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Environmental Site Characterization and Remediation at Lawrence Livermore National Laboratory Site 300

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ENVIRONMENTAL SITE CHARACTERIZATION AND REMEDIATION AT LAWRENCE LIVERMORE NATIONAL LABORATORY SITE 300*

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ABSTRACT

Lawrence Livermore National Laboratory (LLNL) is a research and development laboratory owned by the U.S. Department of Energy (DOE) and operated by the University of California. The Laboratory operates its Site 300 test facility in support of DOE's national defense programs. Operations at Site 300 include a general services area that supports four programmatic activities: (1) hydrodynamic testing; (2) charged particle beam research; (3) physical, environmental, and dynamic testing; and (4) high explosives (HE) formulation and fabrication. In support of these activities, numerous industrial fluids are used and various process or rinse waters and solid wastes are produced. Some of these materials are hazardous by current standards. HE rinse waters were previously discharged to unlined lagoons; they now are discharged to a permitted Class II surface impoundment. Solid wastes have been deposited in nine landfills. Waste HE compounds are destroyed by open burning at a burn pit facility. As a result of these practices, environmental contaminants have been released to the soil and ground water.

Located in a remote region of the Altamont Hills portion of the Coast Ranges about 100 kilometers east of San Francisco, California, the site covers approximately 30 km^2 of ridge and canyon terrain adjacent to California's Central Valley (Figure 1). Local relief is on the order of 100 to 200 meters. The climate at Site 300 is semiarid; average rainfall is about 10 inches per year. No perennial streams exist within or near the site. About 80% of the site is in San Joaquin County, the remainder in Alameda County. Population around the site is sparse in that most surrounding land is used for grazing cattle and sheep.

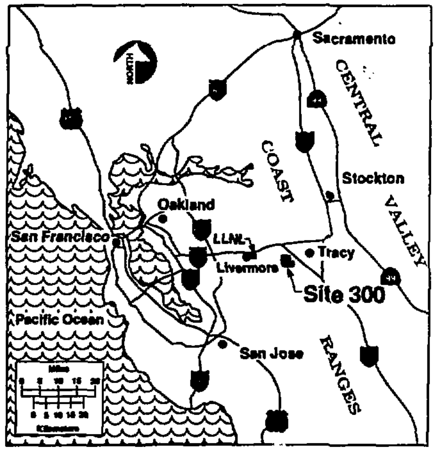

Figure 1. Regional setting of Lawrence Livermore National Laboratory and Site 300, California.

HISTORY OF SITE CHARACTERIZATION AND REMEDIATION

LLNL initiated environmental investigations at Site 300 in 1981 to evaluate the impacts of past operations and waste disposal practices on soils and ground water. By 1987, trichloroethylene (TCE) contamination was found in 10 locations in soil and/or ground water. Most of these occurrences were determined to be the result of spills and leaks from testing facilities where TCE is used as a heat exchange fluid. Preliminary remediation was conducted at areas of highest TCE concentration by the removal and aeration of TCE-contaminated surficial soils. A TCE plume perched several hundred feet above the regional water table

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has been delineated at Building 834, and preliminary vacuum extraction and ground water extraction tests have been conducted (Figure 2). At the southeastern margin of the site, TCE plumes have been identified in shallow ground water beneath the General Services Area (GSA) and adjacent offsite private property. An active program of hydrogeologic investigation is underway and a pump-and-treat facility is in operation. At the southwestern site boundary, TCE has been detected leaking from landfill pit 6 into a shallow water-bearing zone.

The early environmental restoration work was conducted under the oversight of the California Regional Water Quality Control Board (RWQCB). Applicable California State statutes are the Porter-Cologne Act (ground water protection) and Subchapter 15 of the California Administrative Code (discharges of wastes to land). Results of investigations were routinely reported to the RWQCB and the State Department of Health Services, now called the Department of Toxic Substances Control (DTSC) within the California Environmental Protection Agency. As a result of the discovery of high concentrations of TCE in ground water beneath the Building 834 Complex, the U.S. Environmental Protection Agency (EPA) evaluated the site using its Hazard Ranking System. The resulting score of 31.6 caused the site to be named to the EPA's National Priorities List (Superfund) in August 1990. A Federal Facility Agreement (FFA) pursuant to the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) is in final negotiations between LLNL, DOE, EPA, the RWQCB and the DTSC.

