Special Report
Number 4

UWEX UNIVERSITY OF WISCONSIN-EXTENSION
GEOLOGICAL AND NATURAL HISTORY SURVEY

Ground-Water Hydrology and Geology Near the July 1974 Phenol Spill at Lake Beulah, Walworth County, Wisconsin

by

R. G. Borman
U. S. Geological Survey
1975

PREPARED BY
UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
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WISCONSIN GEOLOGICAL AND NATURAL HISTORY SURVEY

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This report is a product of the Geological and Natural History Survey Water Resources Program which includes: systematic collection, analysis, and cataloguing of basic water data; impartial research and investigation of Wisconsin's water resources and water problems; publication of technical and popular reports and maps; and public service and information. Most of the work of the Survey's Water Resources Program is accomplished through state-federal cooperative cost-sharing with the U.S. Geological Survey, Water Resources Division.

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

and the

UNIVERSITY OF WISCONSIN-EXTENSION
GEOLOGICAL AND NATURAL HISTORY SURVEY
M.E. Ostrom, Director and State Geologist
Madison, Wisconsin
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Abstract

Lake Beulah, a village in Walworth County, Wisconsin, was the site of a 9,000-gallon (34,000-litre) phenol spill in July 1974. The phenol reached the water table, and ground water containing phenol is moving southeast through the sand-and-gravel and the Niagara aquifers and should discharge to streams and ditches tributary to Honey Creek. The underlying sandstone aquifer (Cambrian and Ordovician strata) should be unaffected by phenol from the spill because it is overlain by the Maquoketa Shale, which forms a barrier to vertical ground-water movement.

FACTORS FOR CONVERTING ENGLISH UNITS
TO INTERNATIONAL SYSTEM (SI) UNITS

Multiply English units	By	To obtain SI units
feet (ft)	0.3048	metres (m)
miles (mi)	1.609	kilometres (km)
gallons (gal)	3.785	litres (l)

INTRODUCTION

The village of Lake Beulah (also known as Beulah Station) in Walworth County, southeastern Wisconsin, is 25 mi (40 km) southwest of Milwaukee and 55 mi (88 km) southeast of Madison.

On July 16, 1974, a tank car carrying about 21,000 gal (79,000 l) of phenol (carbolic acid) derailed 500 ft (150 m) north of State Highway 24 near Lake Beulah. About 9,000 gal (34,000 l) of phenol was spilled. Phenol solidifies at 41°C (106°F), but was liquid in the tank car because it was still warm from manufacturing. However, at least part of it crystallized in and on the soil at the spill site. On July 17 the ground was strewn with sawdust, which absorbed the liquid, and then the sawdust and ruptured tank car were covered with plastic. On July 25 work began to remove the contaminated soil along the railroad right-of-way. All visible traces of crystallized phenol were removed and chemical tests at the site by the Wisconsin Department of Natural Resources indicated that the contaminated soil had been removed. Five railroad gondolas were lined with plastic, filled with phenol-contaminated soil, and sent to Baton Rouge, LA, for disposal by the phenol manufacturer.

Despite these cleanup efforts, traces of phenol, which is soluble in water, were found in water from two wells tested on July 23, 1974. Phenol had moved downward to the water table and then laterally to the nearby wells.

At a meeting in Governor Patrick Lucey's office on February 18, 1975, the Wisconsin Geological and Natural History Survey and the

Wisconsin Department of Natural Resources recommended a study of ground-water movement in the area to predict further movement of the phenol and to aid in planning remedial action. In February 1975 the University of Wisconsin-Extension, Geological and Natural History Survey, and the U.S. Geological Survey began a study of the ground-water hydrology in the vicinity of the spill.

This report provides basic data and information on the ground-water hydrology and geology in the vicinity of the spill. The study is a cooperative project of the University of Wisconsin-Extension, Geological and Natural History Survey, and the U.S. Geological Survey.

The scope of the project included collection and analysis of ground-water samples and well-log and water-level data to describe the hydrology and geology of the area.

