *Data Manager.* A diverse suite of numerical simulators is currently being applied to predict or understand the performance of enhanced geothermal systems (EGS). To build confidence and identify critical development needs for these analytical tools, the United States Department of Energy, Geothermal Technologies Office sponsored a Code Comparison Study (GTO-CCS), with participating teams representing universities, industry, and U.S. national laboratories. To accurately characterize the

state of knowledge and simulation capabilities, two classes of problems were developed during the study, including benchmark problems and challenge problems. Over the course of the study, participants submitted solutions via GTO-Velo, a data management system which was customized for the project to allow for interactive comparison of simulation results. Responsible for coordinating with the *Velo* development team to address issues and to identify the addition of new features to GTO-Velo. Collected and distributed the extensive data sets that were used for the challenge problem stage of the project, which required converting large volumes of data from the Fenton Hill Enhanced Geothermal System Project, available only as scanned documents, to usable digital format and organizing the data by topic area.

Ar-39 to Refine Mean Residence Time for Groundwater - Lab Directed Research and Development, Pacific Northwest National Laboratory. Richland, WA. 2015 – 2016. Co-PI and Lead Domain Scientist. Provided expertise in hydrogeology to a Lab Directed Research and Development project that had developed a process for purifying and detecting ^{39}Ar in groundwater using ultra-low-background proportional counters (ULBPCs) in PNNL's shallow underground laboratory. PNNL is the 2nd lab in the world to have this capability. As an inert noble gas with constant atmospheric concentration, and a half-life of 269 years, ^{39}Ar is an ideal tracer for dating groundwater with intermediate ages in the range of 50-1000 years. Provided guidance to nuclear scientists regarding environmental applications of ^{39}Ar to support groundwater residence time studies. Led three sampling campaigns in the Central Valley of California in collaboration with the US Geological Survey, where gas samples were extracted from groundwater and analyzed for ^{39}Ar to estimate groundwater age.

Velo Knowledge Management Software Development Project - Lab Directed Research and Development, Pacific Northwest National Laboratory. Richland, WA. 2012 – 2016. Lead Domain Scientist and Software Developer. Velo is a knowledge management system for supporting collaborative, computational modeling projects that enables a diverse spectrum of experts to easily share data, tools, expertise, and computational models. Velo leverages, integrates, and extends Web-based open-source collaborative and data-management technologies to create a scalable and flexible core platform tailored to specific scientific domains. Velo has supported projects under DOE's Geothermal Technologies Office and Office of Fossil Energy, and the US Environmental Protection Agency. The Geologic Sequestration Software Suite (GS3) is a customized version of Velo specific to Carbon Capture Utilization and Storage (CCUS) projects. Provided technical guidance in the areas of subsurface modeling and geoscience data management to web-based software developers. Presented demonstrations and trained users on the Velo software platform.

Regional Modeling of CO₂ Storage in the Arches Province, U.S. Department of Energy and Battelle. Columbus, Ohio. 2010 – 2012. Lead Modeler. The Arches Simulation project was a three-year effort designed to develop a simulation framework for regional geologic carbon dioxide (CO₂) storage infrastructure along the Arches Province through development of a geologic model and advanced reservoir simulations of large-scale CO₂ storage. The Arches Province is an informal region in northeastern Indiana, northern Kentucky, western Ohio, and southern Michigan where sedimentary rock formations form broad arch and platform structures. In the province, the Mount Simon sandstone is an appealing deep saline formation for CO₂ storage because of the intersection of reservoir thickness and permeability. A basin-scale, multiple-phase subsurface model was developed to evaluate large scale injection effects across the region. Simulations using STOMP-CO₂ suggested that a total injection rate of 100 million metric tons per year (approximately to a 40% reduction of CO₂ emissions from large point sources across the Arches Province) may be feasible, though some areas are more suitable due to favorable geology. Sustainable injection rates were higher in areas where there was higher thickness and reservoir permeability. Distribution of injection across well fields is an effective method to reduce pressure and CO₂ saturation front interference. Responsible for development of basin-scale, 1.5 million node numerical model and execution of simulations and visualization of results.

Simulation of Carbon Dioxide Injection in support of the FutureGen and FutureGen 2.0 Projects, U.S. Department of Energy and The FutureGen Alliance - FutureGen Project, Mattoon and Morgan County, IL. 2006 – 2016. Task Lead and Lead Modeler. The objective of the FutureGen Project was to demonstrate at a commercial scale the technical and commercial feasibility of capturing CO₂ generated from a power plant coupled with the subsequent long-term storage of CO₂ in a deep geological formation. Originally, four sites (two in Texas and two in Illinois) were considered for the world's first coal fueled, near zero-emissions power plant. In December 2007, in partnership with US DOE, the FutureGen Alliance announced their plans to build the experimental FutureGen coal-fired plant and geologic storage site in Mattoon, Illinois. In 2010 the project was renamed FutureGen 2.0, and the CO₂ source was changed to a retrofitted power plant in Meredosia, Illinois with the geologic storage being relocated to Morgan County, IL. This resulted in the first EPA Class VI permit being awarded for CO₂ injection. However, the project was discontinued before construction of the site could begin. Responsibilities under the FutureGen Project include:

