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GROUND-WATER MOVEMENT AND CONTAMINATION AT THE AEC FEED MATERIALS PRODUCTION CENTER LOCATED NEAR FERNALD, OHIO SEPTEMBER, 1962

09/01/62

USGS/AEC
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GROUND-WATER MOVEMENT AND CONTAMINATION AT THE AEC FEED MATERIALS PRODUCTION CENTER LOCATED NEAR FERNALD, OHIO

By

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U.S. Geological Survey

Prepared by the U.S. Geological Survey for the U.S. Atomic Energy Commission

Columbus, Ohio
September, 1962

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INTRODUCTION

The purpose of this report is to present data on the movement of ground water and ground-water contamination in the vicinity of the Fernald Plant, a facility operated by the National Lead Co. of Ohio for the U.S. Atomic Energy Commission. The investigation was made at the request of the Atomic Energy Commission specifically to ascertain whether seepage from four large waste disposal pits located near the west edge of the plant production area has entered the principal aquifer from which water is supplied to the AEC plant and to many other ground water users in the area.

This investigation would not have been possible without the wholehearted cooperation of officials of the U.S. Atomic Energy Commission and of the National Lead Co. of Ohio. The authors wish particularly to thank Messrs. Edward L. Giebel of the Atomic Energy Commission and H. Starkey and Leroy Williams of the National Lead Co. of Ohio for their assistance with the investigation.

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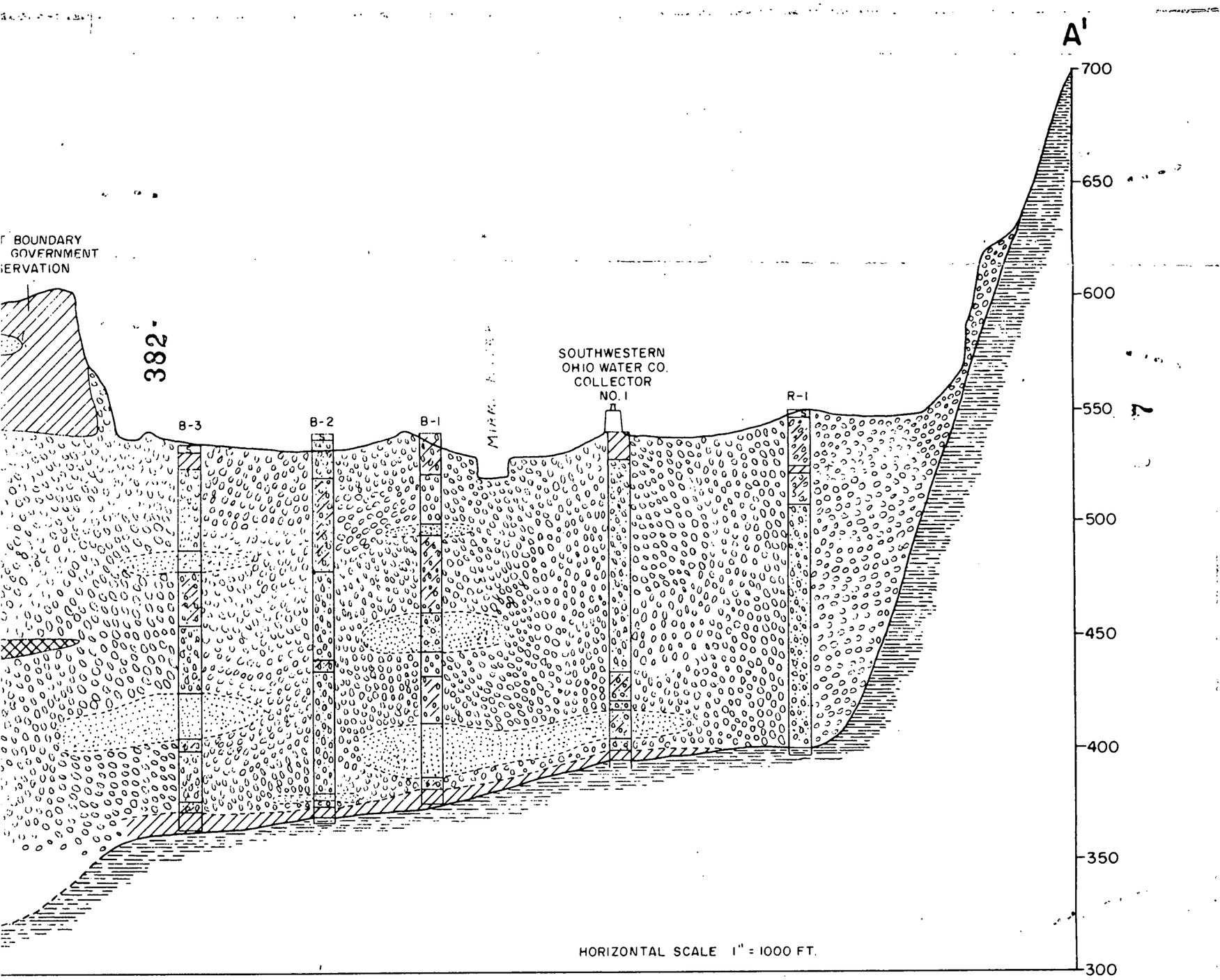
Several earlier reports have covered various phases of the occurrence of ground water in the lower Miami River valley. Klaer and Thompson (1948), Bernhagen and Schaefer (1947), and Spieker (1961) have covered in general terms the geology and occurrence of ground water in the area. Dove (1961) discusses in detail the hydrology of the Venice area.