We are presently conducting CERCLA Remedial Investigation/Feasibility Study (RI/FS) work in six separate Operable Units to investigate and remediate volatile organic compounds (VOCs), the HE compounds hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX) and cyclotetramethyltetramine (HMX), and tritium in soil and ground water. Draft RI or RI/FS reports for each Operable Unit have been prepared and submitted to the regulatory agencies; at the request of the U.S. EPA we are consolidating the information in these reports into a single sitewide RI report to be followed by separate FS reports for each Operable Unit. We anticipate that Records of Decision will be complete by the end of 1995 and that full scale remediation will begin shortly thereafter.

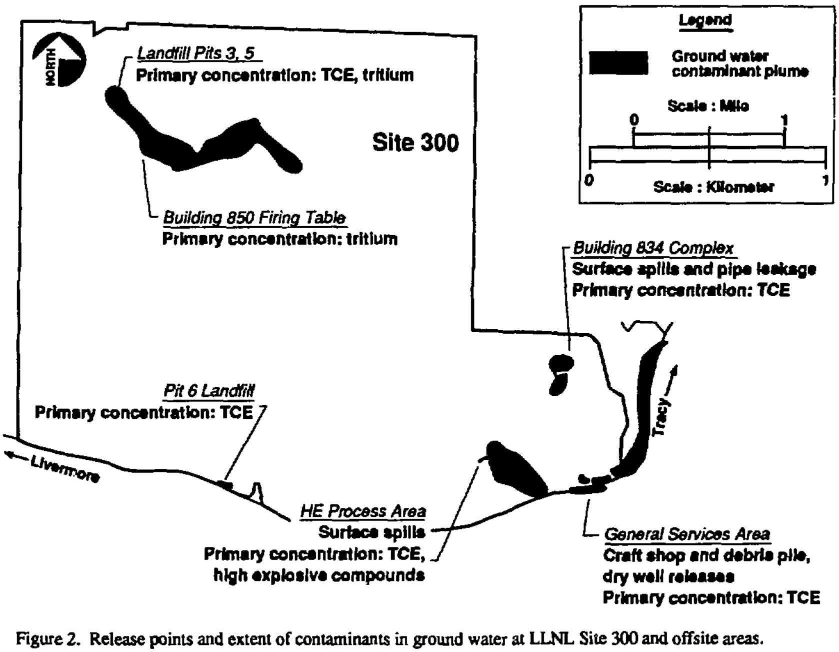

Figure 2. Release points and extent of contaminants in ground water at LLNL Site 300 and offsite areas.

SOURCES OF ENVIRONMENTAL RELEASE

As a result of our investigations at Site 300, we have identified releases of environmental contaminants from solid waste landfills, HE firing tables, HE rinse-water lagoons, drywells, HE Process Area buildings, experimental test areas, and machine and craft shops (Figure 2). Contaminants have migrated to soil and ground water, but no water-supply aquifers or water-supply wells are affected. Neither the public nor employees at Site 300 are at risk as a result of the contamination.

CHARACTERIZATION ACTIVITIES

To conduct a cost effective and efficient environmental restoration program, we have used a variety of field investigation techniques. Each technique was performed using a phased approach whereby all previously collected data were analyzed and integrated prior to conducting additional investigations. We have drilled boreholes and geologically and geophysically logged and analyzed about 4000 soil/rock samples from over 600 boreholes to identify the site geology and determine areas of contamination. Drilling has been primarily by air-mist rotary drilling using wire-line coring. A total of 415 of the boreholes have been completed as 4.5-inch-diameter ground water monitor wells screened across single water-bearing units. A selection of the wells has been hydraulically tested (either pump tests or slug/bail tests) to identify relationships among hydrogeologic units and to define the hydraulic characteristics of each unit.

Each month, we collect water-level measurements from each well and store the data in a VAX 6310 computer using INGRES relational database software. To characterize the water quality at each well site, we routinely collect and analyze an initial ground water sample from each well for a full suite of EPA Method 624 organic compounds, California Title 22 metals and organic compounds, general mineral parameters, HE compounds, and tritium, depending upon the location of each well. Subsequently, quarterly ground water samples are collected and analyzed for a more limited set of parameters. Chemical data are received electronically from the analytical laboratories and are also filed in the INGRES database. Chemical and water-level data are extracted from the VAX for grooming, evaluation, and printing prior to submittal to the regulatory agencies.