State agencies and well owners assisted by providing well and water information. Many allowed access to their wells for water-level measurements or for collecting water samples for chemical analysis. Special acknowledgment is made to the Wisconsin Department of Natural Resources, Southeast District staff, for supplying well data and for instrumental leveling of well altitudes, and the Surveillance Section, for supplying information on chemical analyses. Chemical analyses were made by the Wisconsin State Laboratory of Hygiene in Madison, Aqua-Tech. Inc., of Port Washington, Wisconsin, and Admiral Water Services of Arlington Heights, Illinois.

GEOLOGY

The materials that control the movement and storage of ground water in the Lake Beulah area range from the basement rocks of Precambrian age to the unconsolidated glacial deposits, alluvium, and soils of Quaternary age. Bedrock is overlain by glacial drift throughout the area.

The bedrock, from oldest to youngest, includes Precambrian crystalline rocks; Cambrian sandstone; Ordovician dolomite, sandstone, and shale; and Silurian dolomite (table 1). These units are present beneath the entire area, except for the Silurian dolomite, which is absent in the southern part (fig. 1).

Crystalline rocks of Precambrian age underlie the entire Lake Beulah area. The top of the Precambrian rocks is about 1,600 ft (490 m) below sea level. The rocks have low permeability and mark the effective lower limit of ground-water movement.

Cambrian sandstone overlies the Precambrian rocks throughout the Lake Beulah area. It consists of five units. They are, from oldest to youngest, the Mount Simon, Eau Claire, Galesville, and Franconia sandstones, and the Trempealeau Formation. The sandstone is about 1,700 ft (520 m) thick in the area. The ability of Cambrian sandstone to store and yield water to wells and its great thickness make it an important source of water.

Ordovician sedimentary rocks in the Lake Beulah area include in ascending order the Prairie du Chien Group (mostly dolomite), the St. Peter Sandstone, the Platteville and Decorah Formations and Galena Dolomite, undifferentiated (mostly dolomite and herein called the Galena-Platteville unit), and the Maquoketa Shale.

Table 1.--Stratigraphy of the Lake Beulah area, Walworth County

System	Rock unit	Lithology
QUATERNARY	Holocene deposits	Unconsolidated organic matter
	Pleistocene deposits	Unconsolidated clay, silt, sand, gravel, cobbles, boulders, and organic matter.
SILURIAN	Undifferentiated dolomite	Dolomite, white to gray. Crevices and solution channels abundant but discontinuous.
ORDOVICIAN	Maquoketa Shale	Shale, dolomitic, blue-gray; contains dolomitic beds as thick as 40 feet.
	Galena Dolomite, Decorah Formation, and Platteville Formation undifferentiated	Dolomite and some slightly shaly dolomite, light-gray to blue-gray
	St. Peter Sandstone	Sandstone, dolomitic in some places, shaly at base in places, white to light-gray, fine- to medium-grained.
	Prairie du Chien Group	Dolomite, gray or white; some sandstone and sandy dolomite.

CAMBRIAN	Trempealeau Formation	Sandstone, very fine- to medium-grained; dolomite interbedded with siltstone, light gray.
	Franconia Sandstone	Sandstone, very fine- to medium-grained; siltstone or dolomite; sandstone, dolomitic at base, medium- to coarse-grained.
	Galesville Sandstone	Sandstone, light-gray, fine- to medium-grained.
	Eau Claire Sandstone	Sandstone, dolomitic, light-gray to light-pink, fine- to medium-grained; some shale beds.
	Mount Simon Sandstone	
PRECAMBRIAN	Precambrian rocks undifferentiated	Crystalline rocks.

