





MICHIGAN 84° YEVE AND THE PART OF THE **EXPLANATION** COLUMBIANA Ca NOT SOME Ca + MgNa HCO₃ SO4 LWARREN . CI HAMILTON Area where dissolved-solids content is commonly >1000 mg/l Bedrock yields little water Composition not determined Area boundary 0 10 20 30 40 50 MILES

TABLE 1.—ROCK UNITS USED IN MAPPING THE BASE OF POTABLE WATER IN OHIO.

Pennsylvanian: Monongahela Formation: Uniontown Sandstone Member Sewickley Sandstone Member Conemaugh Formation: Morgantown Sandstone Member Buffalo Sandstone Member Allegheny Formation: Freeport Sandstone Member Pottsville Formation: Homewood Sandstone Member Connoquenessing Sandstone Member Sharon Member Conglomerate unit Mississippian: Cuyahoga Group Black Hand Sandstone Berea Sandstone Cussewago Sandstone Devonian and Mississippian: Undifferentiated shales Devonian: Columbus Limestone Detroit River Group (dolomite) Silurian: Bass Islands Dolomite Niagara Group (dolomite) Brassfield Limestone Ordovician: Richmond Group (shales and thin limestones) Aquifer composition: dol, dolomite; ls, limestone; sh, shale; ss, sandstone.
Geologic age of aquifer: D, Devonian; M, Mississippian; P, Pennsylvanian;
S, Silurian.
Chemical concentrations: In milligrams per liter.

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Source of data: a, U.S. Geological Survey; b, Ohio Department of Natural Resources, Division of Water.

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TABLE 2.—CHEMICAL ANALYSES OF WATER NEAR THE BASE OF THE POTABLE ZONE.