To help select optimum locations of boreholes for monitor wells, we conducted reconnaissance-level soil vapor surveys to identify potential release sites and areas of ground water contamination. We collected 900 soil vapor samples from active vacuum-induced sample collection devices and from Petrex passive collection tubes. After installing monitor wells and analyzing ground water samples, we determined that both soil vapor surveying methods are reliable indicators of subsurface VOC contamination.

GEOLOGY

A. Regional Geology

Site 300 is on the eastern side of the Altamont Hills, a part of the Diablo Range within the Coast Ranges physiographic province (Figure 1). The Coast Range physiographic province consists of a system of north-north-west trending, fault-bounded anticlinal mountain ranges and synclinal valleys. Bedrock consists of igneous, metamorphic, and sedimentary rocks that range in age from Jurassic to Pleistocene. The mountain ranges are composed of Jurassic to Tertiary rocks and locally may exceed elevations of 1300 meters. Valleys are filled with late Tertiary to Holocene sediments, mainly derived from the surrounding mountains.

Rocks exposed in the region surrounding Site 300 may be classified into three general groups:

(1) Late Tertiary-Quaternary, 5 million years ago (mya)-Holocene — alluvium and semi-consolidated sediments of mainly continental origin;

(2) Early to late Tertiary, 65-5 mya — Neroly, Cierbo, and Tesla Formations; shallow marine and continental sedimentary and volcaniclastic rocks; and

(3) Jurassic-Cretaceous, 180-65 mya — Great Valley Sequence, marine sedimentary rocks; Franciscan Complex, intensely sheared and deformed metamorphosed sedimentary and igneous rocks.

B. Site Geology

Site 300 is located within a series of steep canyons and hills. Bedrock is composed of Plio-Miocene volcaniclastic rock, Cretaceous sedimentary rock, and underlying Jurassic-Cretaceous basement. Alluvium in the area is predominantly terrace deposits, colluvium, and ravine fill. The geologic structure is complex because several major folds and several faults occur beneath the site (Figure 3). The general stratigraphy at Site 300 is shown on Figure 4. A generalized NW/SE cross section is shown in Figure 5.

Unconsolidated deposits at Site 300 are Pleistocene to Holocene colluvium, alluvium, and ravine fill (Qa); landslide deposits (Qls); and terrace or older alluvium (Qoa). Colluvium, alluvium, and ravine fill materials vary from silty clays to silty gravels; thicknesses typically vary from zero at bedrock outcrops to 13.5 feet. Terrace deposits are most extensive in the southern part of the site north of Corral Hollow Creek, and consist of sandy silts and clays grading downward to sands and locally coarse cobble and boulder bearing gravels. These terraces range from 3 to 30 feet thick.

