

Mark A. Worthington

Principal Hydrogeologist



Mr. Worthington is the founder of Underground Energy, LLC and a Principal Hydrogeologist with 30 years of diverse consulting and management experience. Areas of expertise include evaluation and design of Earth-coupled (geothermal) systems for heating and cooling buildings, underground thermal energy storage, aquifer hydraulic testing and analysis, FEFLOW modeling subsurface flow and heat transport, and subsurface investigations using geophysical, geotechnical, geochemical and hydraulic monitoring methodologies. Since 2008, he has focused on bringing sustainability and value to geothermal heating and cooling projects by using underground thermal energy storage techniques to optimize the design and performance of the Earth couple. As a Massachusetts Licensed Site Professional (LSP), Mr. Worthington was responsible for technical quality, regulatory compliance, risk-based corrective action, and regulatory site closure at over 80 oil and hazardous material disposal sites in Massachusetts.

Areas of Expertise

- Underground Thermal Energy Storage
- Earth-coupled heating and cooling systems
- Hydrogeologic and geophysical investigations
- Aquifer hydraulic testing and numerical modeling
- Geothermal heat exchanger design
- Assessment of oil and hazardous material releases
- Soil, groundwater and sediment remediation
- Geotechnical and seismic hazard investigations
- Environmental permitting, brownfield redevelopment
- Landfill gas control and vapor intrusion evaluation
- Environmental due diligence

Education

- B.S., Geology/Physics, Stephen F. Austin State University, 1983
- M.S., Hydrology and Water Resources, University of Arizona, 1987
- Adjunct Earth Science Faculty, Massachusetts Maritime Academy, 2009

Selected Publications

“Aquifer Thermal Energy Storage Feasibility at the Ford Site, St. Paul, MN,” 2015, [International District Energy Association 107th Annual Conference and Trade Show, St. Paul, MN, June 2016.](#)

“In-Depth Feasibility Studies of Aquifer Thermal Energy Storage (ATES) at VAMC Medical Centers in Columbus and Chillicothe, OH,” 2015, [International District Energy Association 106th Annual Conference and Trade Show, Boston, MA, June 2015.](#)

“Exploring Synergies between In-Situ Thermal Remediation and Geothermal Energy Storage,” 2012, co-author with Dr. Ralph Baker of Terra Therm, Inc., [27th Annual International Conference of Soils, Sediments, Water and Energy, Amherst, MA, October 2011.](#)

“Aquifer Thermal Energy Storage: An Enabling Green Technology for Campus District Energy Systems,” 2011, Presented to the [International District Energy Association 24th Annual Campus Energy Conference, Miami, FL, February 2011.](#)

“Dating gasoline releases using ground-water geochemical analyses: case studies,” Proceedings of the 1993 Petroleum Hydrocarbons Conference, Houston, Texas, 1993.

“Thermal anomalies and the ground-water flow system south of The Narrows, Upper San Pedro Valley, Arizona”, 1987, Master’s thesis, Department of Hydrology and Water Resources, University of Arizona.

Registrations & Professional Affiliations

- Certified Geologist - Maine (1991-2016)
- Licensed Site Professional - MA (1993-2016)
- Certified Installer - International Ground-Source Heat Pump Association (2009)
- LEED Accredited Professional (2009)
- New England Geothermal Professional Association (Charter Member, Board Member)
- International District Energy Association (IDEA)
- MIT Enterprise Forum

Underground Thermal Energy Storage Projects

Project Manager and Principal Hydrogeologist for Aquifer Thermal Energy Storage (ATES) feasibility study for the City of St. Paul, MN regarding sustainable redevelopment of the 135-acre Ford site. Developed hydrogeologic conceptual model, sized well system and developed a cost estimate to support conceptual engineering design of a 15MW district energy system at the former Ford Twin Cities Assembly Plant.

Project Manager and Principal Hydrogeologist for evaluation and maintenance of the ATES system at Stockton University in Galloway, NJ. Performed field hydrogeologic and geochemical testing of the 6 ATES wells and coordinated with subcontractor IF Technology, BV in preparation of reports and work plans. Project in progress.

Project Manager and Principal Hydrogeologist for in-depth feasibility studies of ATES for Veterans Administration Medical Centers in Chillicothe and Columbus, Ohio. Used GIS tools to screen VAMC facilities in Ohio for aquifer availability, developed hydrogeologic investigation work plan, evaluated hydrogeologic properties at each site, identified regulatory requirements and financing options, and led an exceptionally qualified team of energy engineers in the preparation of detailed ATES feasibility study reports. ATES conceptual designs were developed including cooling-only with district energy system distribution of chilled water, and heating with cooling using a natural-gas-driven heat pump. The VA is currently evaluating ATES design for the Chillicothe site.