Dove and Morris (1951), Hartsock (1960), and Rye (1961a, 1961b, 1961c) have covered various aspects of geology, ground-water movement and contamination in administrative reports which provide a background and foundation for the present investigation.

GEOLOGY

The generalized geologic cross-section across the buried valley of the ancestral Miami River (fig. 1) portrays the geologic relations in the Fernald area. The AEC plant is situated on a terrace, ranging in altitude from 575 to 600 feet, about 50 feet above the Miami River floodplain (fig. 2). This terrace, which may be part of the Hartwell moraine as shown by Goldthwait and others (1961), consists of clay-rich till 35 to 70 feet thick. The surficial till is not continuous to the west side of the valley; it probably pinches out into sand in the vicinity of Paddy's Run. Sand is exposed in the bed of Paddy's Run and is indicated in the drillers log of well Hcr-21. The absence of the till sheet west of Paddy's Run and the thinness of the till in the vicinity of the waste storage pits facilitates seepage of water into the underlying deposits.

Below the till sheet are sand and gravel deposits, about 150 feet thick, which fill the entire buried valley. Underneath the AEC plant these deposits are separated horizontally by a layer of clay 10 to 20 feet thick. The clay layer, the top of which is 130 to 140 feet below the surface, is believed to extend westward to the bedrock valley wall in the vicinity of Shandon Station and southwestward at least as far as New Haven. The clay layer does not extend entirely across the buried valley, as it is reported in none of the test wells drilled for the Southwestern Ohio Water Co. It appears to pinch out near the



