Table 5.--Ground-water conditions by township: Source, bedrock

Location: Letters in parenthesis designate township in well-numbering system

Location	Remarks
T. 24 N., R. 6 W. (A)	No production reported from bedrock.
T. 24 N., R. 5 W. (B)	Ground water is derived from bedrock in secs. 26, 27, and 33-35. (See pl. 3.) Depths to bedrock range from 40 to 210 feet in this area. (See pl. 10.) Of 7 bedrock wells drilled, 3 were reported to have yielded no water.
T. 24 N., R. 4 W. (C)	No production reported from bedrock.
T. 24 N., R. 3 W. (D)	Some ground water is derived from bedrock in secs. 8-11, 14-17, 20, and 21. (See pl. 3.) Of 4 wells drilled in this area, 3 produced "sulfur" water and 1 was reported to be a dry hole. Two oil wells were drilled in secs. 10 and 22. Well TcD 10-1 (1/) penetrated two zones of water-bearing limestone, from 80 to 212 feet and 540 to 565 feet; well TcD 22-1 (1/) penetrated 15 feet of water-bearing shale at 80 feet and two zones of water-bearing limestone at 225 and 975 feet.
T. 23 N., R. 6 W. (E)	No production reported from bedrock.
T. 23 N., R. 5 W. (F)	Ground water is derived from bedrock in the north-central part of the township. (See pl. 3.) The area is underlain by a bedrock high, an extension of the similar area in T. 24 N., R. 5 W. Wells are generally 50 to 320 feet deep. (2/) Of 7 bedrock wells recorded, 5 were drilled in shale and 2 in limestone. Of the 5 wells drilled in shale 2 reported no water and 3, small amounts of water. Wells in the limestone are reported to yield about 2 gpm.
T. 23 N., R. 4 W. (G)	No production reported from bedrock.
T. 23 N., R. 3 W. (H)	Most wells are in sand and gravel but a few have been drilled into bedrock. Two wells drilled in sec. 21 flowed. The bedrock surface is high beneath the east-central part of the township, which is an area of localized production from rock.
T. 22 N., R. 6 W. (I)	Ground water is derived from bedrock in the southern two-thirds of the township. (See pl. 3.) In the area of bedrock production, the unconsolidated material ranges in thickness from a thin veneer to 70 feet and averages 45 feet in thickness. The bedrock wells range from 50 to 116 feet in depth. Production is derived from shale, and yields as high as 10 gpm have been reported.
T. 22 N., R. 5 W. (J)	Ground water is derived from bedrock in the southern half of the township. (See pl. 3.) The general range in well depths is from 50 to about 130 feet. (2/) Of the 20 rock wells recorded, 9 are reported to be drilled in limestone, 7 in shale, and 4 in undifferentiated bedrock. The wells finished in shale yielded very small quantities of water. In at least one well, TcJ 25-2 (1/), the shale is reported to be non-water-bearing. Well TcJ 24-5 (1/) produced 8 gpm from shale with a drawdown of 40 feet. Yields up to 15 gpm with small drawdowns are possible from the limestone, as indicated by well TcJ 19-1.(2/) Well TcJ 14-2 flowed. "Sulfur" water is reported in one limestone well.
T. 22 N., R. 4 W. (K)	In this area the bedrock is an extension of that in T. 22 N., R. 5 W., and ground-water conditions are similar.
T. 22 N., R. 3 W. (L)	No production reported from bedrock.
T. 21 N., R. 6 W. (M)	Some ground water is derived from bedrock. The few wells recorded in rock are less than 80 feet deep.
T. 21 N., R. 5 W. (N)	Ground water is derived chiefly from bedrock. (See pl. 3.) The bedrock wells are generally from 68 to more than 100 feet in depth. (2/) Few data are available on yields of bedrock wells in this township. An indication of the quantity of ground water that can be produced from bedrock is given by well TcN 9-1, which yielded 12 gpm with 10 feet of drawdown. Yields from bedrock wells may differ from place to place.
T. 21 N., R. 4 W. (O)	Ground water is reported from bedrock in localized areas. (See pl. 3.) The bedrock wells are generally less than 110 feet deep. (2/) Production from the bedrock (shale and limestone) is small as indicated by well TcO 5-2 (1/), which yields 8 gpm with 10 feet of drawdown, and by well TcO 26-1, which yields 10 gpm with 15 feet of drawdown.
T. 21 N., R. 3 W. (P)	Ground water is produced from bedrock in three small areas. (See pl. 3.) The bedrock wells are 80 to 120 feet deep, and the production is from shale and limestone. The yields from limestone are greater than those from shale. Of three wells drilled in shale, one was reported to have no water. Two limestone wells drilled in sec. 33 yielded about 8 and 17 gpm, respectively.

1/ See table 3, Rosenshein and Cosner, 1956.
2/ See table 2, Rosenshein and Cosner, 1956.

Table 6.--Ground-water conditions in Tippecanoe County by township: Source, sand and gravel

Location: Letter in parenthesis designates township in well-numbering system.
Ground-water potential: (1) Quantities greater than 500 gpm possible; (2) quantities greater than 100 gpm possible; (3) quantities greater than 10 gpm possible; (4) quantities greater than 10 gpm may be possible; (5) quantities limited.

Location	Approximate thickness of unconsolidated material		Ground-water potential	Remarks
	Range	Average		
T. 24 N., R. 6 W. (A)	56-312	200	(4)	See pl. 3. Areas of thickest unconsolidated deposits may yield large quanties.
T. 24 N., R. 5 W. (B)	40-332	200	(3)	Wells are generally 40 to 190 feet deep. (1/) The shallower wells are in the eastern and western thirds of the township; the deeper wells in the central third of the township. (See pl. 3.) Larger yields possible locally in the areas of thicker unconsolidated deposits or by production from several water-bearing zones.
T. 24 N., R. 4 W. (C)	85-304	220	(2)	Wells are generally 40 to 142 feet deep. (1/) The shallower wells are in the southern part of the township. (See pl. 3.) Large yields possible in the township as indicated by the two 100-gpm wells at Battle Ground (p.27) and by the overall thickness of unconsolidated material. (See pl. 10.)
T. 24 N., R. 3 W. (D)	0-235	125	(3)	Wells are generally 40 to 101 feet deep. (See pl. 3.) As much as 20 feet of saturated material is reported. Thick deposits of water-bearing material are probably present locally. The yields of five sand and gravel wells range from 8 to 12 gpm. (2/) Two of the wells have drawdowns of 5 to 6 feet.
T. 23 N., R. 6 W. (E)	121-420	275	(3)	Wells are generally 55 to more than 200 feet deep. (1/) Shallower wells are in the northeastern third of the township. (See pl. 3.) Well depth and the depth to water increase toward the edge of the upland, where the surface is deeply eroded by the Wabash River and Indian Creek. Wells drilled in bottom lands of the rivers are shallower than those drilled on the upland. At well TcE 34-1 (2/) the deeper unconsolidated material has more than 33 feet of saturated sand and gravel. Thick deposits of water-bearing sands and gravels are present also in the area of shallower production.
T. 23 N., R. 5 W. (F)	30-376	190	(2)	Wells are generally 40 to 265 feet deep. (1/) Shallower wells are drilled in the northwestern part and southern third of the township. (See pl. 3.) The deeper wells are drilled into subunit 5a, which is partly dissected by the Wabash River. Sand and gravel deposits of subunit 5a crop out along the Wabash River terrace scarps. (See pl. 6.) Where this subunit is breached by the Wabash River, the upper deposits are drained of ground water, resulting in progressively deeper water levels toward the valley walls. Yields from sand and gravel wells range from 7 to 300 gpm. The production is from several different water-bearing units, of which two are partly mapped, subunit 5a and subunit 5b.
T. 23 N., R. 4 W. (G)	109-305	190	(1)	Wells are 28 to more than 260 feet deep. (1/) Many of the deeper wells and deeper water levels occur along the terraces of the Wabash River and its tributaries. (See pl. 3.) Ground-water production comes from parts of units 2, 4, and 5. (See pls. 5 and 6.) Ground water occurs under both water-table and artesian conditions. (See table 4.) Locally more than one unit is present. Well logs record as much as 78 feet of saturated material. Well yields range from 5 to 1,400 gpm. The largest yielding wells are the industrial and public-supply wells in the Lafayette and West Lafayette areas. (See fig. 5 for areal distribution of pumpage.) Yields of domestic wells range from 5 to 10 gpm. Of 28 domestic and stock wells the yields of 24 are reported to be greater than 8 gpm, with drawdowns ranging from less than 1 foot to as much as 3 feet. The yields of 34 industrial and public-supply wells, 6 inches in diameter or larger, range from 90 to 1,400 gpm; 21 of them yielded 500 gpm or more.

1/ See Table 2, Rosenshein and Cosner, 1956.
2/ See Table 3, Rosenshein and Cosner, 1956.

Table 6--Ground-water conditions in Tippecanoe County by township: Source, sand and gravel--Continued

Location	Approximate thickness of unconsolidated material		Ground-water potential	Remarks
	Range	Average		
T. 23 N., R. 3 W. (H)	80-285	195	(2)	Wells are generally 32 to 169 feet deep. (1/) Production is from units 2, 3(?), and 4. (See pls. 5 and 6 and table 4.) Deeper wells are drilled into units 3(?) and 4. Flowing wells are present in parts of secs. 21, 28, and 33. The yields of these wells range from 48 to 240 gpm. The yields of nonflowing domestic and stock wells range from 8 to 60 gpm. Probably larger quantities of ground water can be obtained for irrigation and industrial use from the thicker parts of the several units in the area or by utilizing the production from more than one of the units.
T. 22 N., R. 6 W. (I)	0-158	55	(3)	Locally the unconsolidated material is at least 158 feet thick. The northern third of the township is an area of potential production from sand and gravel. (See pl. 3.)
T. 22 N., R. 5 W. (J)	20-315	115	(3)	Wells are 40 to 170 feet deep. (1/) The deeper wells are in the northeastern part of the township. In that area the yields of 4 wells ranged from 7 to 10 gpm with small drawdowns. More than 67 feet of water-bearing material is recorded in well TcJ 1-1. (2/) In the northern part of the township, the unconsolidated material is 115 to 315 feet thick and averages 210 feet. The range and distribution of well depths indicates that water-bearing material occurs in both shallow and deep unconsolidated deposits. In the central and eastern parts of the township the bedrock has been deeply eroded. (See pl. 10.) These areas are places of potential production from sand and gravel. Some production is obtained from shallow unconsolidated material along the eastern edge of the township.
T. 22 N., R. 4 W. (K)	20-337	200	(2)	Wells are from 32 to 194 feet deep. (1/) Of 55 wells drilled in unconsolidated material, 42 are less than 100 feet deep. (See pl. 3.) The deeper wells are generally in areas, where the shallower water-bearing units are either not very productive or absent. Well yields range from 8 to 240 gpm. The yields from domestic and stock wells range from 8 to 15 gpm, and very small drawdowns are reported. Only the upper 100 feet of the thick unconsolidated material is penetrated by wells. The deeper zones of unconsolidated material are potential sources of production from sand and gravel. Production of large quantities of ground water may be possible locally from the thicker zones.
T. 22 N., R. 3 W. (L)	199-340	250	(3)	Wells range from 26 to 196 feet in depth. Of 51 drilled wells 39 are less than 100 feet deep. Deeper wells are in two small areas along the northern and eastern part of the township (See pl. 3.) and are producing from units 3(?) and 4. Most production is from the two shallower water-bearing units, 1 and 2. Well yields range from 6 to 15 gpm and very small drawdowns are reported. Locally the water-bearing sand and gravel is 30 feet thick.
T. 21 N., R. 6 W. (M)	25-114	55	(5)	Parts of secs. 26, 27, 34, and 35 are areas of potential production from sand and gravel. (See pl. 3.)
T. 21 N., R. 5 W. (N)	44-108	60	(5)	See pl. 3.
T. 21 N., R. 4 W. (O)	45-370	210	(3)	Wells range generally from 43 to about 150 feet in depth. (1/) Most of the wells are less than 100 feet deep. (See pl. 3.) Saturated material, as thick as 99 feet, is reported in well logs. A deep trough is eroded into the bedrock surface in the central part of the area. Wells are drilled only into the upper parts of the unconsolidated material in this deep trough.
T. 21 N., R. 3 W. (P)	80-399	265	(2)	Wells range generally in depth from 28 to about 200 feet. (1/) Most of the wells are more than 50 and less than 100 feet deep. The deeper wells are in isolated areas (pl. 3) and shallower production is possible locally. The yields from 12 small-diameter wells range from 4 to 10 gpm. Yields greater than 8 gpm are reported in 9 of these 12 wells. Two larger diameter wells in Clarks Hill yielded 150 and 100 gpm, respectively. The range in well depths indicates that the unconsolidated material has several shallow and deep water-bearing zones. Locally as much as 30 feet of saturated sand and gravel is reported in wells.

1/ See Table 2, Rosenshein and Cosner, 1956.
2/ See Table 3, Rosenshein and Cosner, 1956.

industrial and public water supplies. The estimated use on farms and by farm and rural nonfarm establishments was obtained by evaluating the characteristics of the farm and rural nonfarm dwellings listed by the U. S. Census. The following factors were taken into consideration: (1) the number of occupied dwellings; (2) median number of persons per dwelling; (3) method of distribution of water supply; (4) toilet facilities; and (5) bathing facilities. The record of public supply pumpage is shown in table 8. Figure 5 shows the distribution and average daily public water supply and industrial pumpage in the Lafayette-West Lafayette area. This area uses the largest amount of ground water of any in Tippecanoe County.

Table 7.--Estimated per capita use of ground water in Tippecanoe County

Population area	Usage (gpd/person)
Urban (nonindustrial).....................................	75
a) Lafayette (public-supply pumpage, total)........	115
b) Lafayette (public-supply pumpage, nonindustrial)	75
Rural nonfarm (including towns having waterworks).........	50
Rural nonfarm (not including towns having waterworks)....	30
Rural farm...	25

MUNICIPAL WATER SUPPLIES

Four municipalities in Tippecanoe County use drilled wells to obtain ground water from unconsolidated material for water supply.

Battle Ground

A public water supply was established at Battle Ground in 1927. Water is obtained from two wells drilled into sand and gravel which are reported to be 85 feet deep. Each well is equipped with a 20-horsepower electric pump. The reported capacity of each pump is about 200 gpm, or 288,000 gpd, which is the estimated capacity of the treatment plant. The waterworks has one 40,000-gallon elevated storage tank. The population served by the plant increased from 448 in 1931 to about 634 in 1954. The estimated annual pumpage (table 8) increased during this period from 10 million gallons to 22 million gallons.