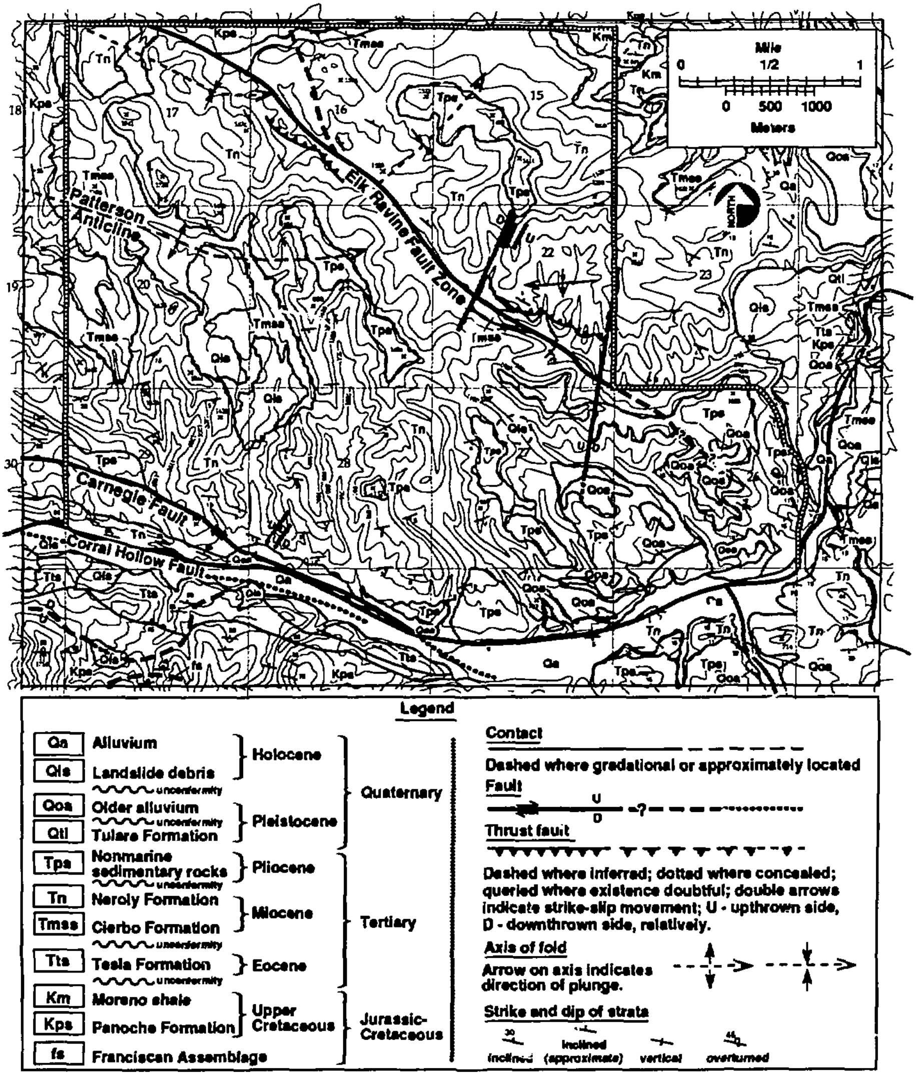

Figure 3. Geologic map of the Site 300 area.

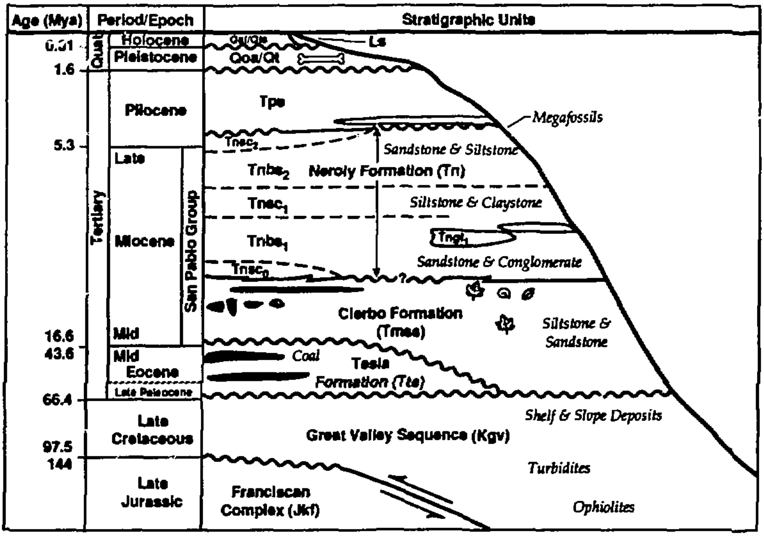

Figure 4. General stratigraphy of Site 300.