ANATION

Gravelly Till or poorly sorted Sand and Gravel

Shale

U. S. Government Reservation near Fernald, Ohio.

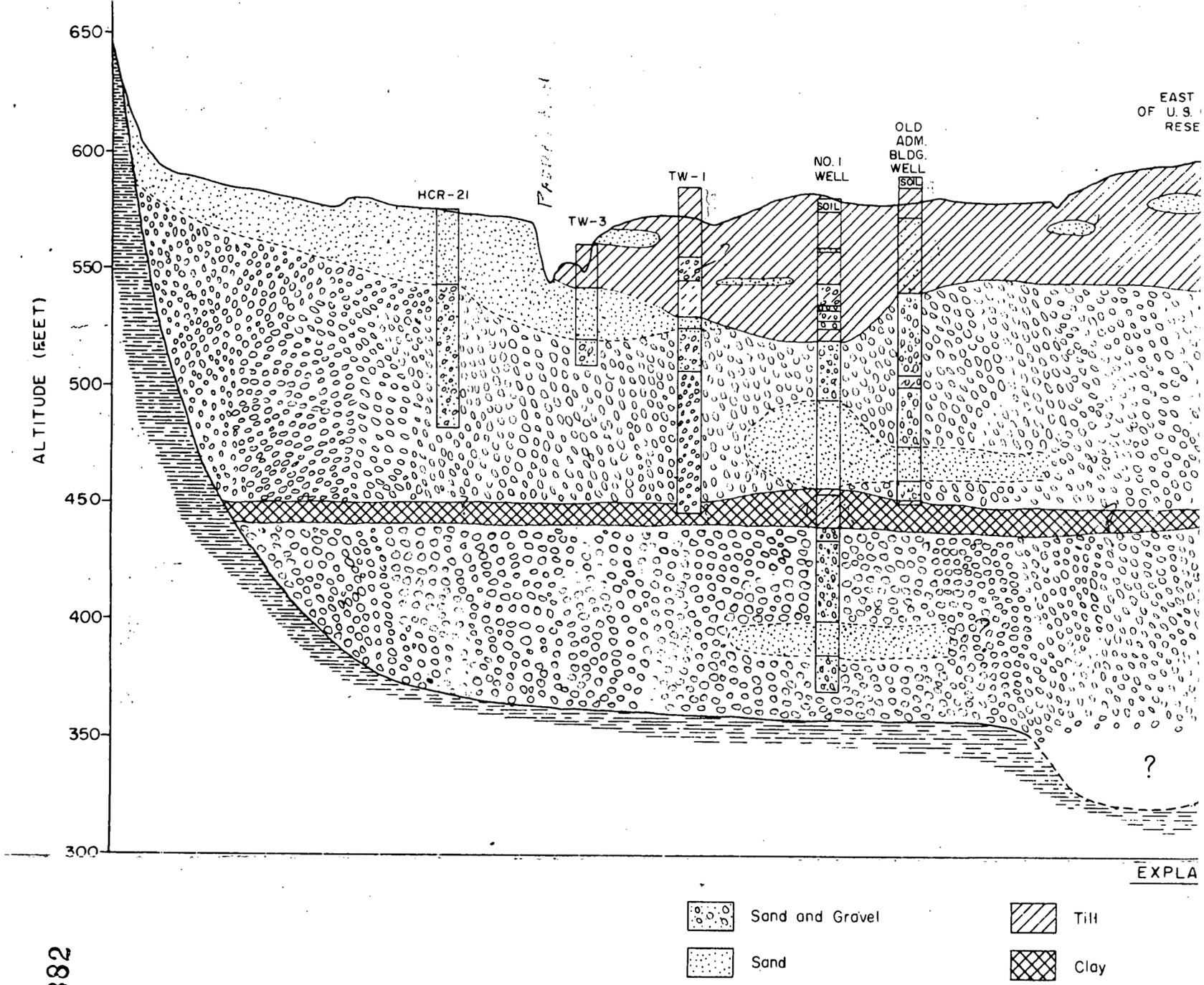


Figure 1. Geologic cross section through

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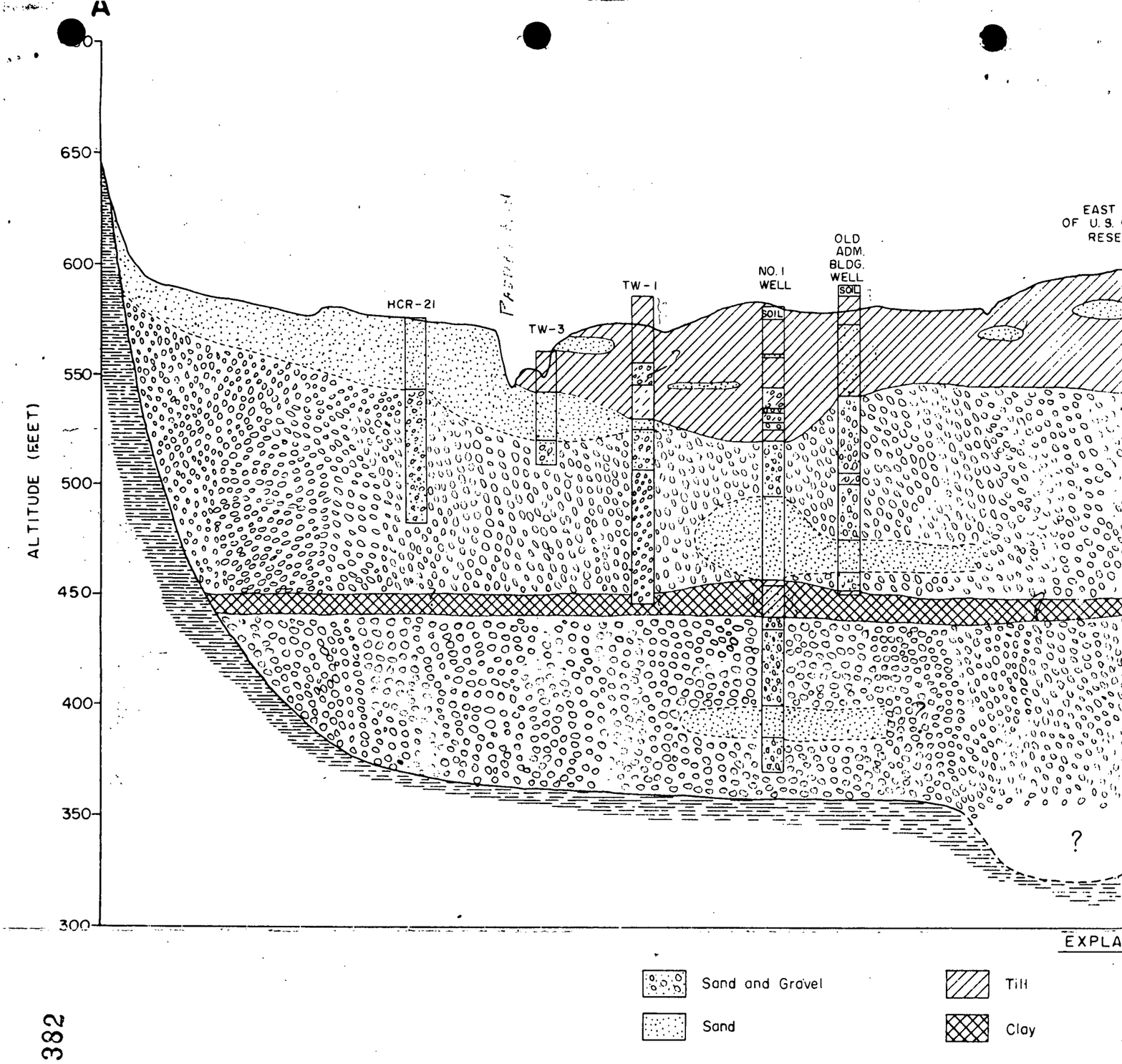
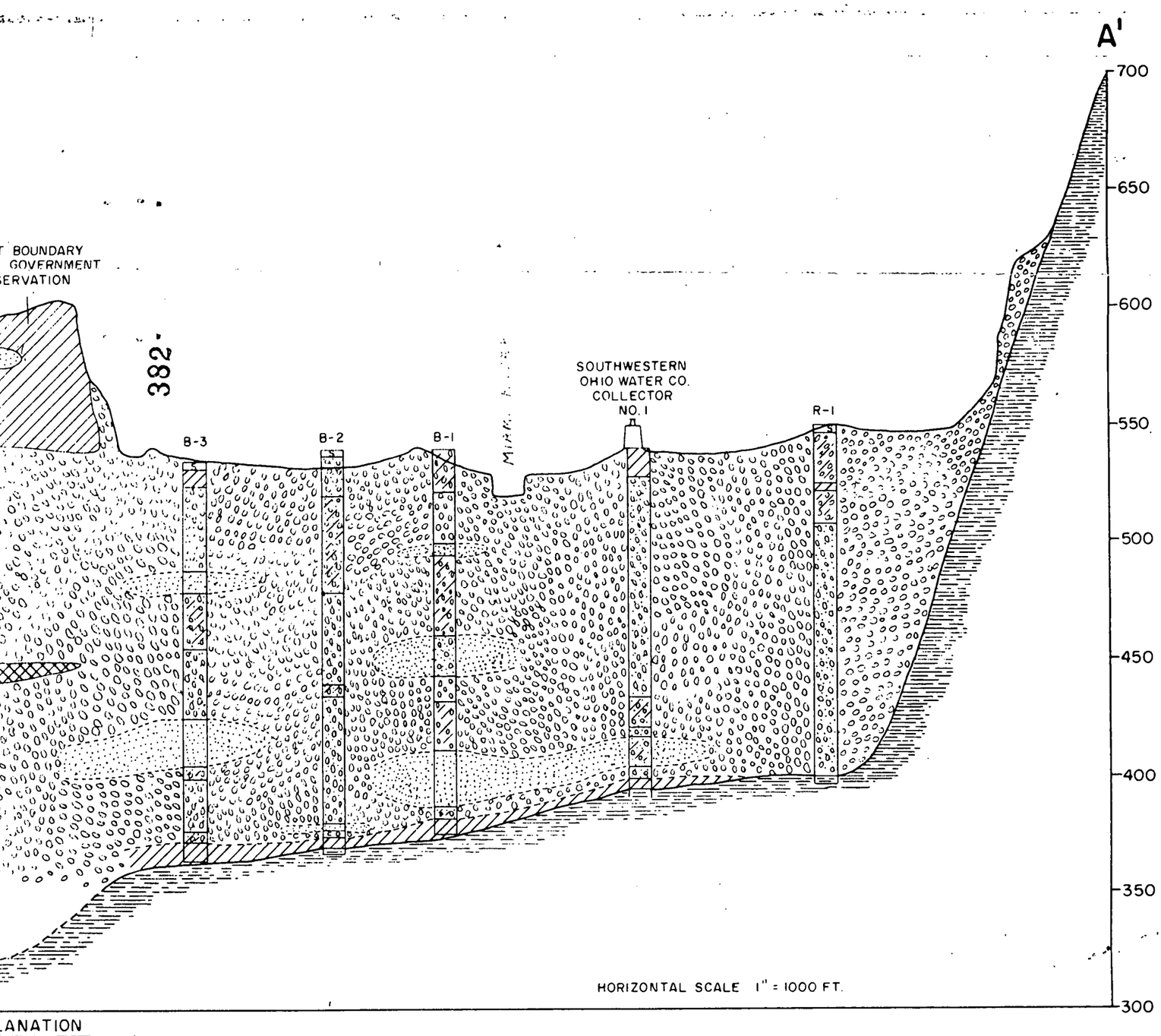


Figure 1. Geologic cross section through



LANATION

Gravelly Till or poorly sorted Sand and Gravel

Shale

U.S. Government Reservation near Fernald, Ohio.

eastern boundary of the Government Reservation. The clay was probably deposited in an ice-marginal lake or as a backwater deposit of a pro-glacial stream.

The "shallow aquifer" of Dove and Norris (1951) is a perched body of water restricted to the high terrace. Dug wells at farms surrounding the Reservation tap this aquifer, which probably consists of discontinuous pockets of sand and gravel interstratified with the surficial till. This perched body of water is probably of little consequence with regard to the movement of ground water under the Government Reservation. In the present report the term upper aquifer refers to that portion of the principal sand and gravel aquifer situated above the clay bed about 140 feet below the surface and not to the perched aquifer. The usage of the present report thus corresponds to that of Eye (1961b, p. 4).