Clarks Hill

A public water supply was established at Clarks Hill about 1938. Originally, water was obtained from an 8-inch well 90 feet deep. In August 1954 another well 6 inches in diameter and 90 feet deep was drilled. Both wells are producing water from sand and gravel. Each well is equipped with a 100 gpm electric pump and the capacity of the treatment plant is reported to be 108,000 gallons per day. The waterworks has one 60,000-gallon elevated storage tank, 128 feet tall. The population served by the plant increased from about 432 in 1944 to 498 in 1954, with a corresponding increase in pumpage. (See table 8.)

Table 8.--Reported annual pumpage of municipal waterworks in Tippecanoe County, in millions of gallons

Year	Battle Ground	Clarks Hill	Lafayette	West Lafayette
1914	....	....	....	320.6
1915	....	....	....	371.3
1916	....	....	1,280.3	230.7
1917	....	....	1,353.3	238.3
1918	....	....	1,373.8	257.2
1919	....	....	1,347.4	267.0
1920	....	....	1,323.4	315.7
1921	....	....	1,266.5	305.2
1922	....	....	1,257.7	300.8
1923	....	....	1,326.5	332.3
1924	....	....	1,289.1	305.1
1925	....	....	1,066.3	367.8
1926	....	....	1,005.3	412.7
1927	....	....	1,056.4	435.5
1928	....	....	1,106.5	520.5
1929	....	....	1,115.1	817.5
1930	....	....	1,162.7	522.4
1931	e10	....	1,140.3	403.0
1932	e10	....	1,129.6	275.8
1933	e10	....	1,242.0	442.1
1934	e10	....	1,333.4	296.3
1935	e10	....	1,128.4	213.7
1936	e10	....	856.7	279.4
1937	e10	....	759.8	341.8
1938	e13	....	767.5	165.9
1939	e13	....	831.8	222.7
1940	e13	....	956.1	220.9
1941	e13	....	1,076.5	218.1
1942	e13	....	1,993.2	191.6
1943	....	....	1,040.5	197.9
1944	....	e7	1,057.5	212.9
1945	....	e7	1,118.7	202.1
1946	....	e8	1,298.8	245.0
1947	e17	e8	1,225.6	342.8
1948	e22	e8	1,234.7	320.2
1949	e22	e8	1,281.8	332.7
1950	e22	e8	1,274.8	335.1
1951	e22	e8	1,398.7	260.6
1952	e22	e8	1,187.2	360.9
1953	e22	e8	1,390.7	375.3
1954	e22	e8	1,386.2	323.7

e - estimated.

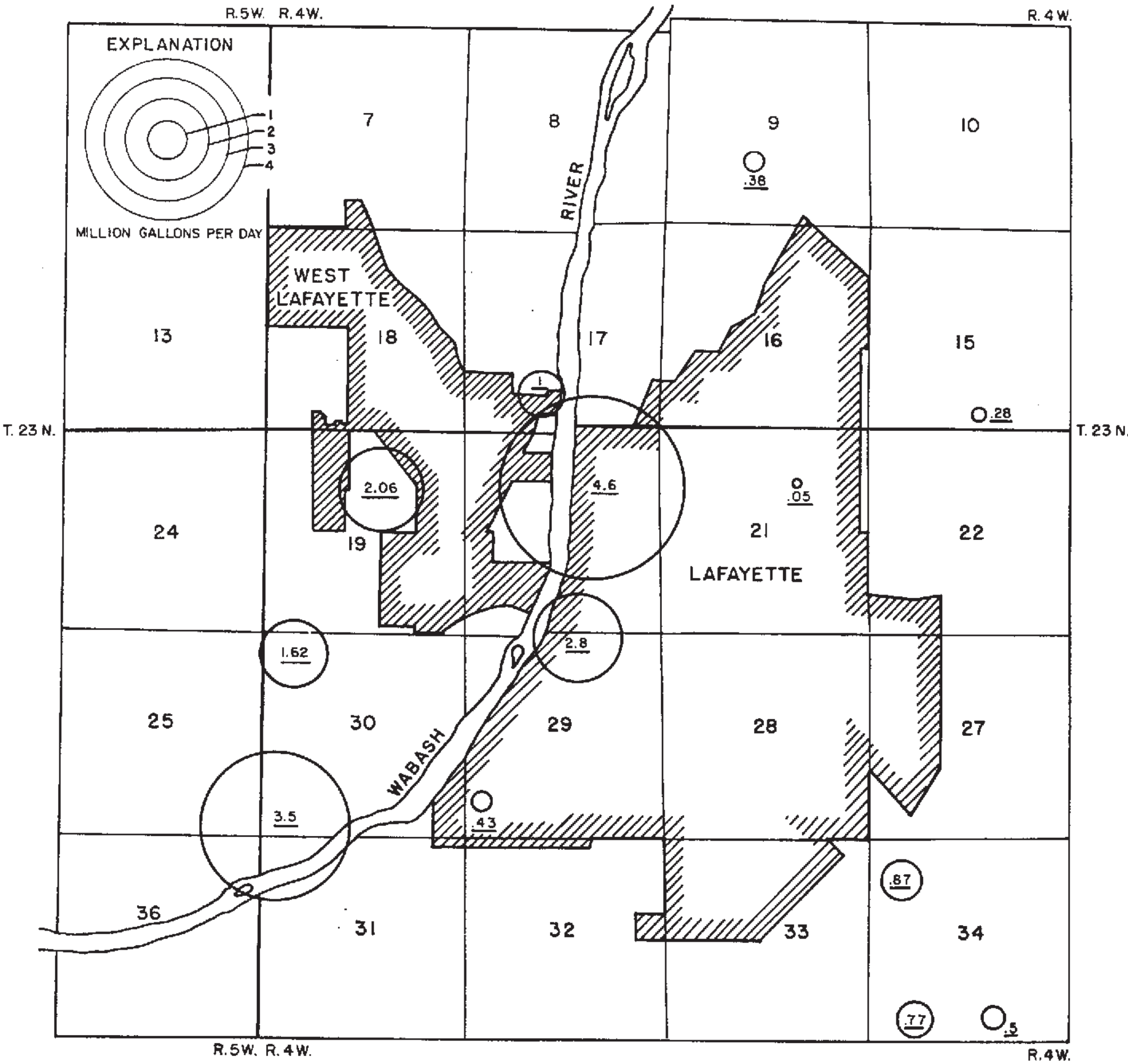

FIGURE 5.- DISTRIBUTION OF PUMPING AND AVERAGE PUMPAGE, IN MILLION GALLONS PER DAY, FROM PUBLIC-SUPPLY AND INDUSTRIAL WELLS IN THE LAFAYETTE-WEST LAFAYETTE AREA, INDIANA.

Lafayette

Ground water is obtained at Lafayette from fourteen 12-inch wells and one 16-inch well drilled in the sand and gravel of subunit 5b. All the wells are reported to be about 100 feet deep and the pumps are chiefly electric powered. The plant has a lined surface reservoir and a standpipe. The surface reservoir has a capacity of 4.9 million gallons. The number of service connections increased from 6,071 in 1916 to 10,397 in 1954. The reported annual pumpage (table 8) increased during this period from 1,280 million gallons to 1,386 million gallons.

West Lafayette

In 1914 the West Lafayette waterworks had 14 wells of which 5 were 12 inches in diameter and 9 were 9 inches in diameter. By 1937 the number of wells had increased to 21. During much of this period water was supplied to Purdue University, which now has its own ground-water supply. In 1954 water for West Lafayette was obtained from three 12-inch wells and a 16-inch well drilled into the sand and gravel of subunit 5b. The wells range in depth from 117 to 128 feet. The plant has one standpipe which has a capacity of 330,000 gallons. The number of connections increased from a reported 967 in 1914 to about 2,600 in 1954. The reported annual pumpage (table 8) increased during this period from 320 million gallons to 324 million gallons.

RECOVERY OF GROUND WATER

PRINCIPLES OF RECOVERY

The pumping of a well causes the water level in the well and in the aquifer in the vicinity of the well to be lowered. As the water level is drawn down, the water surface in the aquifer slopes toward the well and a cone of depression is formed with the vertex at the well.

At the start of pumping the water level in the well is drawn down rapidly. The rate of drawdown decreases as the volume of the aquifer affected by pumping increases and a larger part of the aquifer contributes water from storage. The water level will continue to decline in the aquifer and in the well until a quantity of water equal to the pumpage is added to the aquifer by an increase in recharge or the interception of natural discharge.

The rate of drawdown in a pumped well depends upon the pumping rate, the physical characteristics of the formation, and the construction of the well. The shape of the cone of depression in an aquifer is determined by the rate of pumping and the physical characteristics of the aquifer. In an aquifer under water-table conditions, the cone of depression spreads slowly and the rate of drawdown is relatively slow because of the large release of water from storage as the water-table aquifer is unwatered. In an aquifer under artesian conditions, the cone of depression spreads rapidly and the rate of drawdown is fast during the first few minutes of pumping, because the pressure in the aquifer is reduced at the point of pumping. The water derived from the artesian aquifer is not obtained by unwatering of the aquifer, but by the compaction of the aquifer and its associated beds and from the expansion of water which was compressed in the aquifer.

TYPES OF WELLS

Wells are the chief source of water for domestic, stock, public, and industrial supplies in Tippecanoe County. The wells range in diameter from 2 inches to 13 feet and are constructed by a number of different methods.

Dug wells, drilled wells, and driven wells are used in Tippecanoe County. The oldest wells in the county are dug wells. The dug wells were constructed by excavating a large hole, usually 3 feet or more in diameter, to the water-bearing zone and as far as possible into it. The sides of the well are cribbed or tiled to prevent caving. The dug well is the most effective type of well in tight material of small permeability, such as clayey till. The large diameter provides a large surface area of water-bearing material from which water can seep into the well. Furthermore, the large well acts as a reservoir for water during nonpumping periods. A principal disadvantage of the dug well lies in the difficulty of keeping the well free from surface contamination. Under prolonged drought conditions the dug well may go dry as the water surface declines below the bottom of the well; thus water supplies from dug wells are unreliable because of the shallow depth of well penetration into the water-bearing material. Also the dug well tends to become silted. Most dug wells in Tippecanoe County are used to water livestock.

Wells that are 4 inches in diameter and larger have been drilled in the county by the cable-tool (percussion) method. The cable-tool rig is mounted on the back of a truck or a trailer, and either a separate engine on the truck or a gasoline engine on the trailer provides the power for drilling. The method consists of a combination of drilling, driving, and bailing. After the well is started the casing is driven a short distance into the ground, and the hole is cleaned by bailing. When necessary, water is added to the hole to facilitate the drilling and bailing process. If coarse granular material, compacted clay, or rock are encountered, a percussion bit must be used to penetrate the deposits. The drill cuttings are then removed from the hole by a bailer. Generally the bailer consists of a hollow tube with a hinged flap valve at the bottom.

Most drillers operating in Tippecanoe County case the well throughout the full length of the hole where drilling in unconsolidated material. If it is necessary to drill consolidated rock, the casing is driven a few inches or a few feet into rock in order to set the casing. The rest of the hole is drilled as an uncased open hole in the rock. Usually black or galvanized steel pipe is used as casing.

After a well has penetrated to or into unconsolidated water-bearing material, the well may be finished with a screen or simply with an open end. (See Rosenshein and Cosner, 1956, p. 5 for a detailed description of a well screen.) The purpose of the screen is to keep the water-bearing material out of the well and at the same time allow the water to move into the well. The grain size of the water-bearing material determines the slot size of the screen that is selected. The screen is lowered into the hole, and the casing is pulled back from the hole either by means of jacks or by jarring tools, until all the screen is exposed to water-bearing formation. Usually, a lead fitting called a packer or a turned coupling has been attached to the upper end of the screen prior to lowering the screen into the well. If a packer is used, it is flanged out by a tool called a swage. The flanged packer seals the upper end of the screen tightly against the casing.

Some wells are finished as open-end holes, if the water-bearing material is sufficiently angular and compact and does not flow or heave into the bottom of the hole. In Tippecanoe County, most existing flowing artesian wells are finished with an open end.

A well finished with a screen in sand and gravel is usually developed by surging and pumping. The purpose of this process is to remove the finer material in the aquifer from the area immediately around the well screen. The length of time the driller spends in developing a well depends upon the characteristics of the water-bearing material, the size of the well, and the desired yield. Proper well development decreases the drawdown in the well by increasing the permeability of the aquifer near the well, helps prevent clogging of the screen, and decreases wear on the pump by decreasing the amount of fine material pumped into the well.

The drilled well has a number of advantages over the dug well. Drilled wells make use of deeper water-bearing zones, are faster and more economical to construct for a given yield, are much less susceptible to surface contamination, and under favorable conditions can be developed to yield much larger and more reliable supplies of ground water.

The gravel-packed well and the collector are two special types of wells used by some industries in Tippecanoe County. A gravel-packed well is a modification of the tubular well. An oversized hole is drilled into the water-bearing material and a smaller diameter casing with a screen is set inside the outer casing. Then a lining of clean gravel is poured around the screen, resulting in a gravel envelope between the screen and the water-bearing material. The collector is a large well or caisson 13 feet or more in diameter. The large diameter casing is sunk into the water-bearing material, and slotted pipe is forced out laterally into the water-bearing deposits by hydraulic jacks. A number of radially arranged horizontal pipes extend out into the material from one or more levels.

A few driven wells are used in the county where unconsolidated water-bearing material lies close to the surface. Such a well is constructed by driving a small-diameter pipe having a drive point attached to the end. Some 2-inch wells have been drilled by the hollow-rod (hydraulic) jetting method. Water is forced under pressure out of a hollow rod that is fitted with a jetting bit. As the material is washed out of the hole ahead of the casing, the casing sinks down into the hole. Jetted wells and driven wells are not installed in areas where water-bearing zones are deep, and where there is a predominance of very coarse granular material such as boulders, in consolidated rock, or in the case of jetted wells, where there are great thicknesses of unsaturated permeable material.

QUALITY OF GROUND WATER

All ground water contains dissolved minerals. The dissolved-mineral content of ground water is related to the materials through which the water flows, the length of time it is in contact with the materials, and the temperature and pressure. Much of the material deposited by the glaciers in Tippecanoe County was derived from sedimentary rocks containing calcium carbonate. The ground water obtained from the glacial deposits contains relatively large amounts of calcium bicarbonate and is hard.