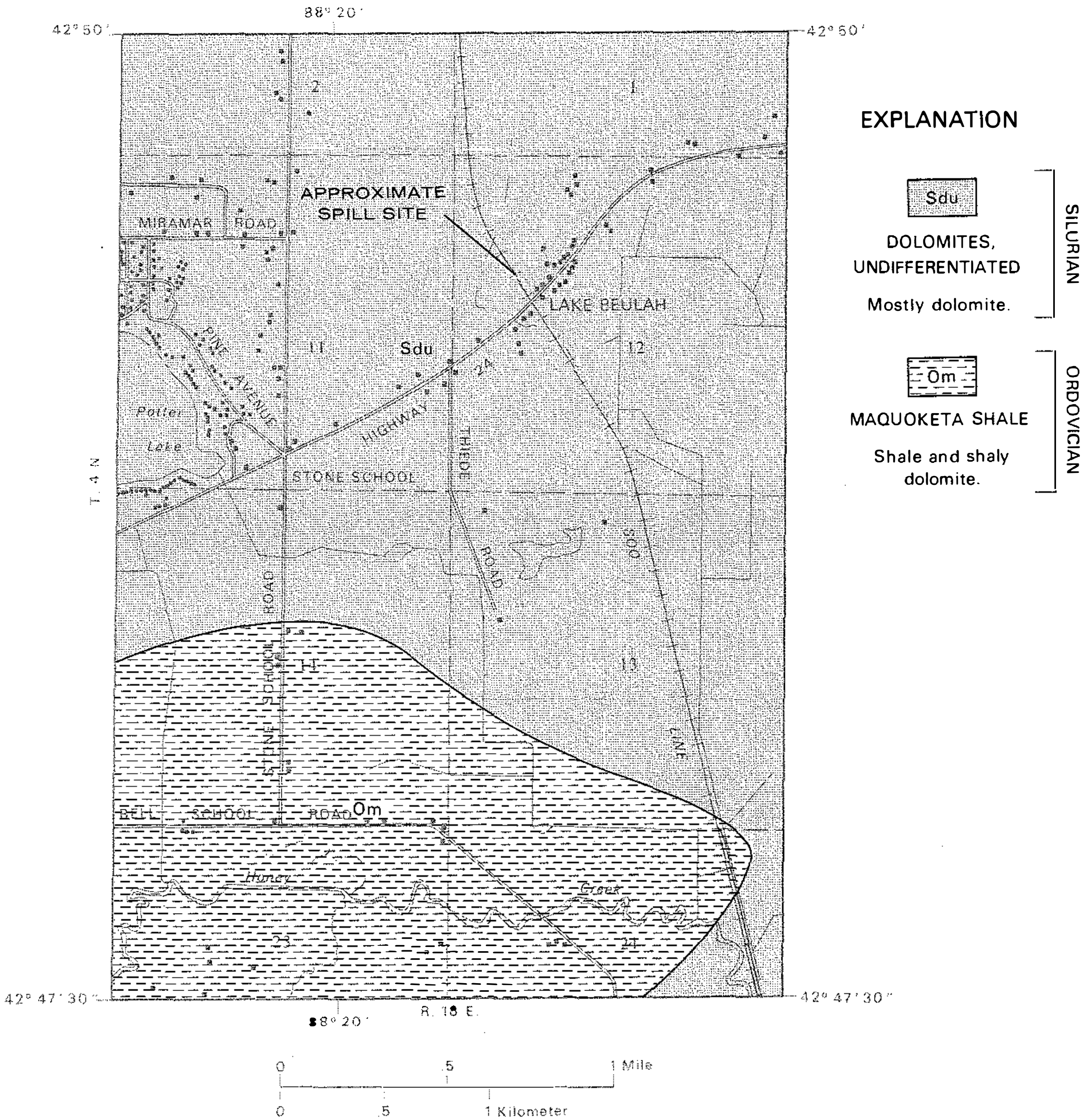

Figure 1. Bedrock geology.

Silurian dolomite is the youngest bedrock rock unit in the Lake Beulah area and is found in most of the area (fig. 1).

The bedrock geologic map (fig. 1) shows the type of rock that would be exposed if the unconsolidated material above it were stripped away. The uppermost bedrock unit throughout most of the Lake Beulah area is the Silurian dolomite. The Maquoketa Shale is the uppermost bedrock unit in the southwestern part of the area.

The bedrock topography was formed by preglacial and glacial erosion of the exposed bedrock. In the Lake Beulah area the bedrock surface slopes from more than 800 ft (240 m) above sea level in the northern part of the area to less than 650 ft (200 m) in the southwest corner.