AQUIFER TESTS

The clay bed constitutes a poorly permeable confining bed, separating the sand and gravel deposits into an upper and a lower aquifer. On August 2, 1962 measurements made with a highly-sensitive, thermistor-type thermometer showed that ground-water temperature above the clay bed was about 0.5° F lower than that below the clay bed in the vicinity of the plant supply wells. Aquifer tests made on August 7 and 8 and on August 14 and 15, using the plant supply wells, show that vertical leakage through the clay bed, by which water moves from the upper to the lower sand and gravel aquifer, is the principal source of recharge to those wells. The tests yielded values of the transmissibility and storage coefficients of the lower aquifer, and of the permeability of the semi-confining clay bed. These factors are essential in assessing the rate of ground-water movement into the lower aquifer.

There are three water-supply wells at the AEC plant, located on the west side of the production area. The wells are spaced 400 feet apart and arrayed in a north-south line, with well 1 being the northernmost well. The wells are 210 feet deep and are screened in the lower 20 feet. Presently plant water-use amounts to about 1.2 mgd (million gallons per day).

In the aquifer test made on August 7 and 8, well 1 was pumped steadily at the rate of 300 gpm (gallons per minute) for approximately 20 hours while the drawdown and subsequently the recovery of the water level were recorded in a 6-inch diameter observation well 185 feet deep, located near supply well 2. For two days prior to and during the test, well 3 was pumped steadily at the rate of 800 gpm to supply the water requirements of the plant. On August 14 and 15 the pattern was reversed, well 3 being test pumped, at 275 gpm, while well 1 was used to supply water to the plant.

During both tests fluctuations in the water level were recorded in a well 118 feet deep, screened above the semi-confining clay bed, and located about 2,000 feet northeast of the supply wells at the site of the "old" Administration Building. The water level in the shallower well was unaffected by the tests; however, the well revealed fluctuations in water level caused by changes in atmospheric pressure in about the same degree as those recorded in the deeper observation well. The hydrograph of the shallow well was used, therefore, as a convenient barograph from which to correct apparent variation in trends of the drawdown and recovery curves caused by atmospheric pressure changes. Plant engineers maintained excellent control of pumping, keeping it at a very steady rate, and results of the two tests are similar.

The lower sand and gravel aquifer has a coefficient of transmissibility of about 140,000 gal per day per ft and a coefficient of storage of 0.001, the latter value being in the artesian range. With a saturated thickness of approximately 70 feet, the aquifer has a coefficient of permeability of approximately 2,000 gal per day per sq ft, a value typical of the sand and gravel deposits in the Miami Valley. At the pumping rates used in the tests recharge became noticeably effective after about 30 minutes, after which time there was essentially no more drawdown.

The coefficient of leakage of the confining bed, that is the ratio of its permeability to thickness, determined by methods described by Walton (1960), was computed as about 0.21 and 0.32 gal per day per ft^3 for wells 1 and 3, respectively. These values multiplied by its thickness at the respective wells, yields values for the coefficient of permeability of the semi-confining bed of 3.2 gal per day per sq ft, at the site of supply well 1, and of 2.5 gal per day per sq ft at the site of supply well 3. Although the semi-confining bed is only about one seven-hundredth as permeable as the sand and gravel aquifer which it overlies, it is nevertheless permeable enough to transmit large quantities of water from the upper to the lower aquifer where the area in which leakage occurs is fairly large, even though the difference in hydraulic head between the two aquifers may be small. For example, if we take as the coefficient of permeability of the semi-confining bed the value of 3.0 gal per day per sq ft, and use 12 feet as its average thickness, the leakage coefficient $\left(\frac{P'}{m'}\right)$ is $\frac{3.0 \text{ gal per day per ft}^2}{12 \text{ ft}}$ or 0.25 gal per day per ft^3.

If the average difference in head (h) between the upper and lower aquifers is, say 1 foot, over an area (A) of 1 square mile, the quantity of water (Q) moving through the semi-confining bed is:

$$Q = \frac{p'}{m'} \quad A \quad h$$
$$= 0.25 \times (5{,}280)^2 \times 1$$
$$= 7 \text{ mgd}$$

To illustrate further, the production area of the plant, including the land on which the disposal pits are dug, comprises about 400 acres. For 1.2 mgd of water, the amount presently being pumped at the plant, to move through the semi-confining bed in this area the average head difference between the upper and the lower aquifer needs only be about 0.2 foot. This is on the assumption that the leakage coefficient averages 0.25 gal per day per ft^3.

GROUND-WATER MOVEMENT

Figure 3 is a map of the Fernald area showing the configuration of the piezometric surface on August 7-8, 1962, based on measurements of nine wells on the Government Reservation, 37 test wells and two collectors of the Southwestern Ohio Water Co., and one domestic well. Movement of ground water is perpendicular to the contours and in the direction of decreasing head. The map is considered to be quite accurate in the area east of the Government Reservation, but owing to sparse data it is somewhat less accurate on and west of the Reservation. Any revisions made possible by additional data would be in the nature of refinement of detail rather than of changing the basic relationships.