Two important chemical properties of ground water are its hardness and the iron content. Hardness is a property which is readily recognized. Hard water increases the amount of soap needed to make a lather, causes scale in boilers and hot water heaters, and leaves curdy films on materials washed in the water. The two kinds of hardness are carbonate and non-carbonate hardness. Carbonate hardness is usually caused by the calcium and magnesium equivalent to the bicarbonate in the water. The remainder of the hardness is noncarbonate hardness and is caused by the sulfate, chlorides, and nitrates of calcium and magnesium. Water having a hardness of more than 200 parts per million is generally considered hard. An iron content of more than 0.3 part per million is ordinarily objectionable in water for domestic and many industrial uses. A higher concentration of iron in water tends to stain clothes, fixtures, and cooking utensils. Water containing iron in larger quantities has an objectionable taste. Most of the ground-water samples whose analyses are given in table 9 contain substantial amounts of iron.

The ground waters of Tippecanoe County are very hard. Table 9 shows the chemical analysis of water samples from a number of wells. One analysis is of highly mineralized water from bedrock which is not typical of potable water from that source; and the others are of water from unconsolidated material. Of the analyses of water from unconsolidated material one is from subunit 5a, six from subunit 5b, and the rest from undifferentiated sand and gravel deposits.

SUMMARY

The sand and gravel deposits within the glacial drift are the most important sources of ground water in Tippecanoe County. The deposits form a single but complex hydrologic system. Five water-bearing sand and gravel units are mapped in parts of the county. Most of the wells furnishing water for domestic purposes are drilled into these sand and gravel deposits. In most parts of the county, the deposits are potentially sources of larger quantities of ground water than are presently withdrawn. Locally, wells have yielded as much as 1,000 gpm. In the southwestern part of the county, the sand and gravel deposits are thin and ground water is obtained principally from bedrock. The bedrock yields small quantities of water and is generally an unreliable source of ground water.

In many parts of the county detailed information is lacking about the subsurface geology, hydrology, and chemical quality of the ground water. In many areas only the upper part of the drift has been penetrated by wells, and the deeper part of the drift may be a source of water for future development. Additional geologic and hydrologic data are needed for a better understanding of the ground-water conditions in these areas and to permit quantitative evaluation of the ground-water resources in Tippecanoe County.

Table 9.--Analyses of water from wells in Tippecanoe County, Ind.

(in parts per million, except pH)

Aquifer: Gr, gravel; Ls, limestone; Sd, sand; 5A and 5B subunit numbers (See text.)

Well No.	Location	Aquifer	Date of collection	Temperature (°)F	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and Potassium (Na K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$ Total	Hardness as $CaCO_3$ Noncarbonate	pH	Remarks
TcF 36-11	NW¼SE¼NW¼ sec. 36 T. 23 N., R. 5 W.	5b	5-15-52	---	12	.35	---	---	---	309	60	6	---	---	434	398	89	6.9	a/ Taken after 22 hrs. pumping.
Do----	do--------	5b	5-16-52	---	12	.35	---	---	---	301	52	6	---	---	429	396	95	6.8	a/ Taken after 55 hrs. pumping.
TcG 19-11	NW¼SW¼NW¼ sec. 19 T. 23 N., R. 4 W.	5a	2- 5-48	---	12	.2	---	---	---	---	---	4	---	---	---	342	80	7.3	b/
TcG 20-1	SW¼SW¼SE¼ sec. 20 T. 23 N., R. 4 W.	Ls	4-25-1858	55-56	8	---	382	131	2160	---	678	3800	---	---	7294	---	---	---	c/
TcG 22-3	SW¼ NE¼ sec. 22 T. 23 N., R. 4 W.	Sd, Gr	8-23-53	55	13	2.8	89	33	5.9+1.5	412	30	2	.2	.2	373	356	20	7.7	h/ From well no. 18 at Brown Rubber Co.
TcG 30-17	NW¼SW¼SE¼ sec. 30 T. 23 N., R. 4 W.	5b	9-12-54	54	10	.85	---	---	---	289	88	12	---	---	444	404	115	6.7	d/
TcG 31-12	NE¼NW¼NW¼ sec. 31 T. 23 N., R. 4 W.	5b	8- 1-52	52.5	16	.3	---	---	---	350	102	2	---	---	458	470	120	7.1	d/ Taken after 24 hrs. pumping.
Do----	do--------	5b	8- 3-52	54	16	.3	---	---	---	343	100	2	---	---	495	448	105	7.2	d/
TcK 4-2	SE¼SE¼ sec. 31 T. 22 N., R. 4 W.	Sd, Gr	5-17-30	---	4	---	77	35	---	---	---	19	---	---	334	---	---	---	e/
TcP 23-1	NW¼NE¼SW¼ sec. 23 T. 21 N., R. 3 W.	Gr	2-17-50	---	---	2.5	---	---	---	---	---	7	---	---	---	288	---	7.6	f/
---	NW¼SE¼ sec. 23 T. 24 N., R. 3 W.	Sd, Gr	10-26-49	---	---	1.6	---	---	---	---	---	9	---	---	---	272	---	8.3	f/ From unidentified well at Battle Ground Waterworks.
---	SE¼SE¼ sec. 17 T. 23 N., R. 4 W.	5b	3-31-52	53	12	.05	102	36	13+3.6	376	96	20	.2	11	496	402	94	7.1	g/ Public Supply of Lafayette.

a/ Analysis by Harvey Wilke, Purdue University
b/ Analysis by Frederick G. Atkinson, Inc.
c/ Analysis by Dr. Charles M. Wetherill (Gorby, 1886, p. 70)
d/ Analysis by Charles W. Gates, Lafayette, Ind.
e/ Analysis by C. B. Hall, chemist, C. C. C. & St. Louis R. R.
f/ 1952, Data on Indiana public water supplies, Indiana State Board of Health, Bull. S. E. 10.
g/ Lohr, Brown, and Lamar, 1953, p. 41
h/ Analysis by U. S. Geological Survey

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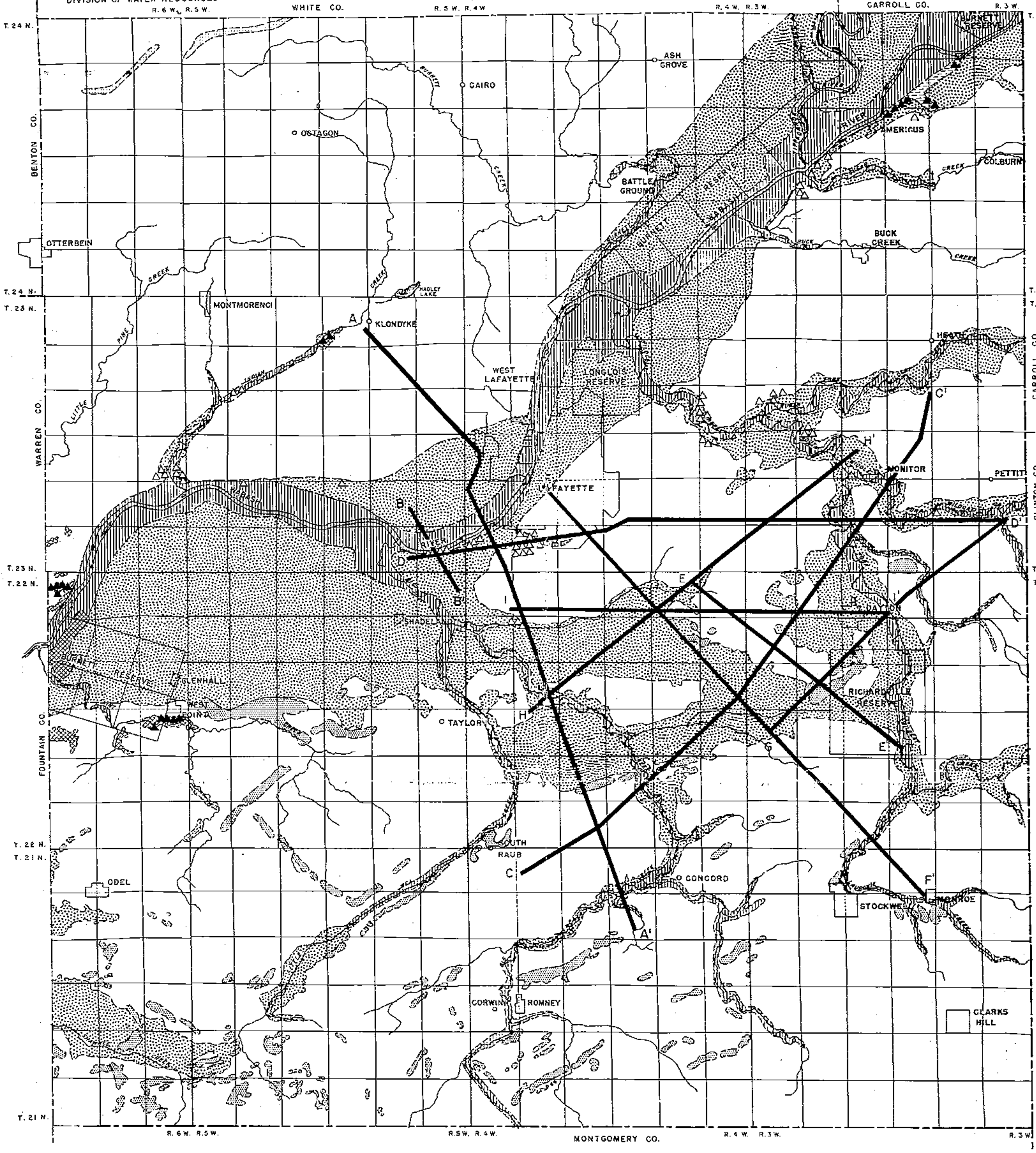
INDEX

STATE OF INDIANA
INDIANA DEPARTMENT OF CONSERVATION
DIVISION OF WATER RESOURCES

PREPARED BY THE
UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

PLATE I



SURFACE GEOLOGY
OF
TIPPECANOE COUNTY, INDIANA

0 1 2 3 4 5 6 MILES
0 5000 10000 15000 20000 FEET

COMPILED BY J. S. ROSENSHEIN

1958

EXPLANATION

QUATERNARY

RECENT

SAND-RIDGE DEPOSITS

ALLUVIUM

PLEISTOCENE

GLACIOFLUVIAL DEPOSITS

GROUND MORAINE; CHIEFLY WISCONSIN TILL

MORAINAL-RIDGE DEPOSITS PARTLY STRATIFIED CLAY, SAND, AND GRAVEL.

MISSISSIPPIAN

SILTSTONE, SHALE AND LIMESTONE

DEVONIAN

SHALE

A —— A'

LINE OF CROSS SECTIONS SHOWN ON PLATE 7 - 9

Δ

OUTCROPS OF PLEISTOCENE SANDSTONE AND CONGLOMERATE

▲

OUTCROPS OF BEDROCK

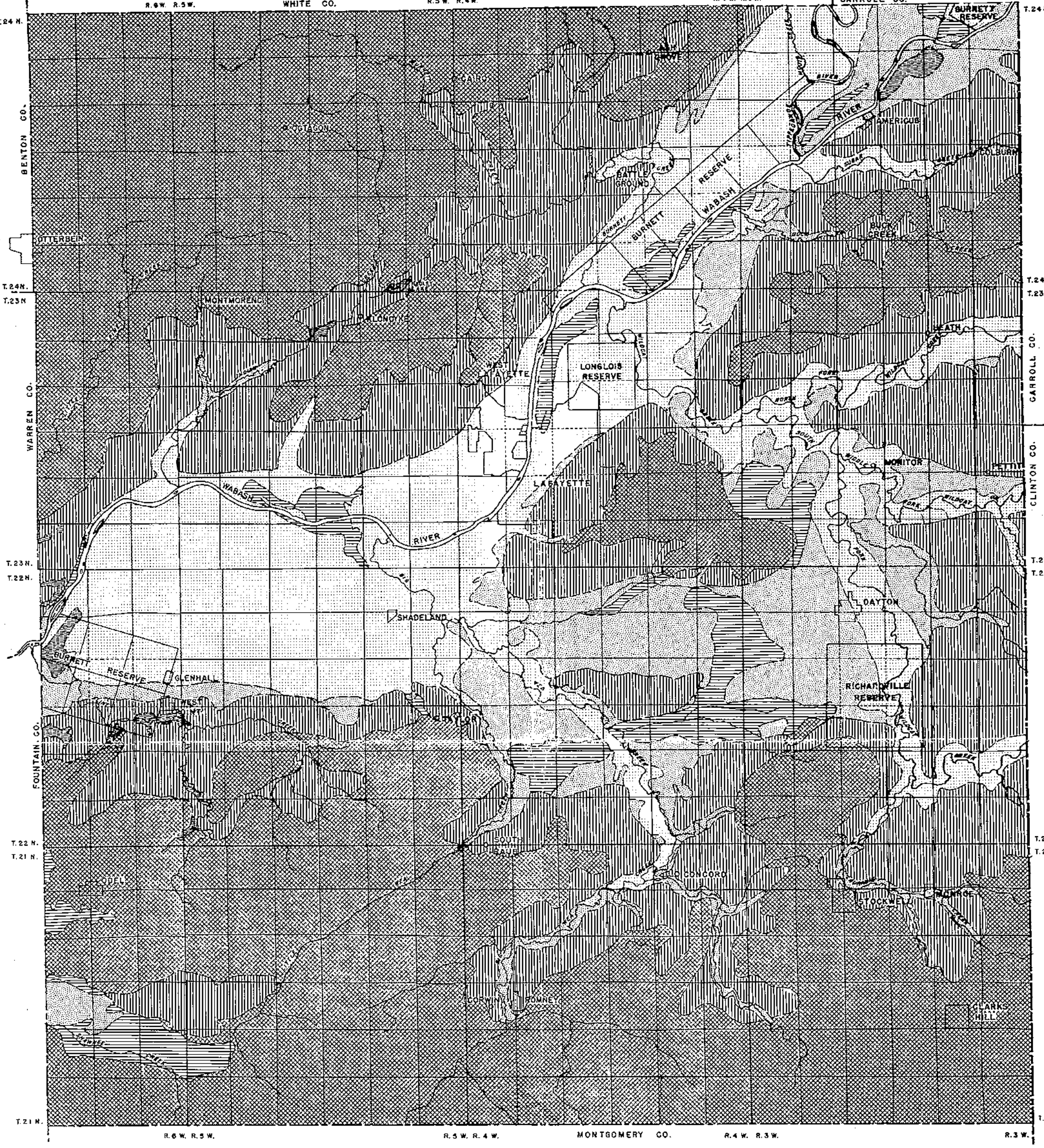
BASE MODIFIED FROM INDIANA DEPARTMENT OF CONSERVATION, GEOLOGICAL SURVEY BASE MAP OF TIPPECANOE COUNTY, INDIANA, MAY 1, 1952

SURFACE GEOLOGY COMPILED FROM UNPUBLISHED SOILS MAP, AIR PHOTOGRAPHS AND RECONNAISSANCE GEOLOGIC SURVEY.