Project Manager and Principal Hydrogeologist for Borehole Thermal Energy Storage (BTES) feasibility study at a remote diamond mine in the Canadian Northwest Territories. The conceptual design diverted waste heat from diesel gensets in summer to charge a large BTES wellfield, which is discharged each winter to preheat ventilation air. This design displaces 20 million litres of diesel fuel annually, with a CAPEX of \$15M CAD for the system and a 7 year simple payback.

Principal Hydrogeologist for regional ATES feasibility screening for the City of Baltimore. Reviewed and modified Maryland Geological Survey GIS maps to prepare

a series of maps depicting Patuxent Aquifer properties in Baltimore, including estimation of ATES well yields.

Principal Hydrogeologist for prefeasibility study of ATES and BTES to expand thermal capacity of Deep Lake Water Cooling system in Toronto.

Principal Hydrogeologist for a feasibility study of ATES for a confidential client in Massachusetts. Evaluated engineering, hydrogeologic, regulatory, and economic feasibility. Developed conceptual design from which a financial analysis was performed.

Principal Hydrogeologist for a feasibility study of Borehole Thermal Energy Storage and redevelopment of a district energy system in Attleboro, Massachusetts. Designed borehole array to accept low-grade heat from a CHP plant and to provide space heating to buildings on the campus.

Earth-Coupled Cooling and Heating Projects

Principal Hydrogeologist for feasibility study and design of a hybrid geothermal/biomass district heating and cooling system for a performing arts facilities in western Massachusetts under Mass Clean Energy Center grant.

Calculated building loads and designed vertical and horizontal ground heat exchangers and associated piping and heat pump systems for various new-construction and retrofit residential geothermal projects in Massachusetts. Worked with an experienced installer on system installations.

Performed forensic geothermal evaluation of poor-performing standing-column well system in Marlborough, MA. Recommendations fixed system.

Evaluated operating performance of standing column well geothermal system at Boston Nature Center at request of Mass Audubon Society Director.

Hydrogeologic Engineering Projects

Expert Hydrogeologist for the successful defense of a remediation construction firm against class-action litigation regarding levee failures in New Orleans during Hurricane Katrina, with potential damages in excess of \$100 billion at stake. In concert with geotechnical experts,

designed and implemented field permeability testing programs involving multiple slug and pumping tests, performed data analysis, and worked with multiple parties to develop standard operating procedures and to coordinate an intensive field program subject to a court-ordered deadline. Assisted geotechnical experts and attorneys with deposition preparation and analysis, and with preparation of expert testimony. Designed, fabricated, tested and demonstrated analog flow simulators as a demonstrative exhibit to that was used to assist the judge in understanding the difference between transient and steady groundwater flow.

Principal Hydrogeologist responsible for hydrogeologic analysis and FEFLOW modeling of groundwater infiltration to tunnels, ore heaps and open-pit mines in South America.

Principal Hydrogeologist responsible for peer review of multi-aquifer pumping test analyses at Eagle Mountain Lake in Tarrant County, Texas. Used AQTESOLV software to model boundary conditions, calculate aquifer properties for seepage analysis and performed sensitivity analyses relating calculated values of hydraulic conductivity to assumed values of aquifer thickness.

Principal Hydrogeologist for analysis of unsaturated flow associated with extraction of copper from crushed ore at a copper mine in Chile. Used HYDRUS-1D model to simulate unsaturated flow through ore heap and provided recommendations for improved operations. Used FEFLOW model to simulate transient 2-D infiltration through ore heap and steady state pore pressure distributions.

Project Hydrogeologist for a wastewater discharge siting study at Otis Air Base on Cape Cod. Hydrogeologic analysis included water table contouring, slug testing, flow net analysis, design, performance and data analysis of a five-day pumping test, an assessment of aquifer tidal response and salt water intrusion.

Senior Hydrogeologist for a dewatering project in Beirut, Lebanon for a deep foundation set in a highly transmissive karst limestone formation. Evaluated construction contractor tenders for dewatering to review applicability of cutoff methods including diaphragm walls, ground freezing and permeation grouting.

Conducted hydrogeologic investigation of a proposed 70,000 gpd subsurface wastewater discharge facility in Lanesborough, Massachusetts. Participation in this project included field collection of seismic refraction data, assessment of hydrogeologic impacts of the discharge facility and writing the EIR draft.