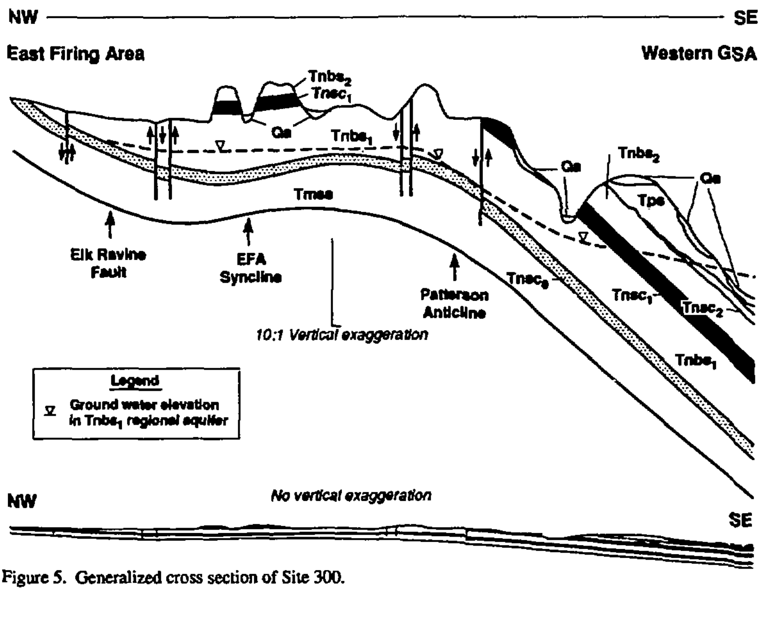

Figure 5. Generalized cross section of Site 300.

An unnamed Pliocene unit (Tps) consists of semilithified non-marine conglomerates with cobbles of angular graywacke and chert, sandstones, and clays. This unit occurs on isolated hilltops as remnants of a once continuous blanket of sediment. It also has been encountered in the subsurface beneath the southerly part of the site.

The bedrock underlying most of Site 300 consists mostly of the continental and estuarine, largely volcaniclastic, sedimentary rock of the Miocene Neroly Formation (Tn). The Neroly Formation, up to 150 meters thick, is composed of distinctive blue-weathering sandstones and siltstones, coarse conglomerates of well-rounded andesitic and basaltic pebbles and cobbles, and interbedded tuffaceous shales. Fractures are common. Conformably underlying the Neroly Formation are interbedded, coarse-grained, coarse-grained, friable sandstones, carbonaceous brown shales, and tuffs of the marine lower Miocene Cierbo Formation (Tmss). The formation has an average thickness of 300 feet in the study area.

HYDROGEOLOGY

Three primary hydrostratigraphic units are present at Site 300: Quaternary deposits, a Pliocene nonmarine sequence, and the Miocene Neroly Formation. The Quaternary unit consists of alluvium, colluvium, and terrace deposits, which are present mainly along the Corral Hollow Creek drainageway and in upland ephemeral drainage ravines. The alluvium and colluvium receive infiltration through seasonal precipitation and runoff along the ephemeral streams, frequently recharging underlying aquifers. Shallow aquifers are present in these Quaternary units. Hydraulic conditions in the Quaternary deposits are predominantly unconfined. In the eastern GSA, ground water flow in the extensive alluvial aquifer is west to east-northeast, with a gradient of 0.003 to 0.009. In the northwest, near Building 850, the gradient is 0.06 to the east-northeast, and in the south the gradient is south-southeast. Hydraulic conductivity is extremely variable. Well yields may vary from <1 to >60 gpm.

The Pliocene nonmarine unit consists of fluvial and lacustrine deposits which may contain ground water. When present, ground water is generally contained within channel-fill deposits and lenses, resulting in local perched water-bearing zones. Siltstone and claystone strata underlying the water-bearing gravel deposits function as a lower confining layer, preventing or impeding the downward migration of the perched ground water. Hydraulic conditions range from perched (Building 834), to unconfined (HE Process Area), to confined (western GSA). Ground water flow is generally south-southeast, subparallel to the structural dip. Hydraulic gradients range from 0.05 in the south (HE Process Area) to 0.1 in the southeast (Building 834 Complex). Hydraulic tests indicate that the hydraulic conductivity of the aquifer ranges from 10^{-5} to 10^{-3} cm/s. Well yields range from <1 to 2 gpm.