STATE OF INDIANA
INDIANA DEPARTMENT OF CONSERVATION
DIVISION OF WATER RESOURCES

PREPARED BY THE
UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

PLATE 2



FAVORABLE FOR RECHARGE: SOIL, SANDY GRAVELLY LOAM TO LOAM; SUBSURFACE MATERIALS, WATER-LAID SAND AND GRAVEL AND SOME CLAY, LYING CLOSE TO SURFACE.

MODERATELY FAVORABLE FOR RECHARGE: SOIL, SILTY LOAM; SUBSURFACE MATERIALS, WATER-LAID SAND AND GRAVEL AND SOME CLAY, LYING CLOSE TO SURFACE.

SOMEWHAT FAVORABLE FOR RECHARGE: SOIL, SILTY CLAY LOAM; SUBSURFACE MATERIALS, WATER-LAID SAND AND GRAVEL AND SOME CLAYS, LYING CLOSE TO SURFACE.

MODERATELY UNFAVORABLE FOR RECHARGE: SOIL, SILTY LOAM; SUBSURFACE MATERIALS, CHIEFLY TILL.

UNFAVORABLE FOR RECHARGE: SOIL, SILTY CLAY LOAM; SUBSURFACE MATERIALS, CHIEFLY TILL.

UNFAVORABLE FOR RECHARGE: SOIL, SILTY CLAY LOAM; SUBSURFACE MATERIALS SHALLOW BEDROCK.

BASE MODIFIED FROM INDIANA DEPARTMENT OF CONSERVATION, GEOLOGICAL SURVEY BASE MAP OF TIPPECANOE COUNTY, INDIANA, MAY 1, 1952

MAP OF
TIPPECANOE COUNTY, INDIANA
SHOWING
SURFACE AND NEAR-SURFACE CONDITIONS AFFECTING GROUND-WATER RECHARGE

0 1 2 3 4 5 6 MILES
0 5000 10000 15000 20000 FEET

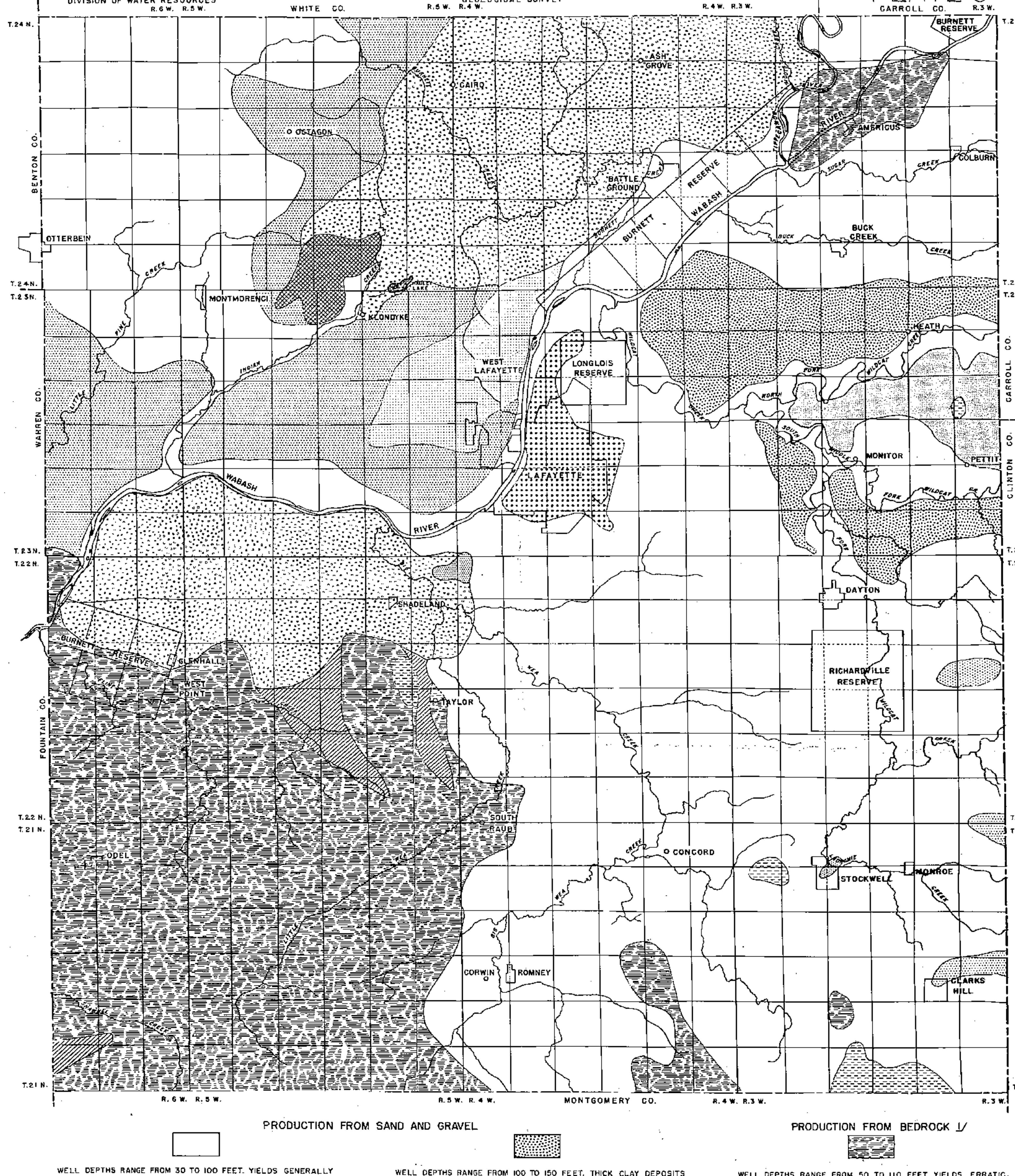
BASED UPON UNPUBLISHED SOILS MAP OF TIPPECANOE COUNTY, INDIANA, PREPARED BY PURDUE UNIVERSITY AGRICULTURAL EXPERIMENTAL STATION AND SURFACE AND SUBSURFACE INFORMATION.

COMPILED BY J. S. ROSENSHEIN
1958

STATE OF INDIANA
INDIANA DEPARTMENT OF CONSERVATION
DIVISION OF WATER RESOURCES

PREPARED BY THE
UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

PLATE 3



PRODUCTION FROM SAND AND GRAVEL

WELL DEPTHS RANGE FROM 30 TO 100 FEET. YIELDS GENERALLY MORE THAN ADEQUATE FOR DOMESTIC USE. LARGER YIELDS POSSIBLE.

WELL DEPTHS RANGE FROM 70 TO 145 FEET. YIELDS GENERALLY MORE THAN ADEQUATE FOR DOMESTIC USE. LARGER YIELDS MAY BE POSSIBLE LOCALLY.

WELL DEPTHS RANGE FROM 110 TO 200 FEET, THE SHALLOWER WELLS BEING ON WESTERN EDGE. AREA OF INDUSTRIAL PUMPAGE AND LARGE YIELDS.

WELL DEPTHS RANGE FROM 100 TO 150 FEET. YIELDS MORE THAN ADEQUATE FOR DOMESTIC USE. MODERATELY LARGE YIELDS POSSIBLE LOCALLY.

WELL DEPTHS RANGE FROM 100 TO 150 FEET. THICK CLAY DEPOSITS OCCUR LOCALLY. YIELDS GENERALLY MORE THAN ADEQUATE FOR DOMESTIC USE. LARGER YIELDS MAY BE POSSIBLE.

WELL DEPTHS RANGE FROM 150 TO 200 FEET. SHALLOWER PRODUCTION MAY BE POSSIBLE. YIELDS GENERALLY MORE THAN ADEQUATE FOR DOMESTIC USE. LARGER YIELDS POSSIBLE LOCALLY.

WELL DEPTHS RANGE FROM 200 TO MORE THAN 260 FEET. YIELDS GENERALLY MORE THAN ADEQUATE FOR DOMESTIC USE. LARGER YIELDING WELLS PRESENT ALONG EASTERN EDGE.

UNDEVELOPED AREAS OF POTENTIAL PRODUCTION FROM SAND AND GRAVEL.

PRODUCTION FROM BEDROCK 1/

WELL DEPTHS RANGE FROM 50 TO 110 FEET. YIELDS ERRATIC, INADEQUATE TO ADEQUATE FOR DOMESTIC USE.

WELL DEPTHS MORE THAN 100 FEET. YIELDS ERRATIC, GENERALLY ADEQUATE FOR DOMESTIC USE.

WELL DEPTHS RANGE FOOM 50 TO MORE THAN 300 FEET. YIELDS INADEQUATE TO ADEQUATE FOR DOMESTIC USE.

1/ LOCALLY SOME PRODUCTION FROM SAND AND GRAVEL.

MAP OF
TIPPECANOE COUNTY, INDIANA
SHOWING
GROUND WATER CONDITIONS

0 1 2 3 4 5 6 MILES
0 5000 10000 15000 20000 FEET

BY J. S. ROSENSHEIN

1958

BASE MODIFIED FROM INDIANA DEPARTMENT OF CONSERVATION, GEOLOGICAL SURVEY BASE MAP OF TIPPECANOE COUNTY, INDIANA, MAY 1, 1952

STATE OF INDIANA
INDIANA DEPARTMENT OF CONSERVATION
DIVISION OF WATER RESOURCES

PREPARED BY THE
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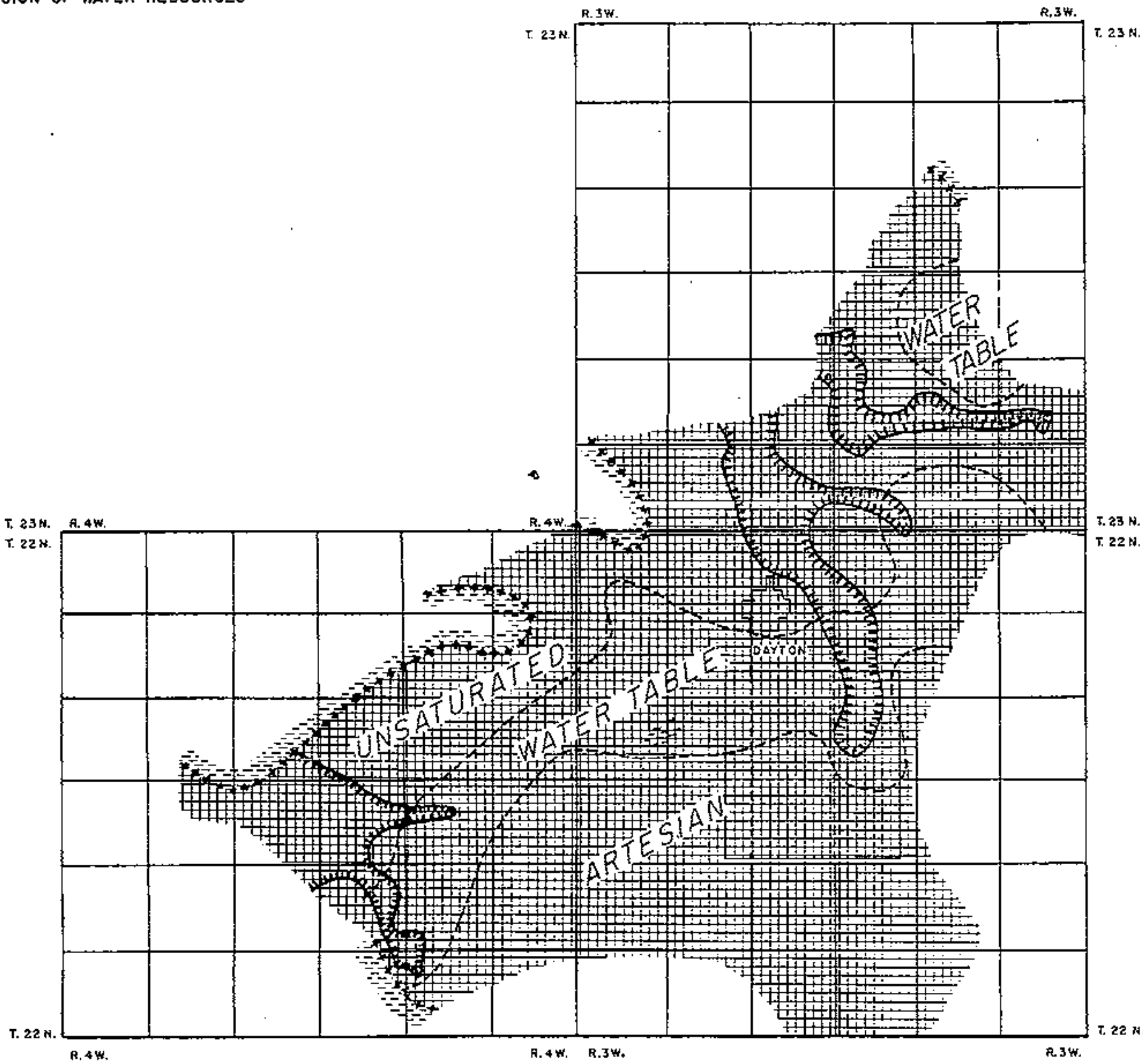
GEOLOGICAL SURVEY

PLATE 4



EXPLANATION

UNIT I
ALTITUDE OF TOP OF UNIT 640-660 FEET

SILT AND CLAY

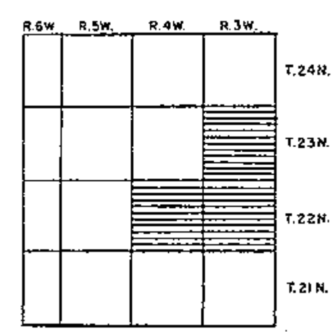
DRIFT UNDIFFERENTIATED

PART OF UNIT BREACHED BY STREAM

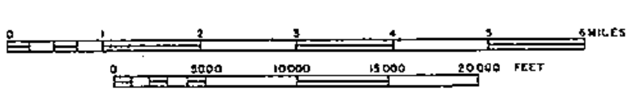
BOUNDARY OF UNIT

BOUNDARY BETWEEN GROUND-WATER CONDITIONS

SUBSURFACE EXTENT OF AND GROUND-WATER CONDITIONS IN SAND AND GRAVEL UNIT I



INDEX MAP OF TIPPECANOE COUNTY
SHOWING AREA COVERED BY PLATE 4



BY J. S. ROSENSHEIN
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GEOLOGICAL SURVEY, BASE MAP
OF TIPPECANOE COUNTY, INDIANA
MAY 1, 1952