The unconsolidated deposits overlying bedrock in the Lake Beulah area are largely of glacial origin and of Quaternary age, but they also include some surficial marsh deposits. The glacial deposits are end moraine, ground moraine, and outwash materials.

The combined thickness of unconsolidated glacial and marsh deposits in the Lake Beulah area ranges from less than 50 ft (15 m) in the northwest to more than 150 ft (46 m) in the southwest corner (fig. 2).

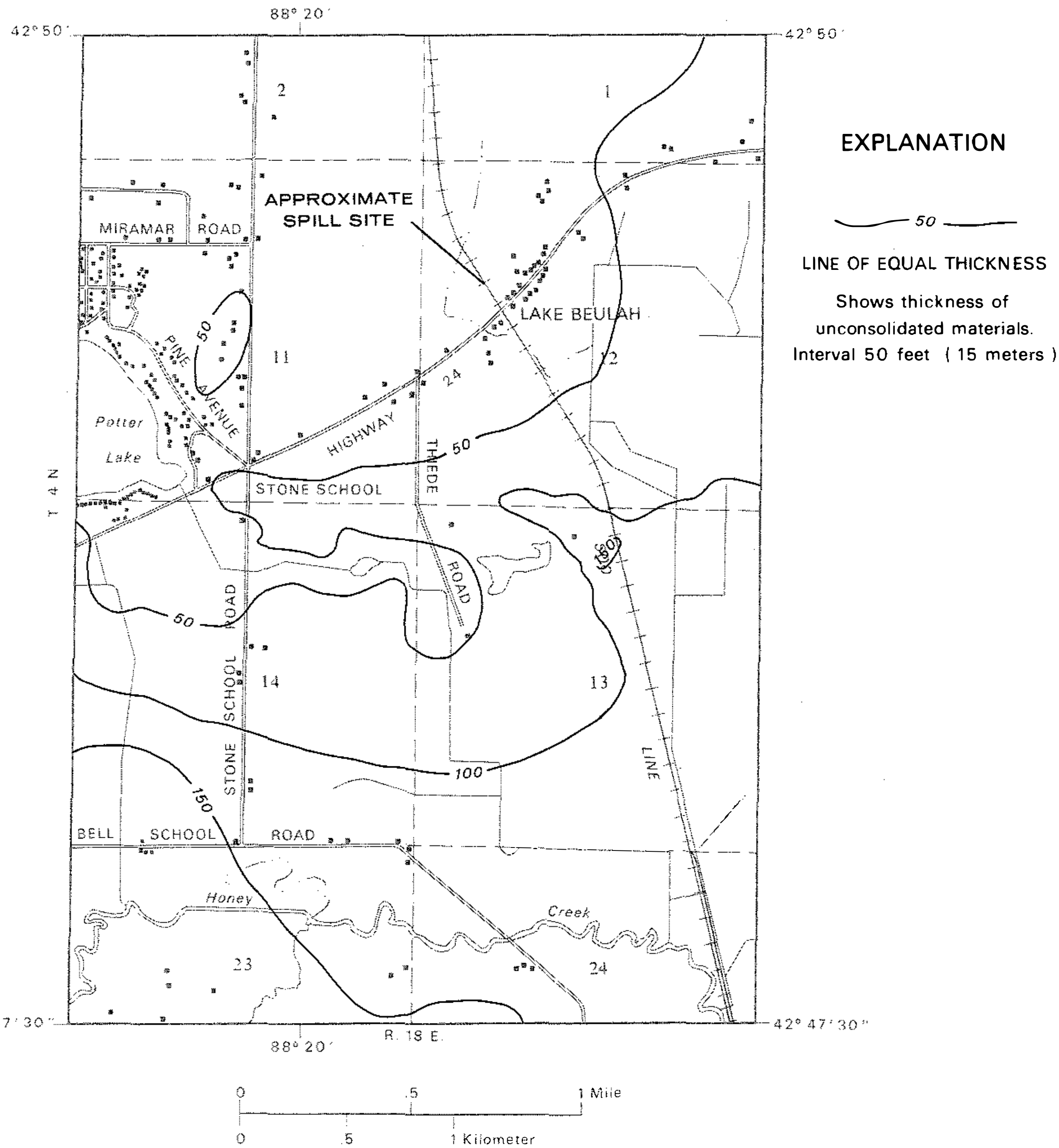

Figure 2. Thickness of unconsolidated materials.