ell	Aquifer composi- tion	age of aquifer	sampling ture °C.	(SiO ₂)	(Fe)	(Mn)	(Ca)	sium (Mg)	(Na)	(K)	bonate (HCO ₃)	(SO ₄)	(Cl)	(F)	(NO ₃)	(residue at 180° C.)	Calcium, magnesium	Noncar- bonate	(micromhos at 25°)	pH	Color	of dat
1234567890123456789012234567890133345678901123445678901223445657890122344567890123344567890133444567890134445678901344456789013444467890134444678901344446789013444467890134467890134467890100000000000000000000000000000000000	ls ls-dol dol dol ls ls dol ls s dol ls s dol ls	D D D D D D D D D D D D D D D D D D D	12-62 11-67 12 11-62 1-62	10 11 14 11 13 16 16 15 9. 5 15 9. 9 10 12 18 11 10 21 11 11 17 10 21 11 14 12 8. 2 7. 2 16 14 18 11 11 11 11 11 11 11 11 11 11 11 11	$\begin{array}{c} 0.\ 2\\ 2.\ 0\\ .4\\ .1\\ .75\\ .00\\ 1.\ 0\\ 1.\ 1\\ 10\\ .3\\ .51\\ .1\\ .3\\ .51\\ .3\\ .51\\ .4\\ .07\\ .05\\ 2.\ 3\\ 2.\ 3\\ 2.\ 3\\ 2.\ 3\\ 2.\ 3\\ 2.\ 3\\ 3.\ 51\\ .4\\ .07\\ .05\\ 2.\ 3\\ 2.\ 3\\ 1.\ 4\\ .02\\ 9.\ 5\\ .3\\ 18.\ 0\\ 17\\ .48\\ 12.\ 0\\ 1.\ 2\\ 1.\ 4\\ 2.\ 2\\ .1\\ 1.\ 6\\ .2\\ .1\\ .04\\ .60\\ .15\\ .05\\ 1.\ 2\\ .9\\ .17\\ .05\\ 1.\ 2\\ .9\\ .17\\ .05\\ .35\\ .35\\ .30\\ .30\\ .30\\ .30\\ .30\\ .30\\ .30\\ .30$	0 . 06 0 0 . 00 . 00 00 00 00 00 02 02 00 03 31	79 330 91 100 106 470 141 184 116 126 100 126 264 94 95 96 92 91 73 481 125 69 143 14 7, 0 113 132 113 44 39 48 62 243 12 81 133 48 62 243 12 81 133 48 62 243 65	37 112 47 29 33 203 51 54 38 64 36 50 58 40 40 37 34 45 44 166 79 52 37 30 45 17 11 51 6. 8 41 25 41 3. 2 60 31 23 9. 2 18 10 20 84 10 30 52 16 18 34 45 46 55 40 40 40 40 40 40 40 40 40 40 40 40 40	39 88 11 5 19 146 16 24 8.6 25 8.0 10 74 17 4.4 10 3.9 7.1 58 38 32.6 63 118 32 4.8 17 105 105 105 105 105 105 105 105	1. 8 8. 3 2. 5 1. 2 2. 2 1. 4 1. 9 1. 9 1. 9 1. 1 7. 5 2. 8 11 3. 4 1. 1 2. 1. 2 1. 2 1. 2 1. 1 1. 1 3. 0 6. 2 4. 3 1. 1 1. 1 1. 1 1. 1 1. 1 1. 1 1. 1 1	268 170 366 366 214 440 396 414 412 396 414 412 396 427 130 471 422 420 348 448 414 555 306 478 670 406 376 180 106 252 500 130 567 342 360 404 314 156 439 256 226 436 382 428 298 226 240 484 240 215 474 301 278	131 1, 160 130 76 239 1, 780 261 369 120 293 81 168 907 49 52 30 59 48 111 1, 410 560 258 18 3. 0 31 34 115 470 45 3. 2 160 67 4. 4 271 171 232 31 173 13 31 592 1. 2 45 432 23 33 101 27 43 223 18 27	52 57 6 0 11 50 0 6 3.5 1 16 14 4 9.0 13 10 10 10 10 10 10 10 10 10 10	2. 2 1. 8 1. 9 1. 2 1. 9 1. 5 1. 5	1. 3 2. 0 4 1. 1 0 1. 0 1. 0 2. 4 2. 9 2. 8 2. 2 2. 1 2. 7 2. 1 2. 1 34 2. 0 2. 2 3. 1 3. 3 3. 3 3. 3 4. 1 6. 1 6. 1 6. 1 6. 1	540 2, 010 530 490 548 3, 120 760 981 513 830 451 630 1, 390 527 421 431 403 451 558 2, 390 1, 069 786 594 326 408 690 273 1, 030 1, 128 1, 320 355 575 420 721 612 651 1, 177 254 353 1, 330 431 1, 900 884 236 241 541 252 243 1, 060 602 272	350 1, 280 420 370 400 2, 010 560 684 446 580 398 520 780 400 402 392 370 435 377 1, 880 785 532 324 263 367 204 160 568 62 24 275 450 40 504 457 377 148 172 160 240 952 71 326 546 160 240 952 419 216 206 280 80 244	130 1, 140 120 70 225 1, 650 235 344 108 255 90 170 673	2, 150 796 3, 190 814 729 764 725 671 731 903 2, 610 1, 360 1, 110 1, 010 596 711 1, 270 394 1, 340 1, 198 2, 430 527 737 1, 010 895 934 318 1, 730 750 3, 600 1, 210 878 418 1, 700 1, 100 476	$\begin{array}{c} 86346283631267639359467436374441093313767384737580579\\ 67777777777777777777$	$\begin{array}{c} 2\\ 5\\ 0\\ 0\\ 5\\ 3\\ 0\\ 1\\ 5\\ 0\\ 0\\ 0\\ 1\\ 5\\ 0\\ 0\\ 0\\ 0\\ 4\\ 1\\ 5\\ 2\\ 2\\ 0\\ 5\\ 5\\ 0\\ 3\\ 4\\ 0\\ 0\\ 0\\ 4\\ 2\\ 2\\ 0\\ 5\\ 5\\ 0\\ 3\\ 4\\ 0\\ 0\\ 0\\ 5\\ 5\\ 3\\ 0\\ 0\\ 0\\ 0\\ 0\\ 0\\ 0\\ 0\\ 0\\ 0\\ 0\\ 0\\ 0\\$	b abbaabbaabbaaabaaaaaabbaaaabbaaabbaa

INTRODUCTION

FIGURE 4.—CHEMICAL CHARACTER OF WATER IN BEDROCK NEAR THE BASE OF THE POTABLE ZONE.

Recent advances in desalting techniques have enhanced the water-supply potential of saline aquifers, especially in areas where only meager supplies of fresh water are available. Disposal of liquid wastes in saline aquifers is a potentially conflicting use. The danger of contaminating potable water supplies or potentially valuable saline reservoirs by subsurface disposal of wastes makes it imperative that more information be obtained on the occurrence of saline ground water throughout the country.

This report presents the results of the first step in a state-wide assessment of Ohio's saline ground-water resources—the identification and mapping of the base of potable water. The most detailed information on saline water is from the eastern part of the State, where commercial brines are obtained at depths greater than about 2,000 feet below the land surface. Limited additional data from water wells and oil and gas wells indicate that aquifers yielding saline ground water occur at depths of less than 500 feet throughout much of the State (Feth and others, 1965).

The maps in this report are based on analysis of all hydrologic and chemical data available. In addition to data in files of the U.S. Geological Survey, geological and well data from the Ohio Water Plan Inventory maps and county water resources reports published by the Ohio Department of Natural Resources, Division of Water, were important sources of material. The work of Stout and others (1943) was helpful in identifying the aquifers penetrated by the deeper bedrock wells.