STATE OF INDIANA
INDIANA DEPARTMENT OF CONSERVATION
DIVISION OF WATER RESOURCES

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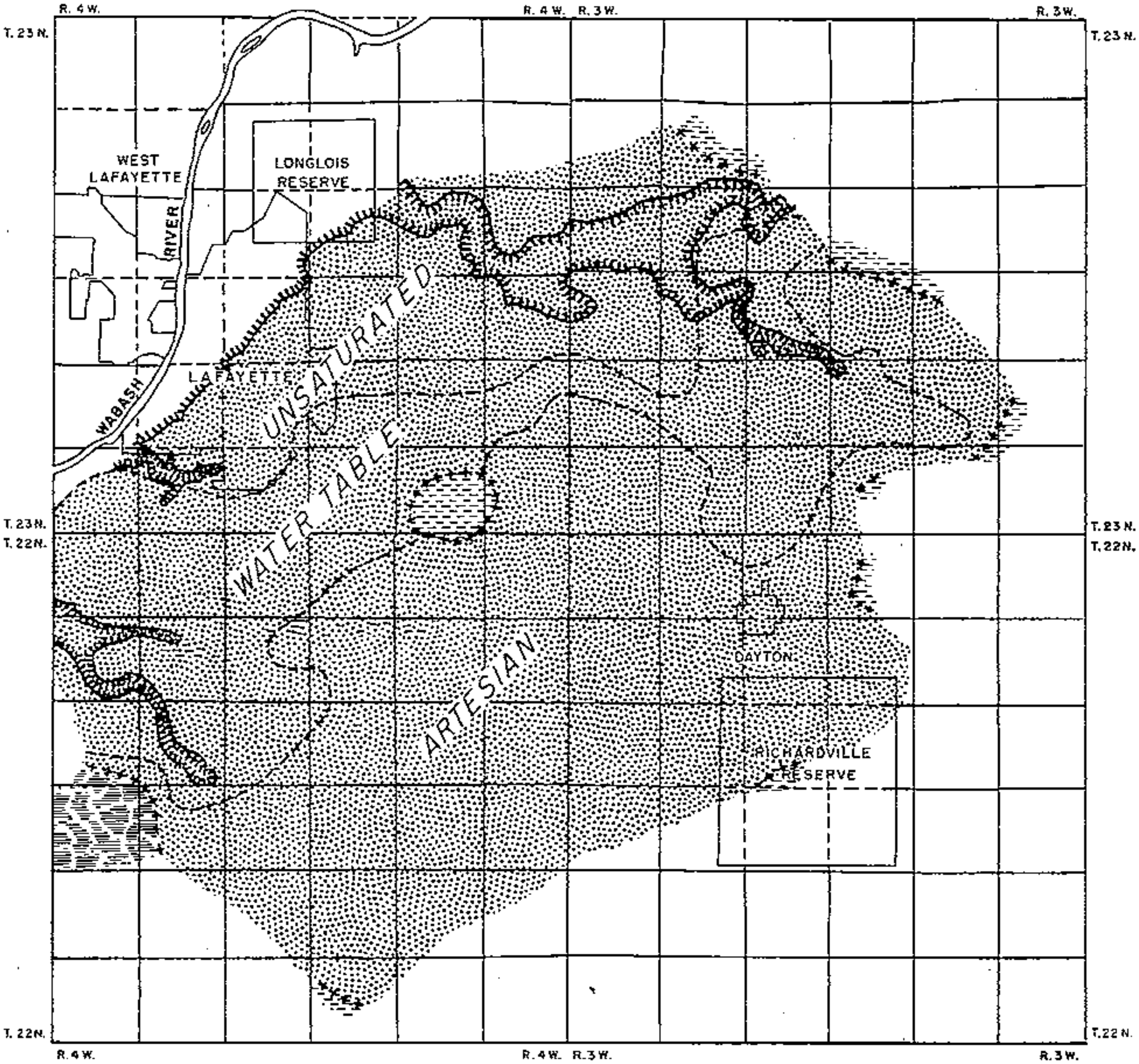
UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

PLATE 5



EXPLANATION

UNIT 2
ALTITUDE OF TOP OF UNIT 600-620 FEET

SILT AND CLAY

DRIFT UNDIFFERENTIATED

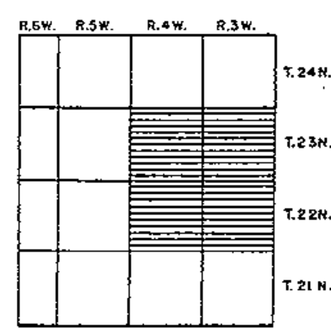
BEDROCK
ALTITUDE HIGHER THAN 620 FEET

PART OF UNIT BREACHED BY STREAM

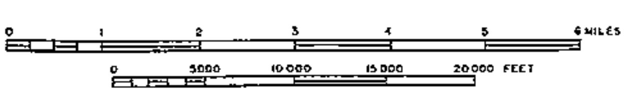
+++++
BOUNDARY OF UNIT

— — — —
BOUNDARY BETWEEN GROUND-WATER CONDITIONS

SUBSURFACE EXTENT OF AND GROUND-WATER CONDITIONS IN SAND AND GRAVEL UNIT 2



INDEX MAP OF TIPPECANOE COUNTY
SHOWING AREA COVERED BY PLATE 5



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1958

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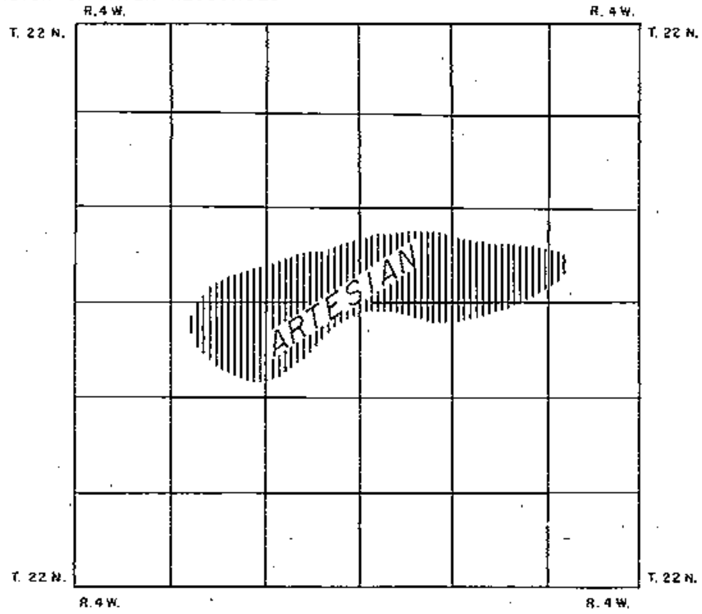
DEPARTMENT OF CONSERVATION
GEOLOGICAL SURVEY, BASE MAP
OF TIPPECANOE COUNTY, INDIANA
MAY 1, 1952

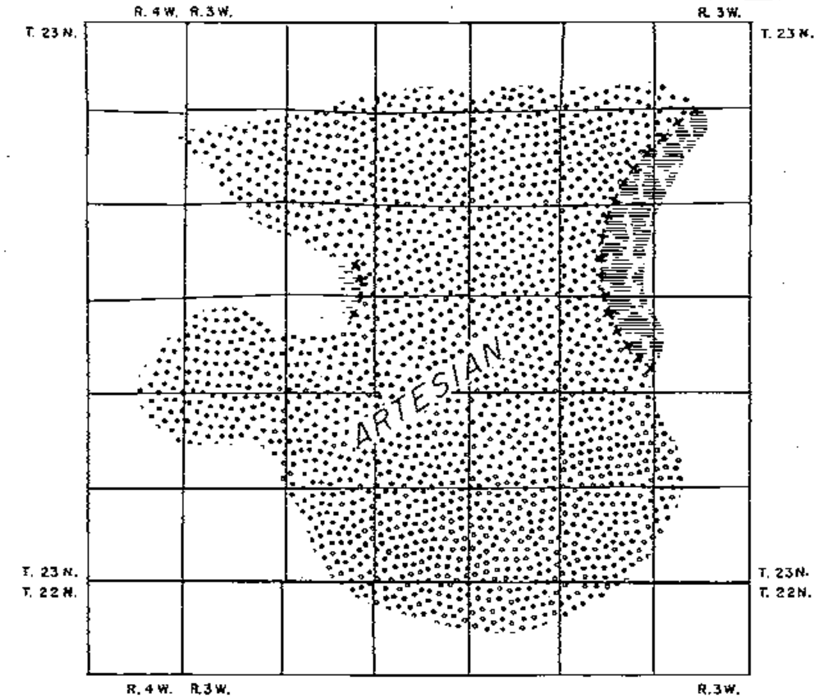
STATE OF INDIANA
INDIANA DEPARTMENT OF CONSERVATION
DIVISION OF WATER RESOURCES

PREPARED BY THE
UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

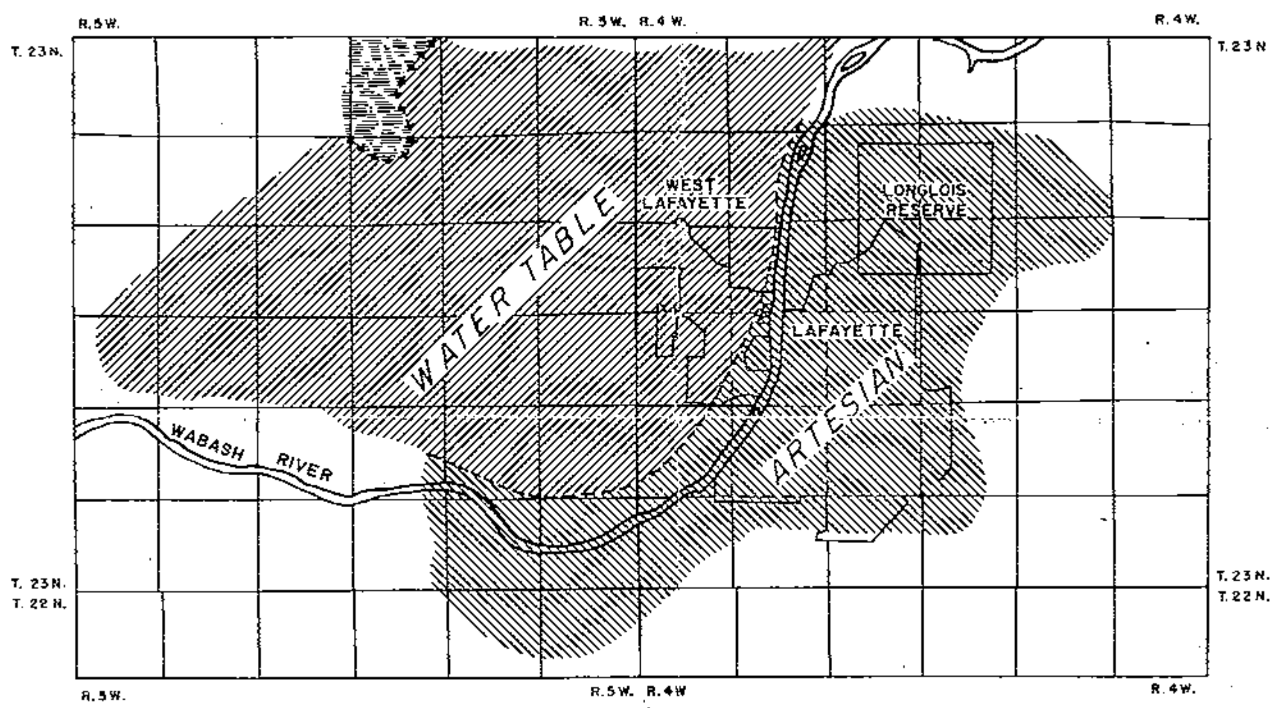
PLATE 6



UNIT 3



UNIT 4



UNIT 5

EXPLANATION

UNIT 3
ALTITUDE OF TOP OF UNIT 535-570 FEET

UNIT 4
ALTITUDE OF TOP OF UNIT 530-550 FEET

UNIT 5

SUBUNIT 5A
ALTITUDE OF TOP OF UNIT 500-540 FEET

SUBUNIT 5B
ALTITUDE OF TOP OF UNIT 490-510 FEET

SILT AND CLAY

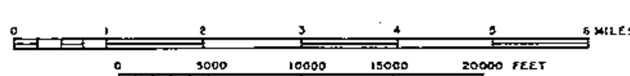
DRIFT UNDIFFERENTIATED

BEDROCK
ALTITUDE HIGHER THAN 550 FEET

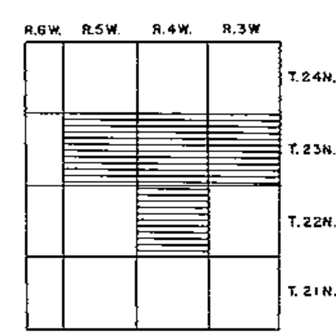
+++++++
BOUNDARY OF UNIT

- - - - - - -
BOUNDARY BETWEEN GROUND-WATER CONDITIONS

SUBSURFACE EXTENT OF AND GROUND-WATER CONDITIONS IN SAND AND GRAVEL UNITS 3-5



BY J. S. ROSENSHEIN
1958



INDEX MAP OF TIPPECANOE COUNTY SHOWING AREA COVERED BY PLATE 6

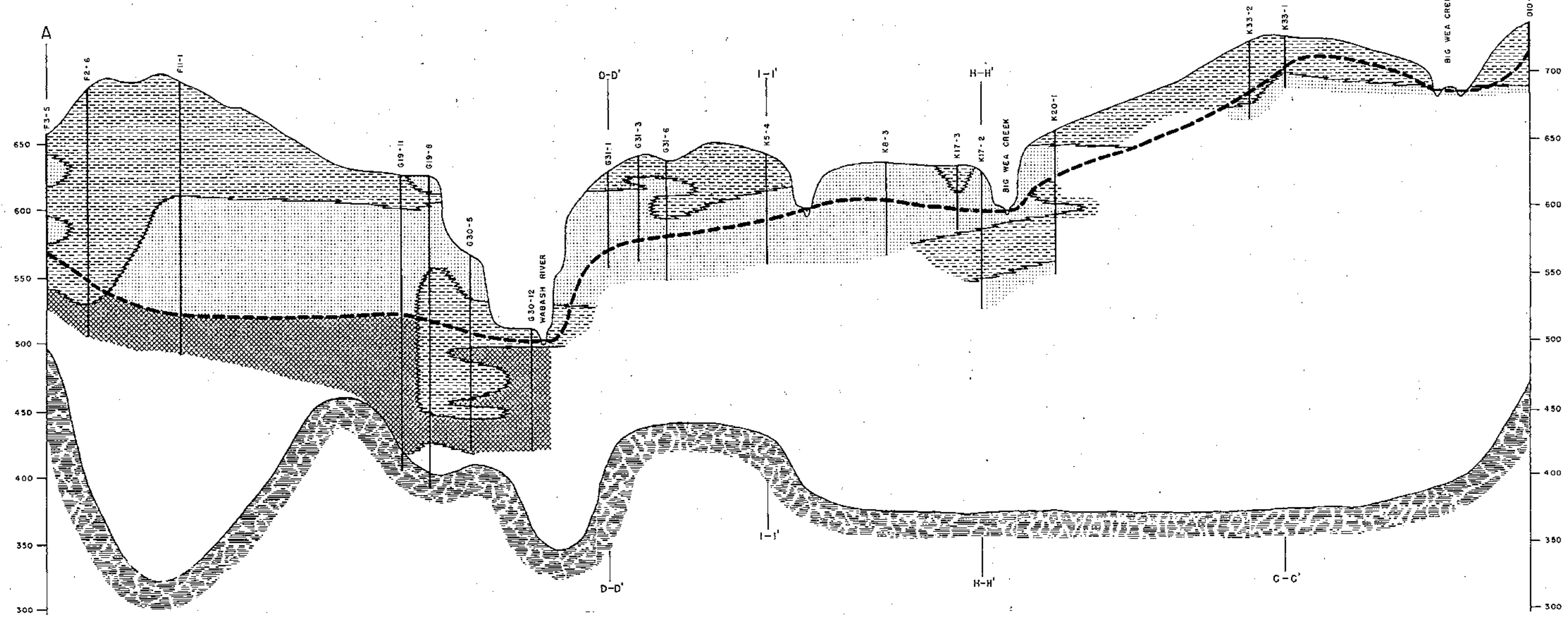
BASE MODIFIED FROM INDIANA DEPARTMENT OF CONSERVATION, GEOLOGICAL SURVEY, BASE MAP OF TIPPECANOE COUNTY, INDIANA MAY 1, 1952