- **Scoping Simulations in Support of Initial Site Selection, 2006 – 2007.** *Lead Modeler.* Conducted scoping simulations using STOMP-CO₂ for each of the four candidate sites (two in Texas and two in Illinois) to be considered for the proposed FutureGen power plant and geologic storage site. All four sites were deep saline reservoirs. Contributed to the Environmental Information Volume for each proposed site.
- **Evaluation of FutureGen Geologic Storage Site, Mattoon, IL. 2009 – 2010.** *Lead Modeler.* Conducted simulations of scCO₂ injection into the Mt. Simon Sandstone Formation at Mattoon, Illinois using STOMP-CO₂, in anticipation of this being the geologic storage site for the FutureGen project.
- **Simulations to Support Class VI UIC Well Permit for FutureGen 2.0, 2011 – 2016.** *Task Lead and Lead Modeler.* Developed three-dimensional numerical model of the proposed storage site in the Mt. Simon Sandstone in Morgan County, IL. Led the modeling team in conducting multi-phase simulations of scCO₂ injection into a highly stratified reservoir over a 20-year period, distributed among four lateral wells using STOMP-CO₂. Results showed that each of the multiple reservoir layers with low permeability behaves as a baffle, trapping the scCO₂ and hence safely sequestering a total of 22 million metric tons of CO₂ in the reservoir. An approach for determining the Area of Review (AoR) based on the integrated mass of CO₂ was developed. A local sensitivity analysis (LSA) was conducted for injectivity and plume size at the end of the 20-year injection period. The LSA indicated that the imposed initial conditions and the hydraulic properties of the injection layer contribute the most to the sensitivity. The LSA was used to guide site characterization, injection well design, estimating the AoR uncertainty and, and monitoring network design. This work resulted in successfully obtaining the first, Class VI permit granted under the Underground Injection Control Program of the U.S. Environmental Protection Agency.

Development of System Assessment Capability Rev. 1 - U.S. Department of Energy - Hanford Site, Bechtel Hanford, Hanford, WA. 2003 – 2005. *Software Developer.* Development of production version (Rev. 1) of SAC, an integrated, sitewide, total system performance assessment simulator for the Hanford Site. Developed the Atmospheric Transport Module which was a new addition in this revision of the SAC management decision-basis tool. The SAC Rev. 1 software development effort was successfully completed in FY 2004, and the software was approved for use in preparing an updated Hanford Site Composite Analysis.

Site Characterization, Investigation, and Model Development of Groundwater Contamination at a Russian Nuclear Production Facility for the Joint Coordinating Committee for Environmental Restoration and Waste Management, Russian Federation Ministry of Atomic Energy/U.S. Department of Energy, Western Siberia, Russia. 1992 – 2004. *Modeler.* Member of a joint U.S. and Russian team of scientists investigating groundwater contamination of radionuclides at Russian nuclear production facilities in western Siberia through site characterization and the development of models at regional and local scales. Member of the U.S. modeling team in a model inter-comparison study with a group of Russian scientists at the Mayak (Chelyabinsk) site. Developed a three-dimensional regional ground-water flow model of the West Siberian Basin using the Coupled Fluid, Energy, and Solute Transport (CFEST) simulator and the GeoFEST software system. Member of the modeling team that developed local-scale models of the Mayak site and the Tomsk Site within the larger West Siberian Basin.

Hanford Site Groundwater Monitoring Project - U.S. Department of Energy – Hanford Site, Hanford, WA. 1992 – 1998. *Modeling Task Lead, Modeler.* Managed the ground water modeling subtask under the Flow System Characterization Task. Led multi-year effort to create the first 3-dimensional Sitewide Groundwater Model of the Hanford site unconfined aquifer system. Conducted simulations of groundwater flow and contaminant transport at the Hanford Site using CFEST, for a number of site-wide and local-scale studies and performance assessments (PAs). Member of the analysis team for the Composite Analysis performed for the Dept. of Energy in 1998. Developed an interface between the CFEST groundwater modeling software library and the commercial GIS package, ARC/INFO for model development and visualization.

Calculation of Groundwater Discharge to the Columbia River in the 100-N Area – Westinghouse Hanford – Hanford Site, Hanford, WA. 1992. *Software Developer.* The 1301-N and 1325-N liquid waste disposal facilities were used for disposal of effluents with low-fission and activation products from N Reactor operations, much of which remains in the sediments. These products are then mobilized by natural groundwater flow through the area and then discharged to the Columbia River. Responsible for developing the software program called WATDIS, which when used with the commercially available

software program WATER_VEL (In-Situ Inc. 1991) estimates the regional groundwater flow component discharging through a given cross-sectional area within the aquifer.

Public Dose from Radioactive Nickel and Exposure from Elemental Lead Impact Assessment - U.S. Department of Energy – Hanford Site, Hanford, WA. 1992 – 1994. Modeler. An assessment was performed to evaluate release and transport of nickel radioisotopes and lead from large metal components containing nickel-bearing alloys and lead at the Hanford Site 218-E-12B Burial Ground. The potential for nickel and lead to be released from the burial site and to enter groundwater was investigated by examining available data on the site's geology, geochemistry, and geohydrology to develop a conceptual model for release and transport of nickel and lead from the components. In addition, laboratory studies were performed to provide information needed for the model, but which was not available from existing databases. Responsible for modeling Hanford site-wide groundwater flow using CFEST and TRANSS to estimate travel times from the 218-E-12B Burial Ground to a well and the Columbia River.

Hanford Site Performance Assessment - U.S. Department of Energy – Las Cruces, NM. 1990 – 1991. Modeler. Data from a field-scale unsaturated zone flow and transport experiment, conducted near Las Cruces, New Mexico, were used for model validation using PORFLO-3. A spatial moment analysis was used to provide a quantitative basis for comparing the mean simulated and observed flow behavior. Two-dimensional simulations produced water content changes that matched the observed data reasonably well. The results of this study demonstrated the importance of site-specific data for model calibration. Conducted simulations, analyzed results and contributed to the final report.

Publications, Presentations, and Reports

*Note earlier publications are under maiden name Wurstner

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