GROUND-WATER HYDROLOGY

All of the Lake Beulah area depends on ground water for potable water supplies. The principal sources are the sand-and-gravel and the Niagara aquifers. The sandstone aquifer, although not used in the Lake Beulah area, is a reliable potential source of ground water.

The sand-and-gravel aquifer is contained within glacial drift and alluvium and occurs either at land surface or buried beneath less permeable drift.

The Niagara aquifer is composed of dolomite of Silurian age, which overlies the Maquoketa Shale in much of the area. The Niagara aquifer is the most important aquifer for domestic supplies in the Lake Beulah area.

The sandstone aquifer includes all sedimentary bedrock below the Maquoketa Shale. The sandstone aquifer overlies the relatively impermeable Precambrian rocks. The sandstone aquifer underlies the entire Lake Beulah area and includes, in ascending order, from oldest to youngest, sandstones of Cambrian age, the Prairie du Chien Group, the St. Peter Sandstone, and the Galena-Platteville unit of Ordovician age. The St. Peter Sandstone is the most important water-yielding Ordovician rock. The dolomites yield some water to deep wells.

The Maquoketa Shale separates the Niagara and sandstone aquifers. Because of its very low permeability, the shale restricts the vertical movement of water.

The source of all ground water is precipitation. Part of the precipitation returns to the atmosphere by evaporation, part runs off into streams, and the remainder infiltrates to become ground water.

Most ground water in the Lake Beulah area circulates slowly through shallow flow paths within the unconsolidated material and the Silurian dolomite and then discharges to streams.

The water-table map (fig. 3) shows the altitude of the top of the zone of saturation in the sand-and-gravel and Niagara aquifers. Ground water flows from areas of high to areas of low water-table altitudes along flow paths generally perpendicular to the water-table contours. Phenol dissolves readily in water and should move in the direction of ground-water movement from the spill area generally to the southeast. The phenol should then discharge into the steams and ditches tributary to Honey Creek.

The spill is unlikely to affect the sandstone aquifer. Water percolating downward from the spill is separated from water in the sandstone aquifer by about 200 ft (61 m) of nearly impermeable Maquoketa Shale.

Chemical analyses for phenols in well water suggest that ground water containing phenol is moving mainly southeast (fig. 4) (standard laboratory methods do not determine phenol, $C_6H_5O_4$, but phenolic materials). Concentrations of phenolic materials of more than 1 mg/l (milligram per litre) are common in well water near the spill site. Water from these wells tastes and smells of phenol, according to owners and William Miles, sanitarian, Department of Natural Resources (oral commun., 1975). According to the well owners, the taste and smell were not present before the spill.