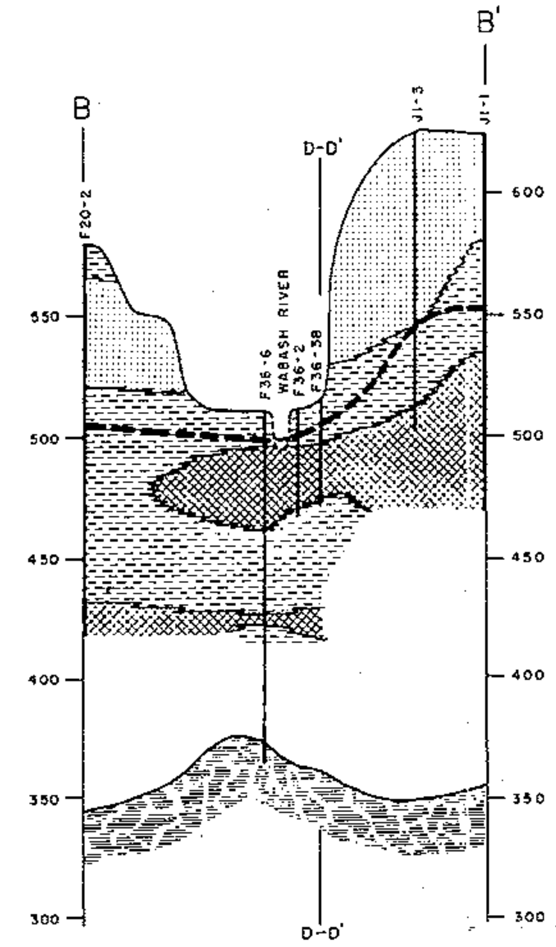
STATE OF INDIANA
INDIANA DEPARTMENT OF CONSERVATION
DIVISION OF WATER RESOURCES

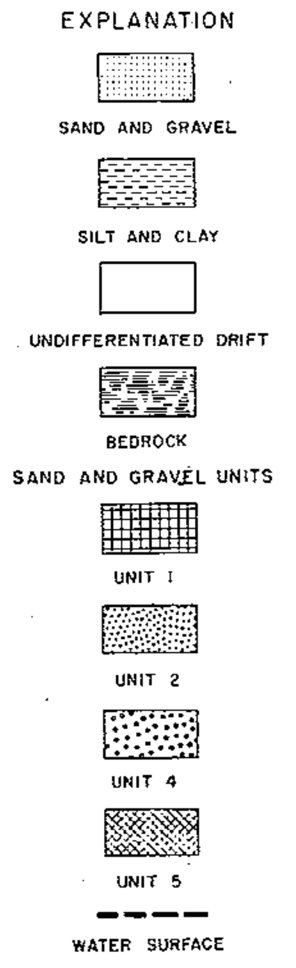
PREPARED BY THE
UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

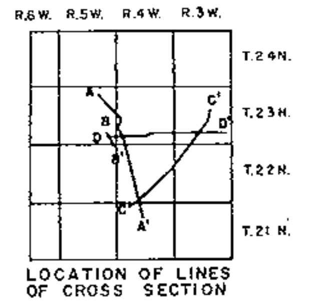
CROSS SECTIONS
SHOWING
GENERALIZED GEOLOGY AND WATER-BEARING UNITS
LINES A-A' TO D-D'

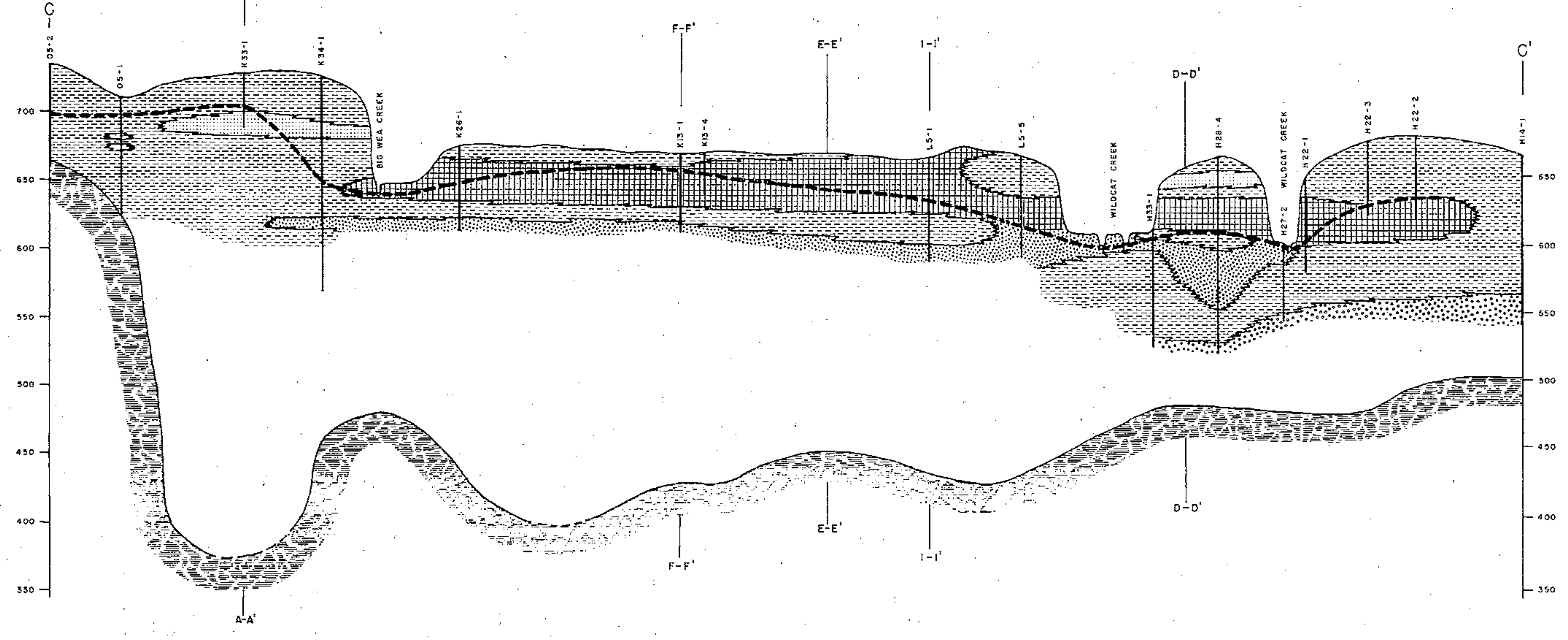
VERTICAL EXAGGERATION 65 TIMES
DATUM IS MEAN SEA LEVEL
BY J. S. ROSENSHEIN
1958

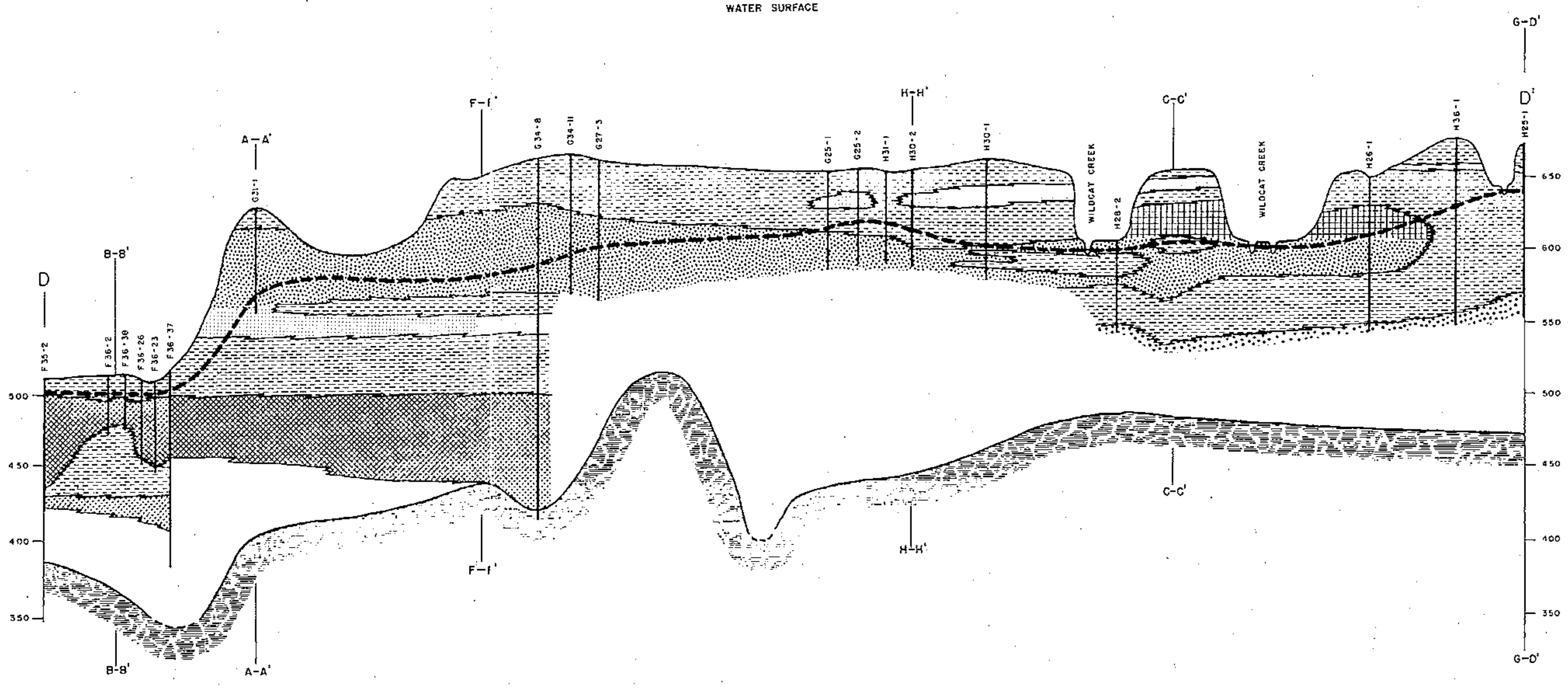












STATE OF INDIANA
INDIANA DEPARTMENT OF CONSERVATION
DIVISION OF WATER RESOURCES

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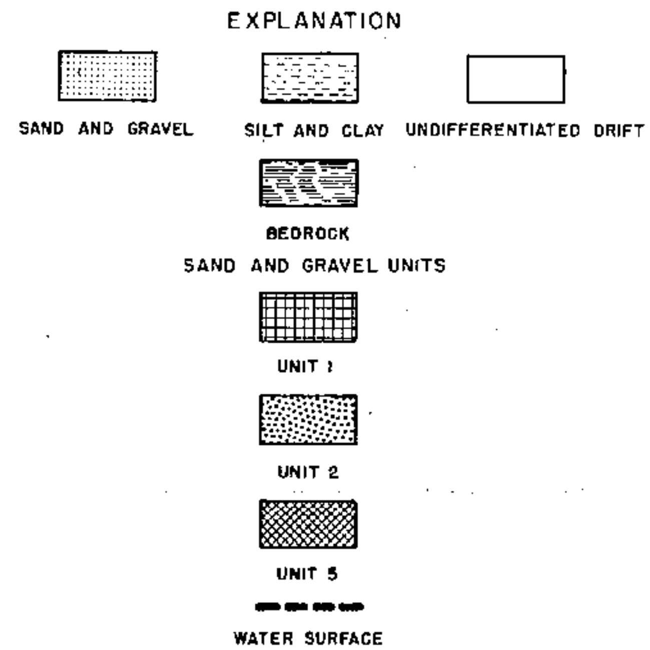
UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

