A Confluence of Water Research
at Lawrence Livermore National Laboratory

As a California-based facility, Lawrence Livermore National Laboratory (LLNL) understands the importance of responsible and sustainable water management. LLNL's water-related research and operational programs span and connect many aspects of leading-edge water research and applications, including remediating legacy contamination at Department of Energy (DOE) facilities, understanding climate impacts on the hydrological cycle, and improving the resiliency of our state and national water infrastructure. Our work builds on the interdisciplinary strength of our workforce, unique laboratory capabilities, and world-class computational expertise.

FUNDAMENTAL WATER SCIENCE

Behavior of Water at Surfaces and Interfaces: LLNL scientists are using nanomaterials, in situ measurements, and first-principles simulations to understand the physics of water and solute molecules near the surfaces of catalysts or membranes and in the confined spaces of pores and channels. By understanding transport of water, ions, and contaminants, we can design more efficient and selective materials for water treatment. The LLNL team is also an active contributor to a DOE-funded center that focuses on nanofluidic solutions for water research.

Physics of Clouds and Precipitation: Climate scientists at Livermore study interactions between the land and atmosphere, combining observations from DOE’s Atmospheric Radiation Measurement facility with state-of-the-art Earth system simulations. We develop models of how those interactions affect cloud formation and precipitation, ultimately informing the global terrestrial water cycle.

WATER IN THE ENVIRONMENT

Isotope Hydrology: Scientists at LLNL study the sources, flowpaths, and residence times of water, from headwaters to groundwater, using novel isotopic and geochemical tracers. This research supports sustainable management of water resources and enhances our understanding of water−mineral interactions, ecosystem functioning, nutrient and contaminant transport, and climate change impacts.

Subsurface Reservoir Management: LLNL reservoir engineers, hydrologists, and geochemists couple state-of-the-art modeling and analysis with field studies to quantify fluid movements in the subsurface and important rock−water interactions that control water composition and transport of contaminants. This research informs the design of geothermal reservoirs, oil and gas wells, subsurface energy storage systems, and geologic repositories for captured carbon dioxide, spent nuclear fuels, and other radioactive byproducts.

Climate Change Detection and Attribution: Through rigorous statistical analysis and model interrogation, LLNL scientists improve our understanding of the nature and causes of climate change. The same techniques that attribute overall changes in atmospheric temperature to human activity are being used to quantify how natural and human-made factors can influence atmospheric moisture, precipitation, and sea level, thereby enhancing our ability to plan for times of water scarcity and flooding.
Groundwater Protection: Livermore has long supported the protection of surface water and groundwater resources. We have contributed to many national environmental science programs, including watershed system science supported by DOE’s Office of Science. Understanding the biogeochemical processes controlling water quality at a mechanistic level is a central focus of our research programs. Within California, LLNL geochemists and hydrologists have applied their skills to aquifer storage projects in Orange County and water management challenges in the Salton Sea basin.

Seasonal Snowpack Forecasts: Snowpack supplies over 75% of the annual water to the Western United States, with over 80% being used for agriculture. Accurate predictions of snowpack several months in advance are critical to efficiently manage water supply and demand. Scientists at LLNL are using advanced data science techniques, leveraging both model and observed data, to generate probabilistic season-ahead forecasts of snowpack, essential for improved water security in the face of climate change.

WATER TECHNOLOGY AND INFRASTRUCTURE

Flow-Through Electrode Capacitive Deionization (FTE-CDI): Engineers at LLNL are developing revolutionary desalination technologies that use electricity to remove salt from water. FTE-CDI requires special materials called carbon aerogels that have high capacitance, good electrical conductivity, and are porous enough to let water flow through freely in order to extract salts. For brackish water, which is plentiful in the arid West, FTE-CDI is fundamentally more energy efficient than traditional desalination technologies that use heat or pressure to extract fresh water from saltwater.

Carbon Nanotube Membranes: Chemists and material scientists are studying molecular and ionic transport in single nanochannels and in nanoporous membranes under a variety of driving forces. Efforts are also underway to fabricate nanocomposite and biomimetic membranes for various applications, including physical and chemical separations, protective and breathable fabrics, and skin-inspired responsive systems.

Systems Analysis: Leveraging a rich legacy of energy system visualizations, LLNL analysts have turned their attention to the energy–water nexus. We are using a broad range of economic data to quantify the relationships between irrigation and biofuels, water and wastewater treatment and electricity, produced water and fossil fuels, and fresh water and power plant cooling—generating relevant findings for policymakers and other stakeholders.

Exascale Cooling: With the next generation of supercomputing already being installed on the Livermore campus, our facilities and infrastructure team is investigating ways to reduce, reuse, and recycle the vast quantities of water needed to cool one of the world’s most powerful computers.

Emerging Technologies: LLNL is always pursuing the next innovation in sustainable water management. From enhanced surfaces that improve ultraviolet treatment to novel ways to neutralize persistent contaminants to engineered microbes that can recover heavy metals, researchers at the Laboratory are committed to advancing clean water innovations.