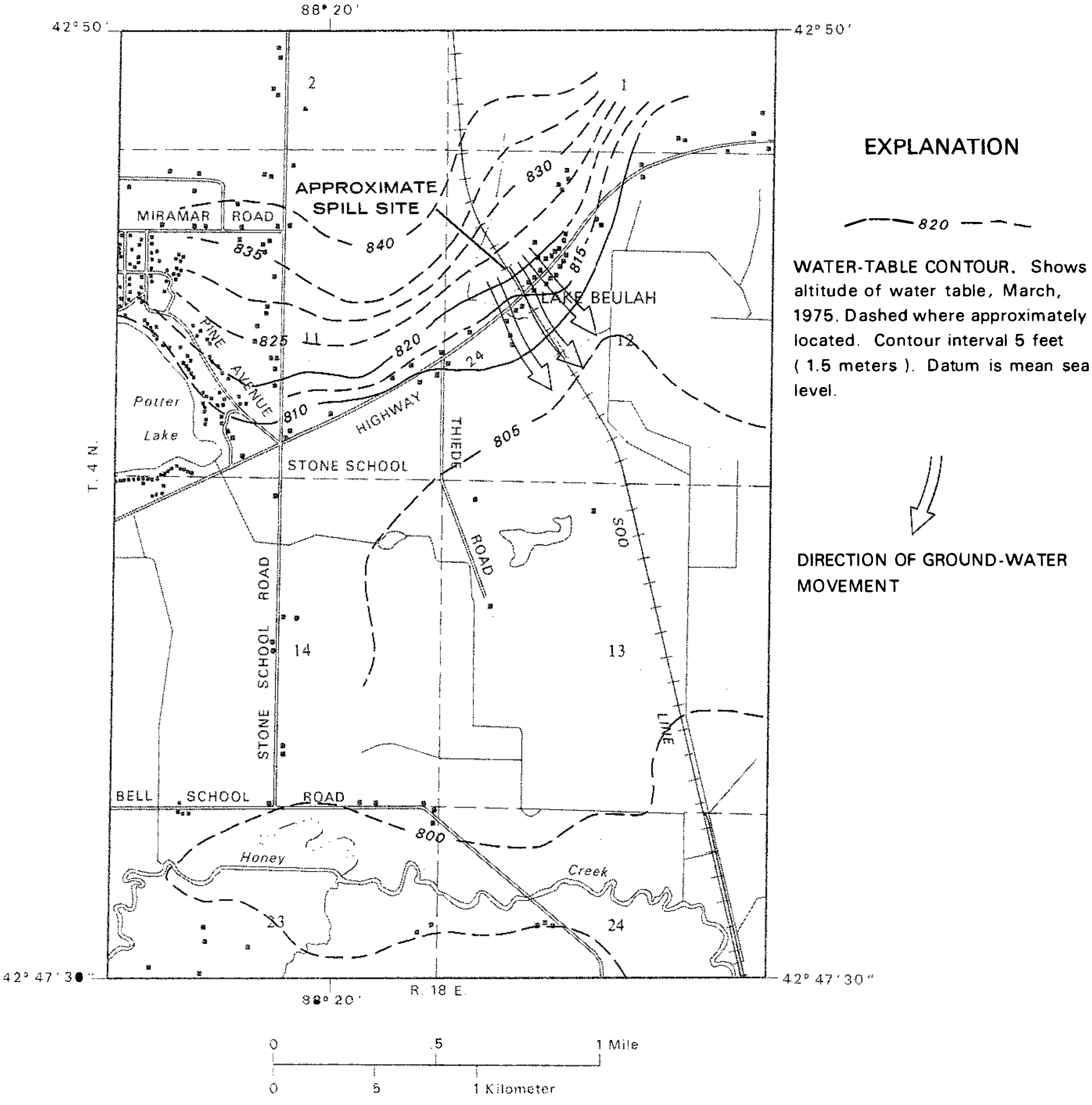

Figure 3. Water table.