Most ground water at Site 300 is found in Neroly Formation sedimentary rocks, which underlie all of Site 300. The Neroly Formation upper blue sandstone member ($Tnbs_2$) contains an aquifer whose hydraulic conditions range from unsaturated in central and eastern Site 300, to semiconfined in the HE Process Area, to flowing artesian in the south near the western GSA. Ground water flow in the upper blue sandstone is generally south-southeast subparallel to the structural dip. The hydraulic gradient varies from 0.04 to 0.08. Hydraulic tests indicate hydraulic conductivity is on the order of 10^{-4} cm/s. Maximum pumping rates range from 1 to 43 gpm. The Neroly Formation middle siltstone and claystone member ($Tnsc_1$), lies beneath the $Tnbs_2$ unit and is an aquitard. Beneath this member is the Neroly Formation lower blue sandstone member ($Tnbs_1$), which consists mostly of well-consolidated sandstones and conglomerates with interbedded siltstones and claystones. The $Tnbs_1$ unit contains the regional water-supply aquifer. Based on field estimates, primary and secondary (fracture) permeabilities vary greatly. Hydraulic conditions change from unconfined (water table) in the west near Pit 6 and the north near Pit 8 and the East Firing Area (Building 850) to confined in the southeast near the western GSA. Depth to water varies from 8 to 125 meters across the site. Hydraulic conductivity ranges from 10^{-6} to 10^{-1} cm/s. Maximum pumping rates vary from <1 to 290 gpm.

EXTENT OF CONTAMINATION

As a result of our investigations we have identified 12 ground water contaminant plumes. VOCs, primarily TCE, comprise the majority of the plumes (Figure 2). We have identified TCE releases from two inactive landfills, one old debris pile, dry wells (decommissioned), an HE Process Area building, and experimental test facilities where TCE is used as a heat transfer fluid. With the exception of the Building 834 test facility, TCE concentrations in ground water are generally less than 100 parts per billion (ppb). At Building 834 TCE concentrations range up to 500 parts per million (ppm) in a shallow perched water-bearing zone extending approximately 150 meters by 400 meters along a ridge top. Approximately 100 meters of low permeability sedimentary rocks separate this zone from the regional water-supply aquifer. Two TCE plumes emanating from the GSA have moved offsite through permeable gravels to private ranch land, one of them a distance of about 1300 meters. At closed landfill pit 6, a small plume of TCE is migrating from the southeast corner of the landfill through alluvium. Its TCE content of 250 ppb or less is self-remediating as ground water evaporates along a seepage face where the alluvial water-bearing zone crops out.

We have identified tritium in shallow ground water at the northern part of the site (Figure 3). Most of the tritium was released from two inactive landfills when ground water rose into the bottoms of the landfills during heavy rains of 1982-83. Tritium-containing debris, mostly pea gravel and lumber from firing table experiments, had been disposed of in the landfills from the early 1960s to the late 1970s. The remainder of the tritium in ground water was leached by infiltrating rainwater and dust suppression water from tritium-containing gravels beneath one of the firing tables. Activities of tritium in ground water range up to 1.2 million picocuries per liter (pCi/L). Results of two-dimensional analytical modeling indicate that by the time the tritiated ground water reaches the site boundary it will have radioactively decayed to background levels of several hundred pCi/L.

The HE compound RDX is present in two small areas of a perched water-bearing zone and an unconfined aquifer in the HE Process Area where concentrations in ground water range up to 350 ppb. HMX has been detected only sporadically. Although HE compounds are fabricated in the HE Process Area and rinse-waters were disposed of in unlined lagoons, we have not identified a release site for the HE compounds.

REMEDIATION ACTIVITIES

Concurrent with the remedial investigation of the site, we have conducted cleanup activities by removing from service and capping nine HE rinse-water lagoons and replacing them with double-lined surface impoundments; installing Resource Conservation and Recovery Act caps on two inactive landfills; excavating and aerating TCE-contaminated soils at two experimental facilities; decommissioning 25 drywells; sealing and abandoning eight old water-supply wells; and conducting a CERCLA Removal Action using pump-and-treat at the Eastern GSA TCE plume.

In support of feasibility studies, we have conducted tests of such innovative remediation technologies as electron beam destruction of TCE in vapor and HE compounds in ground water; pulsed ultraviolet destruction of TCE in vapor; forced evaporation of tritiated water; and electrically heated of TCE-containing soils to enhance vacuum extraction. Data from these tests are still being evaluated.

SUMMARY

In summary, we have found that remedial investigations of complex hydrogeologic environments, especially those having multiple water-bearing units such as at Site 300, require an integrated approach to address the inherent interrelationships and interdependence of aquifer hydrogeology, chemical characteristics, fate and transport, and ultimate risk to human health and the environment.