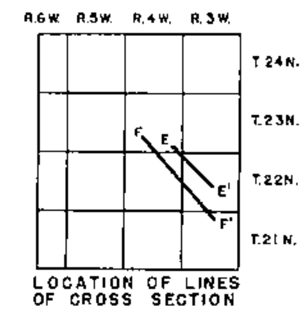
PLATE 8

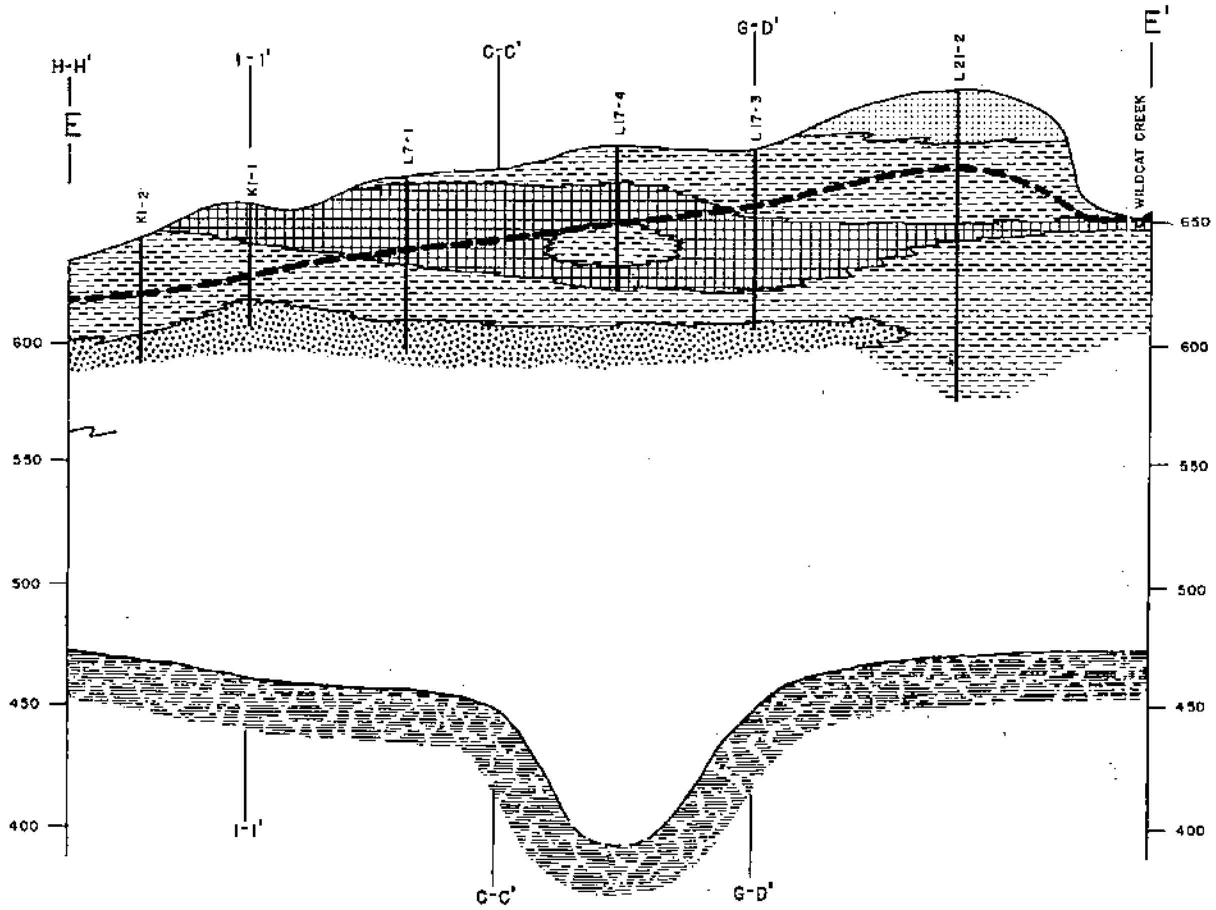
CROSS SECTIONS
SHOWING
GENERALIZED GEOLOGY AND WATER-BEARING UNITS
LINES E-E' TO F-F'

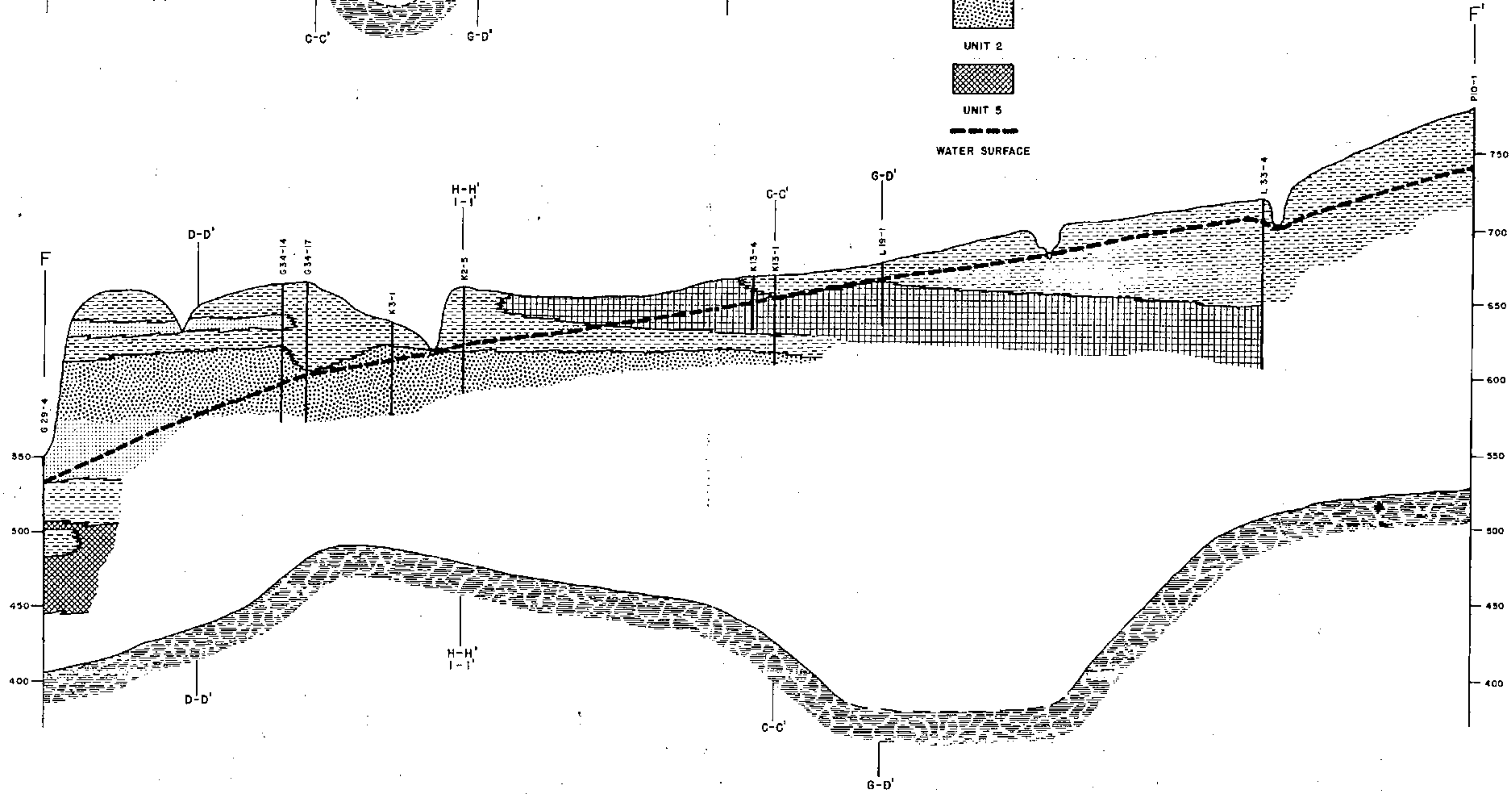
0 1 2 3 MILES
0 5000 10000 FEET

VERTICAL EXAGGERATION 65 TIMES
DATUM IS MEAN SEA LEVEL
BY J. S. ROSENSHEIN
1958









STATE OF INDIANA
INDIANA DEPARTMENT OF CONSERVATION
DIVISION OF WATER RESOURCES

PREPARED BY THE
UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

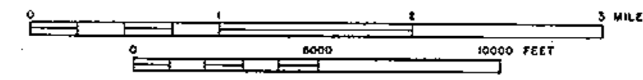
PLATE 9

CROSS SECTIONS

SHOWING

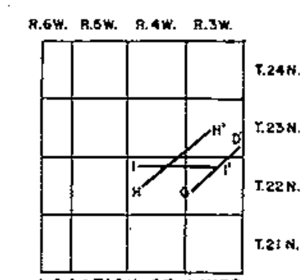
GENERALIZED GEOLOGY AND WATER-BEARING UNITS

LINES G-D' TO I-I'