The Government Reservation is situated just west of a major ground-water divide. Ground-water movement is in general from the vicinity of Shandon Station southeastward through the Reservation toward the Miami River. The divide is roughly parallel to and generally east of the east boundary of the Reservation. Water west of this divide moves toward the Miami River between Fernald and New Baltimore. The cone of influence caused by pumping at the AEC plant does not change the regional ground-water movement.

The effect on ground-water movement of the semi-confining clay layer reported in the AEC wells at the depth of about 140 feet is considered to be only of local extent. The regional ground-water movement in the sand and gravel is practically horizontal, and the head difference between the upper and lower aquifers is slight -- generally

less than 1 feet. Pumping of the plant's wells has caused vertical leakage through the clay by lowering the hydraulic head in the lower aquifer in the immediate vicinity of the pumping wells, but the bulk of the regional movement remains horizontal and parallel in both aquifers. In the preparation of figure 3, therefore, wells in both aquifers were used.

The average regional hydraulic gradient based on the piezometric contours is extremely flat -- about 0.0014 foot per foot, or 7.5 feet per mile. Locally, in the vicinity of pumping wells, this gradient is much steeper. The average velocity of ground-water motion can be determined using the equation

$$v = \frac{pI}{7.48\theta}$$

where:

v = velocity, in feet per day

I = hydraulic gradient, in feet per foot

p = coefficient of permeability of the aquifer, in gallons per square foot per day

θ = porosity of the material, in percent

Using the value of $p = 2{,}000$ gal per ft^2 per day, as determined from the aquifer tests, and the hydraulic gradient $I = 0.0014$, and assuming the porosity θ to be 25 percent;

$$v = \frac{2{,}000 \times 0.0014}{7.48 \times 0.25}$$

Thus, the average ground-water velocity in the vicinity of the Government Reservation is about 1.5 feet per day.

The quantity of ground water moving in an aquifer can be calculated by the formula

$$Q = TIW$$

where:

Q = gallons per day

T = coefficient of transmissibility of the aquifer, in gallons per day per foot

I = hydraulic gradient, in feet per foot

W = width in feet of the section through which flow is occurring

Based on a coefficient of transmissibility of 300,000 gal per day per foot, for the entire saturated thickness of the aquifer (2,000 gal per day per sq ft x 150 ft), a hydraulic gradient of 0.0014, and width W;

$$Q = 300{,}000 \times 0.0014 \times W$$

$$= 420 \text{ gal per day} \times W$$

Taking 800 feet as the width (W) of the disposal pits, approximately 350,000 gallons of water move daily beneath the pits, in a generally southeastward direction.

The plant supply wells are located generally down-gradient from the disposal pits and much of the water being pumped enters these wells after passing beneath or in close proximity to the disposal pits. Part of the water moving beneath the pits bypasses the area of influence of the supply wells and discharges naturally to the Miami River near New Baltimore. If pumping is increased in the supply wells the extent of their area of influence will also be increased and they will then capture a correspondingly greater part of the water moving beneath the pits. It is not unlikely that a doubling of the present pumpage would result in capture by the supply wells of virtually all the flow that presently passes beneath the disposal pits.

Five test wells, located roughly in a circle about the disposal pits (fig. 4), were drilled in the summer of 1959 and have been pumped more or less continuously since the spring of 1962. Test well 1 is pumped at the comparatively high rate of about 200 gpm; each of the other test wells is pumped at less than about 20 gpm. Water from test well 1 is pumped back into the disposal pits; water pumped from the other wells is discharged to Paddy's Run.

Pumping of the test wells has created small cones of depression around these wells which locally reverse the regional gradient and capture part of the water that otherwise would move towards the supply wells. Data upon which to base the extent of the cones of depression around the test wells consist only of water-level measurements made in

wells themselves, and consequently the piezometric contours are approximate. It is possible, using these data, to draw the contours in such a way as to indicate a cone of depression extending entirely around the disposal pits, thus producing a ground-water divide between the pits and the plant supply wells. Under such conditions all seepage from the pits would be captured by the test wells and none would move towards the supply wells. However, unless the aquifer in the vicinity of the test wells is very much below average in permeability[1/], the cones of depression produced around the test wells at present pumping rates will be essentially of local extent, as indicated by the piezometric contours on figure 3.

Owing to the low regional velocity of the ground water, distant effects of contamination will not be noted until long after the contaminated water enters the aquifer. It requires an estimated 2 to 5 years for ground water to move the 2,000 feet from the pit area to the plant supply wells and as much as 25 or 30 years to move 14,000 feet to the Miami River near New Baltimore. These are believed to be the average travel times. Actual travel times could vary from the average by as much as 100 percent, either faster, owing to preferential flow paths of higher than average permeability, or slower, owing to more circuitous flow paths.

1/ The specific capacity of test well 1, that is the ratio of its yield to drawdown, is only about half as high as the specific capacities of the supply wells. This might indicate that the aquifer is less permeable in the vicinity of test well 1 than in the area of the supply wells but, as no data have been collected on relative well efficiencies no definite conclusion is warranted.