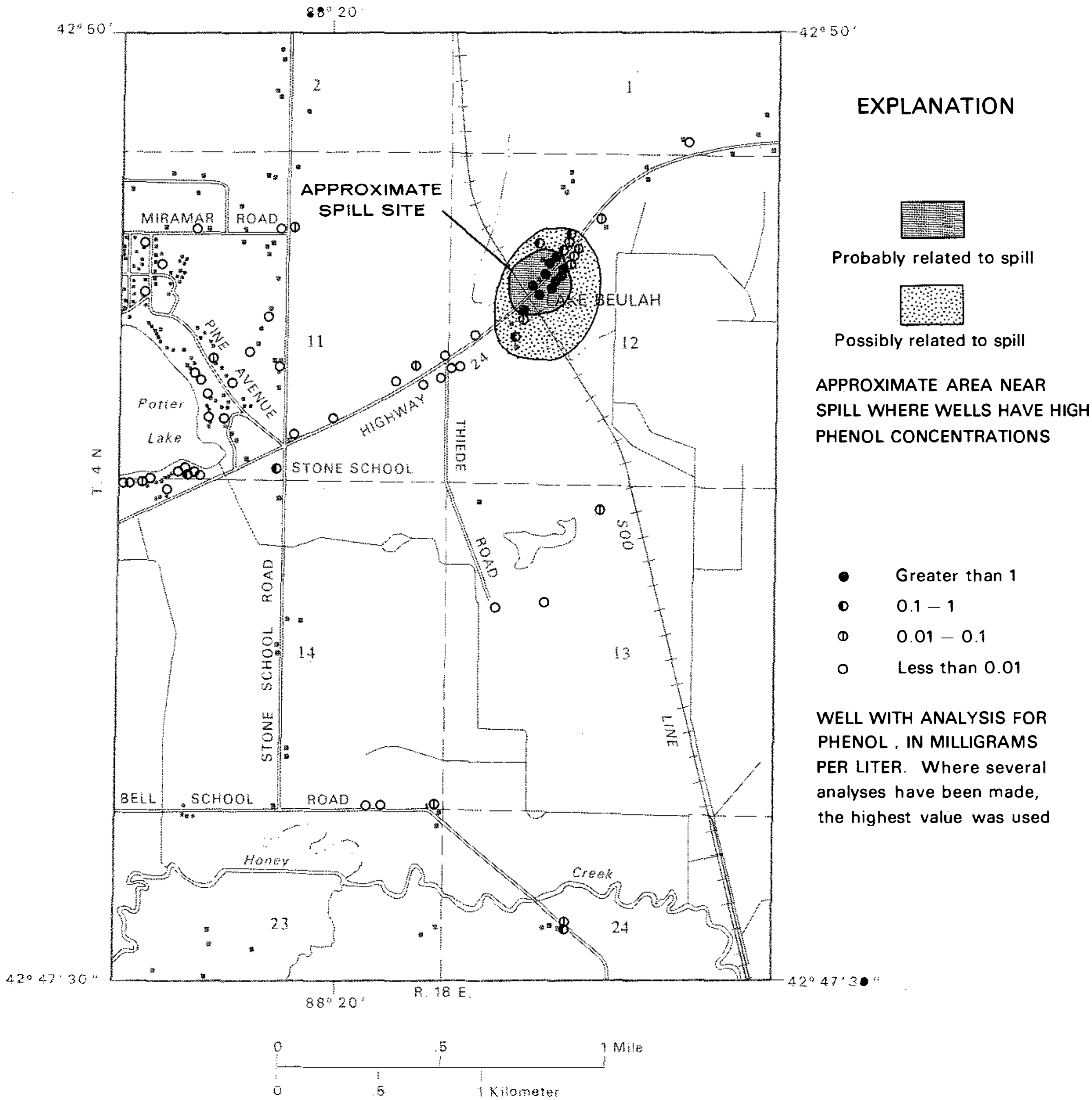

Figure 4. Phenol concentrations in well water.

Reportedly phenol was identified as the only phenolic material present in water containing more than 1 mg/l from six wells near the spill site, as shown by gas chromatography tests by the U.S. Environmental Protection Agency. The wells with water containing more than 1 mg/l phenol are south to slightly northeast of the spill and as far as 1,000 ft (300 m) from the spill. Some movement of the phenol to the east and northeast may have been caused by a local ground-water gradient toward Lake Beulah and to increased head at the spill site caused by artificial flooding from November 6 through November 14, 1974, in an attempt to flush the phenol away.

Concentrations of phenolic material between 0.01 mg/l and 1 mg/l are common in water from wells near the spill (fig. 4). A few wells outside the immediate vicinity of the spill contain water having phenolic-material concentrations between 0.01 and 1 mg/l. Concentrations of phenolic material of less than 0.01 mg/l are common outside the immediate vicinity of the spill. Other sources of phenolic materials are decaying vegetation, petroleum products, pharmaceutical products, and human and animal wastes.

As of June 1975 indications are that water with the highest concentrations of phenolic materials has moved past Lake Beulah. Analyses of well water nearest the spill site and down the ground-water gradient show a decrease in the concentration of phenolic materials. These wells were the first to show an increase in phenolic materials after the spill, and had shown the highest concentrations of all of the ground-water analyzed. Monitoring of well water in the area is continuing.