STANDARDS OF POTABILITY ds recommended by the Federal V

Standards recommended by the Federal Water Pollution Control Administration (1968, p. 18–20) for raw water to be used for drinking purposes are essentially the same as those recommended by the U.S. Public Health Service (1962) for drinking water subject to Federal regulation. Limits for constituents pertinent to this study are as follows:

Recommended limit (milligrams per liter)

Chloride															250
Iron															.3
Manganese															.05
Nitrate															
Sulfate															250
Dissolved solids															

Water has been further classified in terms of its dissolved solids content by the U.S. Geological Survey (Winslow and Kister, 1956) as follows:

Dissolved-solids content (milligrams per liter)

Fresh
Slightly saline
Moderately saline
Very saline
Brine

Many domestic wells in Ohio yield water with dissolved solids contents considerably in excess of the recommended limits for drinking water. Some of the waters are in the slightly saline category, based on the above classification. That people develop a tolerance for such water is evidenced by the fact that more than 100 public water supplies in the United States have a dissolved-solids content of 2,000 mg/l (milligrams per liter) or more (U.S. Public Health Service, 1962, p. 33). In Ohio, water containing up to 3,000 mg/l dissolved solids is used for domestic and public purposes in areas where highly mineralized ground water is the only source of adequate supply. Therefore, in compiling the map (sheet 1), the upper limit of potability of water was set at 3,000 mg/l dissolved solids.

PHYSICAL SETTING

The bedrocks of Ohio (fig. 1) are consolidated Paleozoic sediments which are essentially horizontal or gently dipping. Western Ohio is underlain by interbedded shales and limestones of Ordovician age and limestone and dolomite of Silurian age. The oldest rocks, of Ordovician age, are exposed in southwestern Ohio as a result of erosion along the top of the north-plunging Cincinnati arch. In the northwestern part of the State, Devonian limestones and Devonian and Mississippian shales dip gently northward toward the Michigan basin. Devonian limestones and shales in central Ohio are overlain progressively eastward by sandstone and shales ranging from Mississippian age in central Ohio to early Permian age in southeastern Ohio. The beds dip gently east and southeastward from the Cincinnati arch toward the Appalachian basin in Pennsylvania and West Virginia.

The bedrock terrane in Ohio has been significantly modified by continental glaciers which covered about two-thirds of the State (fig. 2) and left deposits of unconsolidated sediments throughout the glaciated region. Except for the featureless lake plains in the north, the glaciated part of Ohio is largely a flat to gently rolling surface of ground moraine marked by belts of more hilly end moraines. At their southernmost limits, the glaciers overrode and modified the northern part of the eroded Appalachian plateau. The bulk of the plateau, which includes the southeastern third of the State, is unglaciated and its thorough dissection by streams has made it the area of greatest local relief in the State.

PRINCIPAL SOURCES OF POTABLE WATER

The most productive aquifers in the State are of glacial origin. The dendritic patterns in figure 3 that show areas of highest yield represent permeable beds of sand and gravel outwash, which were deposited by the glaciers in the valleys of Ohio's major preglacial streams. These so-called watercourse aquifers yield three-fourths of the ground water used in the State (Norris, 1969, p. 27).

Outside the major watercourses, deposits of glacial till are considerably less productive, except where interbedded with deposits of sand or gravel. For example, in the northwest corner of the State, extensive sand and gravel layers within the glacial deposits provide high yields.

Many bedrock aquifers are used regionally or locally as important sources of ground water. The limestone and dolomites underlying the glacial till plain are the principal, and in some areas the only, sources of ground water in western Ohio. The aggregate thickness of the beds ranges from 200 feet or less in western Ohio to about 800 feet in the central part of the State. The more productive wells yield 250 to 500 gpm (gallons per minute) on a sustained basis (Norris, 1969, p. 31).

Bedrock aguifers in the eastern part of the State consist of elongated lenses of sandstone and shaly sandstone generally interbedded with shale. The sandstone aguifers are highly variable in their water-yielding properties. Where such aquifers are near the surface, permeability is high and wells are relatively productive. Sustained yields of 100 gpm or more are not uncommon from wells in such aquifers in northeastern Ohio. In areas far from the outcrop, on the other hand, especially where the sandstone is covered by a great thickness of shale, wells commonly yield only 1 or 2 gpm. Such low yields are common for wells in bedrock units in much of the unglaciated part of Ohio. In this region, three of the Pennsylvanian formations in which the base of potable water occurs have low water-yielding properties and are thus distinguished from other potable aquifers on sheet 1 by the line pattern. Locally, however, where these aquifers are recharged by infiltration from surface streams, yields to wells of 10 to 20 gpm are not uncommon.