CONTAMINATION

Early in 1959 the large liquid waste disposal pit (Pit 3) was placed in use as a settling basin. Waste water, after being decanted to a clear-well portion of the pit, is pumped into the Miami River through a pipe line. The pit is dug into the surficial till at a point where this till is relatively thin. There is evidence that in excavating the pit the till was removed in places to the top of the underlying sand and gravel aquifer. Eye (1961, p. 4) states: "The waste disposal pits ... excavated to a depth of approximately 25 feet, extend below the somewhat impervious surface layers, and in some of these pit excavations lenses or deposits of pure sand and gravel were encountered. The bottom and sides of these pits were sealed initially with a layer of clay but there is no assurance that the seal is still completely continuous and water tight. The inside walls of Pit #3 show evidence of considerable 'slipping' or 'spalling' and it is likely that some of the clay liner on the sidewalls has been destroyed. If this is the case, pronounced seepage may occur when the water level in the pit rises above these 'slip' zones."

Formerly, about 1.3 mgd of waste effluent went into the pit and thence was pumped to the Miami River. Presently, about 0.8 mgd are going into the pit, which is kept nearly brim-full. About 50 million gallons are currently in storage in the pit, which comprises an area of about 7½ acres. Although the flow into and out of the pit is known with some accuracy, it is probable that several tens of thousands of gallons per day of effluent could seep from the pit without being detected.

Seepage into the underlying aquifer has been occurring ever since the pit was placed in use, as indicated by contamination in varying degree, reported in the shallow test wells drilled around the pit. Test wells 3 and 5 became contaminated in 1959, and test wells 1, 2, and 4, first showed contamination late in 1960. To date the plant's supply wells show no sign of contamination.

Of several potential contaminants, of principal concern are uranium and thorium compounds, chlorides, nitrates and fluorides. Eye (1961, p. 5) states: "Of these, the chlorides, nitrates, and fluorides are the most likely contaminants. Chlorides and nitrates are present in the wastes in high concentrations (in the 1,000's of parts per million by weight). The chlorides and nitrates are extremely soluble and the fluorides relatively soluble. The uranium products are only slightly soluble and as such are probably of secondary significance in a consideration of ground water pollution in the area."

Listed as follows are nitrate and chloride concentrations in water samples collected from the test wells and plant supply wells on August 3, 1962:

Well	Parts per million NO_3	Cl
Supply 1	0.8	22
Do-- 2	.4	18
Do-- 3	.4	10
Test-- 1	900	800
Do-- 2	-	-
Do-- 3	350	150
Do-- 4	11	18
Do-- 5	300	100
Maximum permitted by U.S. Public Health Service for drinking water	45	250

More complete analyses of water samples from test well 1, plant supply well 1 and disposal pit 3, made by the National Lead Co. of Ohio, are listed as follows:

No 1 test well (sample collected September 16, 1962)

Constituents	Parts per million
Total hardness, as $CaCO_3$	1,460
Ca as $CaCO_3$	922
Mg as $CaCO_3$	538
Chlorides, as chlorides	820
Nitrates, as nitrates	1,350
Fluorides, as fluoride	1.12
Uranium, as uranium	.024
Alpha activity (disintegrations per minute per milliliter)	.04
Beta activity (disintegrations per minute per milliliter)	.05
pH	7.22
Total dissolved solids, based on conductivity	3,100

No 1 supply well (composite samples collected chiefly in past 6 months)

Constituents	Parts per million
Total hardness as $CaCO_3$	368
Ca as $CaCO_3$	248
Mg as $CaCO_3$	120
Methyl orange alkalinity as $CaCO_3$	294
Sulfates, as sulfate	72
Chlorides, as chloride	16
Silica as SiO_2	10.5
Nitrates, as nitrate	0.7
Fluorides, as fluoride	0.12
Uranium, as uranium	0.003
Iron, as Fe	3.0
Total dissolved solids based on conductivity	424
pH	7.25
Alpha activity (disintegrations per minute per milliliter)	.03
Beta activity (disintegrations per minute per milliliter)	.01

Pit 3 (samples collected during past several months)

Constituents	Parts per million
Total hardness, as $CaCO_3$	5,260
Ca as $CaCO_3$	1,220
Mg as $CaCO_3$	4,040
Phenol alkalinity as $CaCO_3$	80
Methyl orange alkalinity as $CaCO_3$	560
Chlorides, as chloride	4,500
Nitrates, as nitrate	2,950
Sulfates, as sulfate	400
Fluorides, as fluoride	29
Uranium, as uranium	1.95
Iron, as Fe	0.54
Oil	4.0
Organic (ether extractable)	33
Silica as SiO_2	10
Phosphate as PO_4	1.4
Chromium as Cr	2.2
Total suspended solids	17
Total dissolved solids, based on conductivity	30,000
pH	8.62
Alpha activity (disintegrations per minute per milliliter)	4.04
Beta activity (disintegrations per minute per milliliter)	.95
Radium (micro micro gram per milliliter)	.06

The concentrations of the contaminants in the test wells fluctuate depending on the relative rates at which the wells are being pumped. In the fall of 1960 test well 1 yielded as much as 3,000 ppm (parts per million) Cl before continuous pumping at the rate of 220 gpm lowered these concentrations to near their present levels.