Conducted hydrogeologic investigations for a proposed Superconducting Super Collider (SSC) site in Mississippi. Investigated water-supply and dewatering/tunneling aspects of the state's SSC proposal.

Aquifer Testing and Hydrogeologic Analysis

Designed hydrogeologic, geochemical and geothermal subsurface investigation programs for two VA hospitals in Ohio being considered for Aquifer Thermal Energy Storage (ATES). Work included installation and testing of 17 observation wells, four pumping wells, and four pumping tests. Analyzed all field data and prepared updated feasibility study reports.

Designed and performed 5-day pumping test at Otis Air National Guard Base in Bourne, Massachusetts. Prepared specifications regarding monitoring well and pumping well design, instrumented wells with pressure transducers, sited water discharge location, performed step-drawdown tests, and 5-day pumping test (300 gpm discharge rate), post-test recovery monitoring and data analysis in support of a Class III groundwater discharge permit application.

Performed 8-hour pumping test of 1,500-gpm irrigation well in Benson, Arizona. With minimal resources as a grad student, used kinematics to calculate discharge rate and collected groundwater elevation data using Stevens analog chart recorder. Calculated aquifer hydraulic properties using analytical techniques.

Performed 24-hour pumping test of artesian wells in Benson, Arizona. Designed and constructed mercury U-tube manometer to record artesian pressure head data, and calculated aquifer hydraulic properties using analytical techniques.

Performed step-drawdown tests and 24-hour pumping tests of LNAPL-contaminated aquifers in Mattapoisett and Acton, Massachusetts for a major oil company. Analyzed

data and prepared capture zone analyses for use in groundwater recovery remedial systems.

Performed step-drawdown test and 8-hour pumping tests of residential wells in fractured rock in Westbrook and Tenants Harbor, Maine. Calculated aquifer hydraulic properties using analytical techniques.

Performed slug tests at multiple LNAPL-contaminated sites in Massachusetts, Connecticut and Maine.

Provided peer review services and reviewed slug test and pumping tests at various locations in New England, Texas and South America.

Performed slug tests and evaluated injection tests at a former oil terminal and then-proposed LNG import terminal in Fall River, Massachusetts. Instrumented monitoring wells to record tidally affected groundwater elevations, used analytical techniques to evaluate aquifer tidal response.

Performed flow net analyses of hydrogeologic systems at multiple sites in New England and the Americas to evaluate contaminant transport, remedial strategies, and spatial variability of aquifer hydraulic properties.

Taught short courses and gave presentations on aquifer testing techniques to law firms, major oil company clients, and university students.

Used available boring logs and an understanding of continental glacial depositional processes to prepare hydrogeologic cross sections and conceptual site models at numerous sites in New England.

Performed dye tracing studies to evaluate subsurface conditions at sites in Massachusetts, Maine and Pennsylvania.

Ground-Water Supply Investigations Projects

Principal Hydrogeologist for hydrogeologic studies in support water supply development for two LNG export terminal projects in coastal Louisiana. Performed desktop studies and designed/implemented subsurface testing for production well design and to assess saltwater intrusion.

Project Manager for multi-disciplinary studies to locate high yield water-bearing bedrock fractures in Weston, Massachusetts. Coordinated borehole, crosshole, and surface geophysical methods to trace a fracture system towards Town-owned land.

Expert Hydrogeologist representing the Blackstone River Consortium appeal of a Water Management Act permit issued to Town of Shrewsbury by Massachusetts DEP. Evaluated hydraulic effects of municipal pumping effect on tributary stream and upstream impoundment.

Expert Hydrogeologist for defense in litigation regarding alleged adverse hydraulic impact to private water supply well in Plympton, Massachusetts.

Program Hydrogeologist for the investigation of a potential municipal water supply aquifer in Weston, Massachusetts. Designed and conducted exploration program and pump tests and analyzed data by analytical and computer modeling techniques.

Project Manager of a comprehensive study of the safe yield of all aquifers in the Town of Marshfield, Massachusetts. Developed and quantified water budget equations for drainage basins in the town. Developed five computer models to simulate safe yield aquifer conditions and characterized the potential for salt water intrusion in coastal aquifers using calibrated flow models.

Conducted a ground-water adequacy investigation near Benson, Arizona. Included aquifer tests, two of which were for an artesian aquifer, requiring the design and construction of special hydraulic testing equipment. Other work included mapping piezometric configurations over a 300 mi² area. A computer model was developed, calibrated, and used to simulate future exploitation of ground-water resources.