APPROXIMATE BASE OF POTABLE WATER

The contour map of the base of potable water in Ohio (sheet 1) is based on chemical analyses of water in deep bedrock wells, and on the geology of the producing aquifer systems. Above the altitude shown by the contours, water of sufficient quantity and acceptable quality can be obtained from aquifers for domestic use. For the purpose of this study, a yield of 1 gpm from individual wells has been set as the arbitrary limit for sufficient quantity, and a dissolved-solids content of 3,000 mg/l has been set as the upper limit of acceptable quality.

The aquifer in which the base of potable water is believed to occur is named on the map, and the area of occurrence in that aquifer is outlined by heavy solid lines. The rock units used in preparing the map, and listed in table 1, comprise only a generalized stratigraphic section for the State. Because of the scale of mapping used, it was not practical to include in this study many other minor rock units which may actually contain the base of potable water in places. For this reason, the contours on sheet 1 represent the approximate base of potable water.

In some areas, such as in eastern Ohio where sandstone aquifers predominate, the base of potable water is at the contact of the aquifer with an underlying impermeable rock unit. In such areas, the contours on the map correspond to the estimated base of the aquifer. Elsewhere in the State, the base of potable water lies within a gradational zone in a sin-

gle aquifer between potable water above and saline water at depth. The factor controlling the location of this interface is usually a down-dip increase in dissolved solids, although local variations can occur, also. To this category belong the carbonate aquifer systems of western Ohio and the eastern (down-dip) margins of the sandstone aquifers.

(down-dip) margins of the sandstone aquifers.

In western Ohio, the limestone and dolomite aquifers of Silurian and Devonian ages are characterized by an irregular system of fractures and porous zones developed in part by preglacial weathering. Water in individual wells may come from various depths and the quality cannot always be predicted. Drilling records indicate that below the level the contours shown on the map for this area the ground water is highly mineralized and usually contains objectionable amounts of hydrogen sulfide.

In three areas of the State (shaded areas on sheet 1), the bedrocks yield little water to wells. These include an area in southwest Ohio underlain by alternating beds of limestone and shale of Ordovician age, an area in northwest Ohio underlain by Devonian and Mississippian shales, and a narrow band of Devonian and Mississippian shales that extends northward from south-central Ohio to Lake Erie and thence eastward along the lake. Although weathered and fractured zones in these rocks yield small quantities of water locally, water is generally available only from the overlying glacial deposits. The contact between the bedrock and the glacial deposits thus represents the base of potable water in the three areas. The contours shown on sheet 1 have been drawn on the bedrock surface as mapped by Cummins (1959).

Locations of representative wells are shown on sheet 1. The depths of the wells shown are not necessarily the same as the depth to the base of potable water, as some wells do not penetrate to the base of the potable zone.

GEOGRAPHIC DISTRIBUTION OF WATER TYPES Figure 4 shows the principal cations and anions in water near the base of the potable zone. In general, the most common anion is bicarbonate. Over most of the State calcium is the predominant cation although the cations are usually a

In western Ohio the prevalence of magnesium along with calcium can be attributed to the dolomitic Silurian aquifer systems in that region. Toward the north and east where the base of the potable zone is in or not far below limestones of Devonian age, the cations are dominated by calcium.

mixture of calcium, magnesium, and sodium.

Gypsiferous deposits that are common in the Bass Islands Dolomite of Silurian age probably account for the abundance of the sulfate ion at the base of the potable zone in several areas of northwestern Ohio (fig. 4). Local occurrences of sulfate in northeastern Ohio may have been de-

Coal deposits in eastern Ohio are a source of iron and sulfide minerals, and infiltrating sulfate solutions resulting from oxidation of these minerals have increased the mineralization of water locally in the sandstone aquifers of Pennsylvanian age, especially in areas affected by acid mine drainage.

rived from fragments of gypsum in glacial drift.

The Berea and Black Hand Sandstones in northeastern Ohio and the Black Hand Sandstone in southern Ohio are the only major aquifers in the State which yield potable water of the sodium chloride type. However, sodium and chloride are the predominant ions down-dip from the limit of potable water in the eastern half of the State. Bedrock aquifers of Silurian, Mississippian, and Early Pennsylvanian age that yield potable water in western, central, and east-central Ohio, respectively, are sources of commercial brine in east-

Figure 4 shows several areas (stippled pattern) where water at the base of the potable zone commonly contains concentrations of dissolved solids near the upper limit of potability and where, locally, differences of considerable magnitude in the dissolved solids content exist. For example, in suburban areas northwest of Columbus, in west-central Ohio, some residents are using water from limestone aquifers that contains as much as 3,000 mg/1 dissolved solids. Others in the same locality are more fortunate and obtain water from the same stratigraphic horizon that is only about one-third to one-half as highly mineralized.

Selected chemical analyses of water from near the base of the potable zone are given in table 2.

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