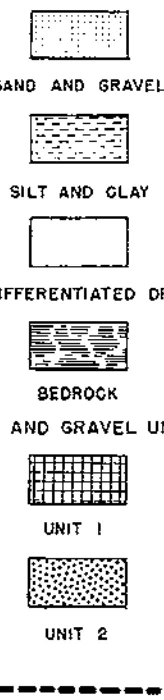
VERTICAL EXAGGERATION 66 TIMES
DATUM IS MEAN SEA LEVEL
BY J. S. ROSENSHEIN

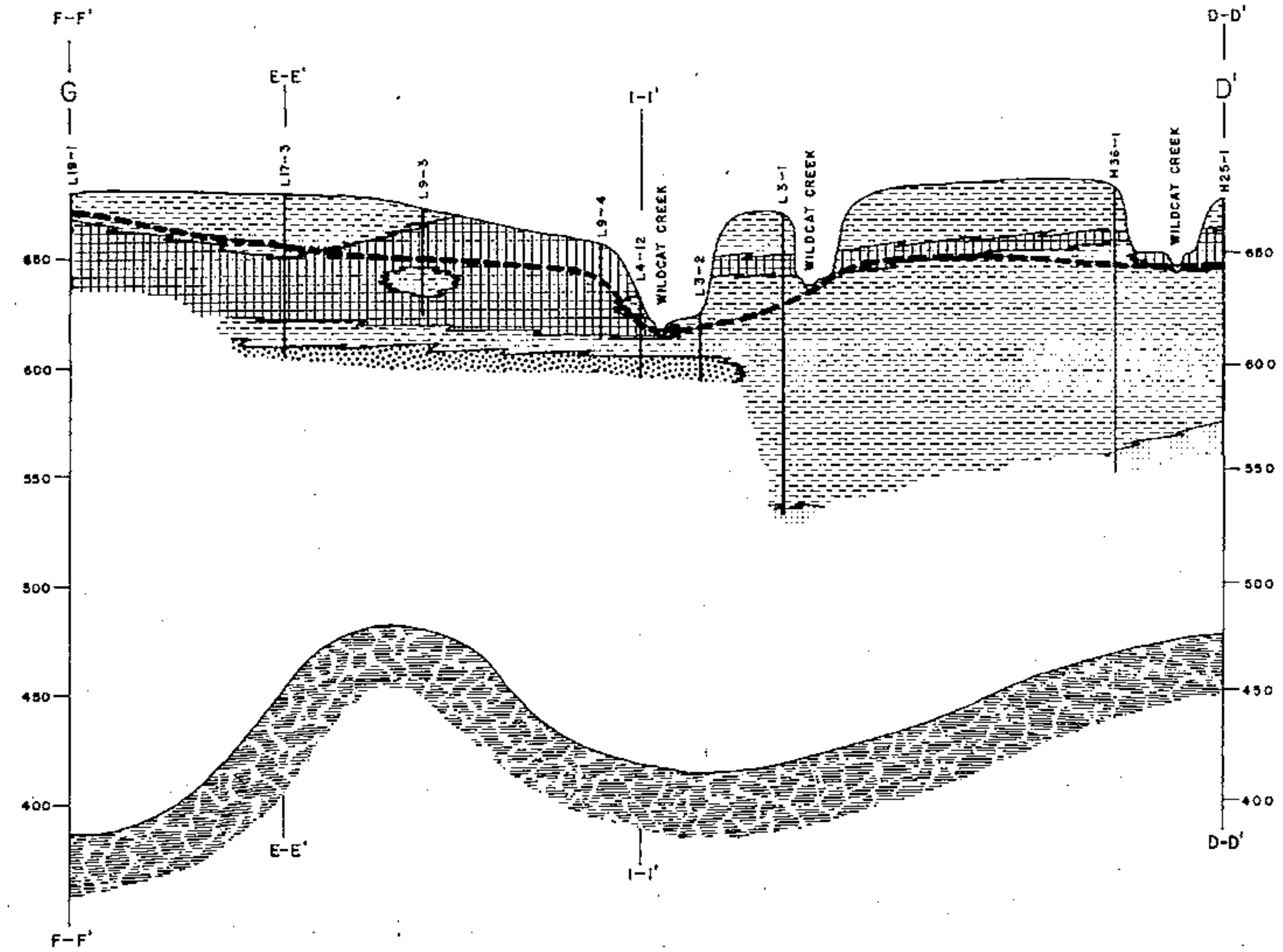
1958

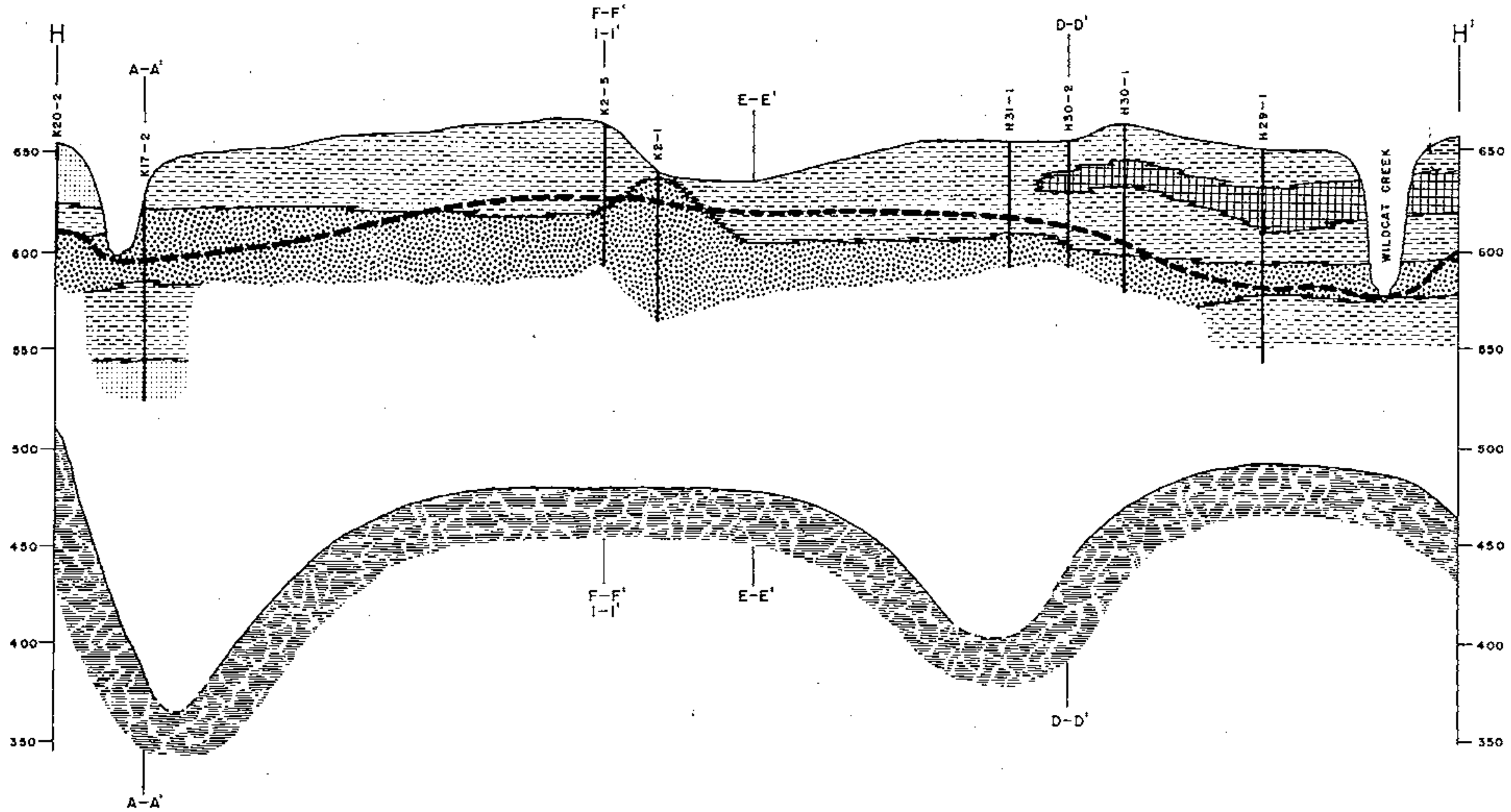


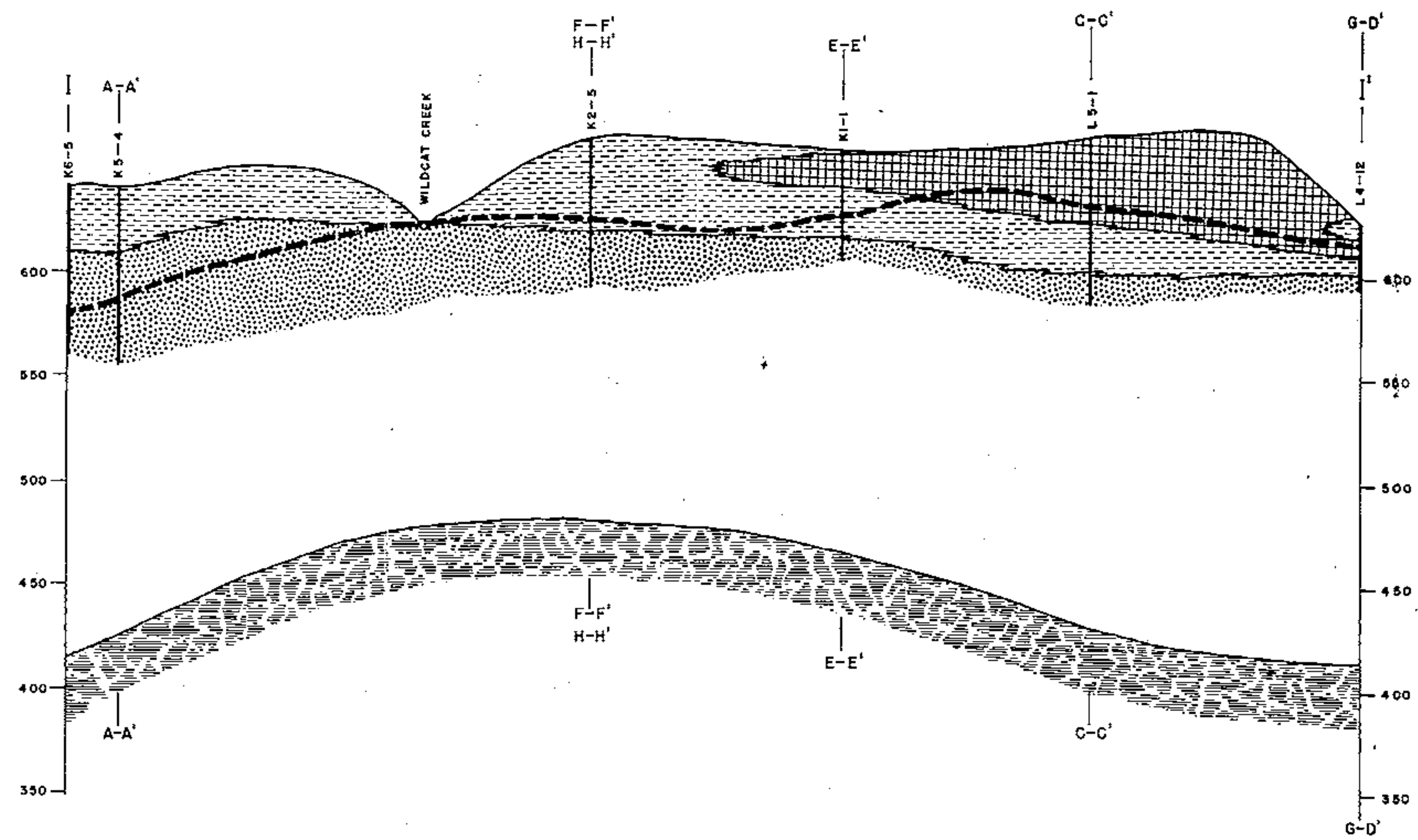
LOCATION OF LINES OF CROSS SECTION

EXPLANATION





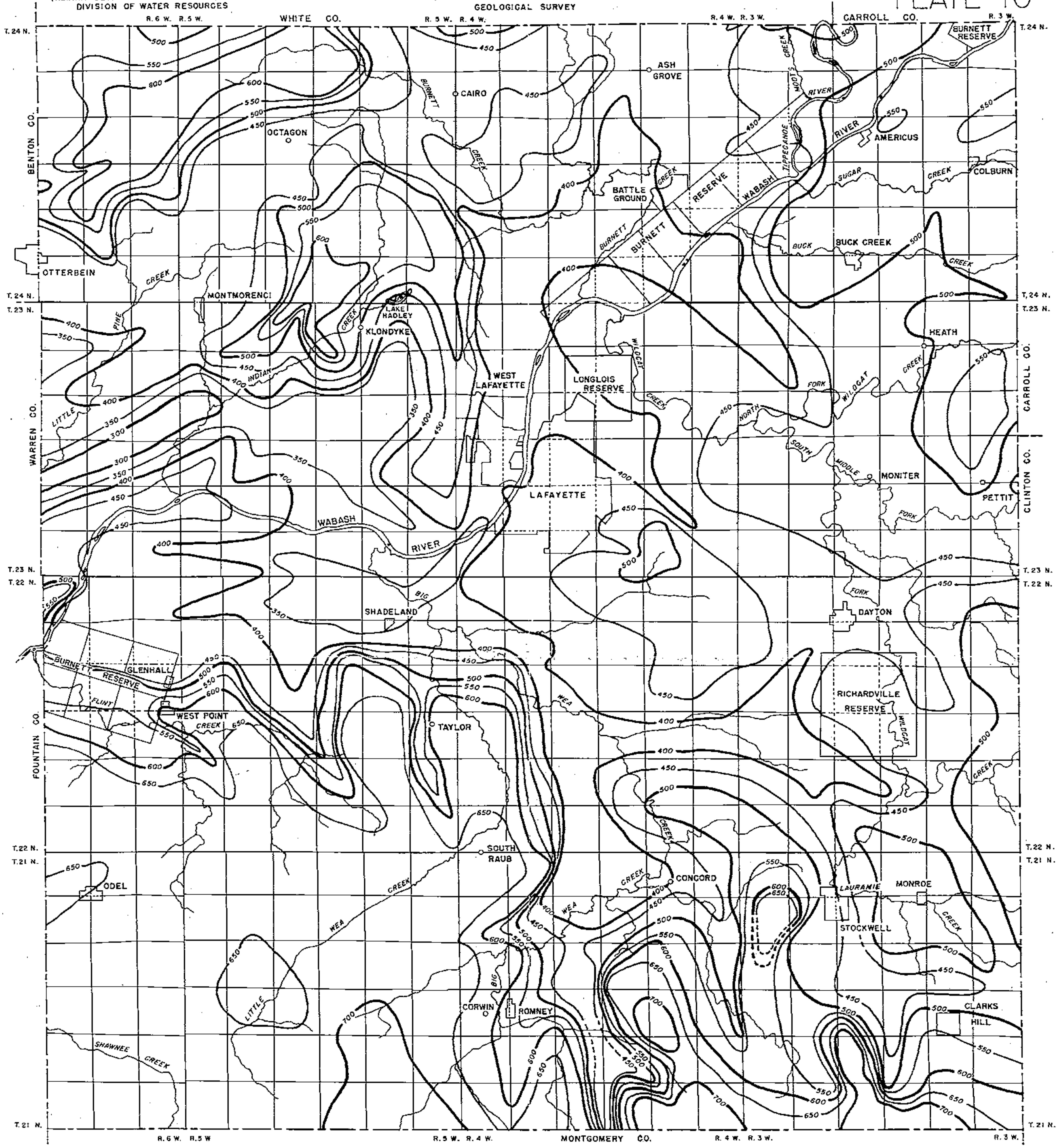




STATE OF INDIANA
INDIANA DEPARTMENT OF CONSERVATION
DIVISION OF WATER RESOURCES

PREPARED BY THE
UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

PLATE 10



BASE MODIFIED FROM INDIANA DEPARTMENT OF CONSERVATION, GEOLOGICAL SURVEY, BASE MAP OF TIPPECANOE COUNTY, INDIANA, MAY, 1952.

MAP OF
TIPPECANOE COUNTY, INDIANA
SHOWING
CONTOURS ON THE BEDROCK SURFACE

MAP COMPILED FROM SEISMIC DATA OBTAINED FROM THE INDIANA DEPARTMENT OF CONSERVATION, GEOLOGICAL SURVEY, AND SUBSURFACE GEOLOGIC DATA OBTAINED FROM DRILLERS' LOGS OF WELLS.

0 1 2 3 4 5 6 MILES

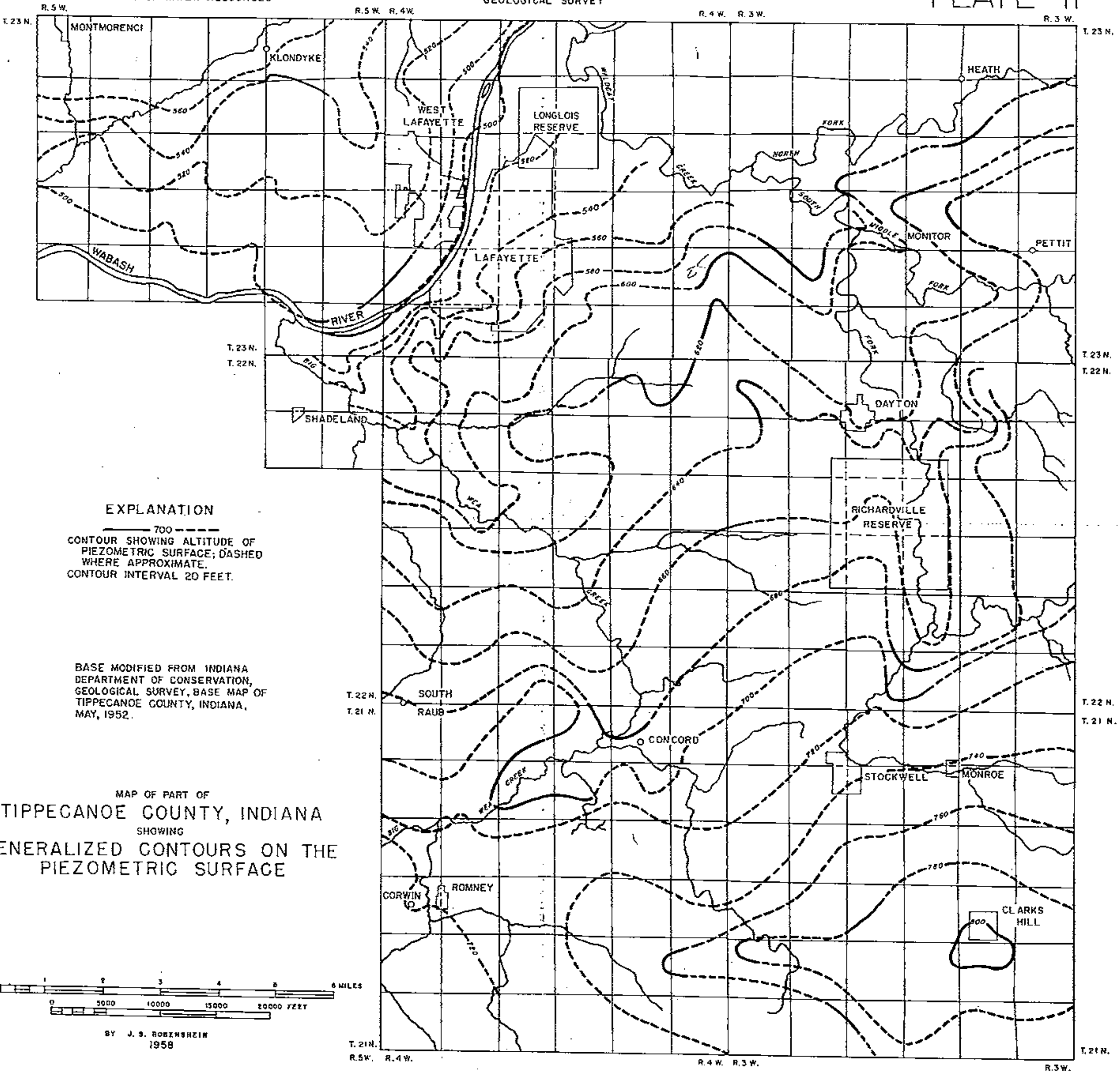
0 5000 10000 15000 20000 FEET

CONTOUR INTERVAL 50 FEET.
DATUM IS MEAN SEA LEVEL.
COMPILED BY J. S. ROSENSHEIN
1958

STATE OF INDIANA
INDIANA DEPARTMENT OF CONSERVATION
DIVISION OF WATER RESOURCES

PREPARED BY THE
UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

PLATE II



EXPLANATION

700
CONTOUR SHOWING ALTITUDE OF PIEZOMETRIC SURFACE; DASHED WHERE APPROXIMATE.
CONTOUR INTERVAL 20 FEET.

BASE MODIFIED FROM INDIANA DEPARTMENT OF CONSERVATION, GEOLOGICAL SURVEY, BASE MAP OF TIPPECANOE COUNTY, INDIANA, MAY, 1952.

MAP OF PART OF
TIPPECANOE COUNTY, INDIANA
SHOWING
GENERALIZED CONTOURS ON THE PIEZOMETRIC SURFACE

BY J. S. ROSENSHEIN
1958