On the basis of presently available information it is not possible to determine either how far contamination has spread beyond the pits or whether the contaminants have leaked through the clay layer into the lower aquifer. Several additional test wells located between the pits and the production area and tapping both aquifers would be required to provide this information. On the basis of the piezometric contours (figure 3) the pit area is situated west of the major ground-water divide, and the contaminated water, once it leaves the immediate vicinity of the pits, will move toward the Miami River between Fernald and New Baltimore. It would thus appear that there is no danger of contaminating the Southwestern Ohio Water Co. supply. But the ground-water divide is not static. Its position is constantly shifting in response to changes in pumping and recharge. Although movement of ground-water from the pit area to the Southwestern Ohio Water Co. well field does not appear likely it cannot be ruled out. It can be stated with reasonable certainty, however, that there would be no potential danger of contaminating the proposed Cincinnati well field near Fairfield. The water table in this vicinity stands at an altitude of about 550 feet, nearly 30 feet higher than its altitude at the Fernald plant. The possibility that pumping at the proposed Cincinnati installation would spread a cone of depression downstream far enough to intercept ground-water runoff from the Fernald plant is indeed remote.

If contaminated water continues to enter the aquifer at the present rate some of the contaminant almost certainly will move into the cones of depression around the plant supply wells and, after leaking downward through the clay layer, will enter those wells. The chemical properties of the clay bed may be of great importance, therefore, with respect to potential contamination, as in passing through this bed concentrations of some of the more harmful constituents may be reduced. If the pits could be sealed to prevent further contamination of the aquifer, the contaminants already in the aquifer probably would eventually be sufficiently diluted to render them harmless. The need for sealing the pits to prevent further contamination cannot be too highly stressed.

Of major concern is the possibility that a catastrophic break might occur in the lining of the disposal pits, allowing the quick release of all the contaminant to the underlying aquifer. This would result initially in a ground-water mound being formed beneath the pits, thus steepening the hydraulic gradient locally, and causing water to move outward rapidly from the pits, possibly at a rate as high as 20 or 25 feet per day. Most of this water would bypass the test wells, even though these wells were being pumped to their present maximum capacity, and eventually would arrive in the area of influence of the plant supply wells. The rate of movement of the contaminanted water would decrease progressively with its distance from the pits, as the hydraulic gradient became less steep.

An accident to the pit bottom might require drastic measures to prevent contamination of the plant supply wells. The supply wells might have to be relocated -- perhaps to a site upgradient from the pits -- or wells might have to be drilled and pumped between the pits and the supply wells. Such pumping would probably contain the contaminant and prevent it from reaching the supply wells, but disposal of the contaminated water pumped would create a problem in itself. The slow rate of ground-water movement would fortunately allow time for remedial action before the contaminants spread too far beyond the pit area.

SUMMARY AND RECOMMENDATIONS

The Fernald plant of the AEC is located on a high terrace, composed of poorly permeable glacial till about 50 feet thick, overlying the highly permeable sand and gravel aquifer which fills the ancestral Miami River valley. In the vicinity of the plant the sand and gravel is divided into two aquifers, each about 75 feet thick, by a layer of clay about 10 to 20 feet thick. The clay layer, though poorly permeable, is capable of transmitting large quantities of water from one aquifer to the other where a head difference between these aquifers exists. The regional hydraulic gradient of the sand and gravel aquifer is about 7.5 feet per mile toward the southeast. Near the east border of the Government Reservation is a ground-water divide, east of which water moves eastward toward the Southwestern Ohio Water Co. collectors.

Contaminated water from the waste disposal pits northwest of the production area has already entered several test wells surrounding the pits. How far beyond the pit area contamination extends is as yet unknown, but it is assumed that contaminated water has moved beyond the test wells in response to the regional hydraulic gradient. Owing to the slow movement of ground water in the area, it will take from 2 to 5 years for contaminated water to reach the plant supply wells and from 25 to 30 years for it to reach the Miami River.

The following specific recommendations are made both to determine more precisely the extent and degree of contamination, and to minimize chances of greater contamination in the future:

(1) Approximately 18 test wells should be drilled as indicated on figure 4. Three of these should penetrate the clay confining bed into the lower aquifer, while the remainder should terminate in the upper aquifer at a depth of 70 to 100 feet. The shallow test wells should be drilled to the top of the semi-confining clay layer. Accurate logs should be kept of all wells. Samples should be collected, and changes in the water level as the wells are deepened should be carefully noted. An experienced geologist should observe and supervise all drilling.

(2) Monthly samples should be taken from all test wells, both existing and proposed, to determine the extent of contamination. A portable submersible pump would be suitable for such sampling.

(3) Periodic measurements of the static (non-pumping) water level should be made in all wells to determine any shifting of ground-water divides caused by changed patterns of pumping. These data should be pooled with similar measurements already being made by the Southwestern Ohio Water Co.

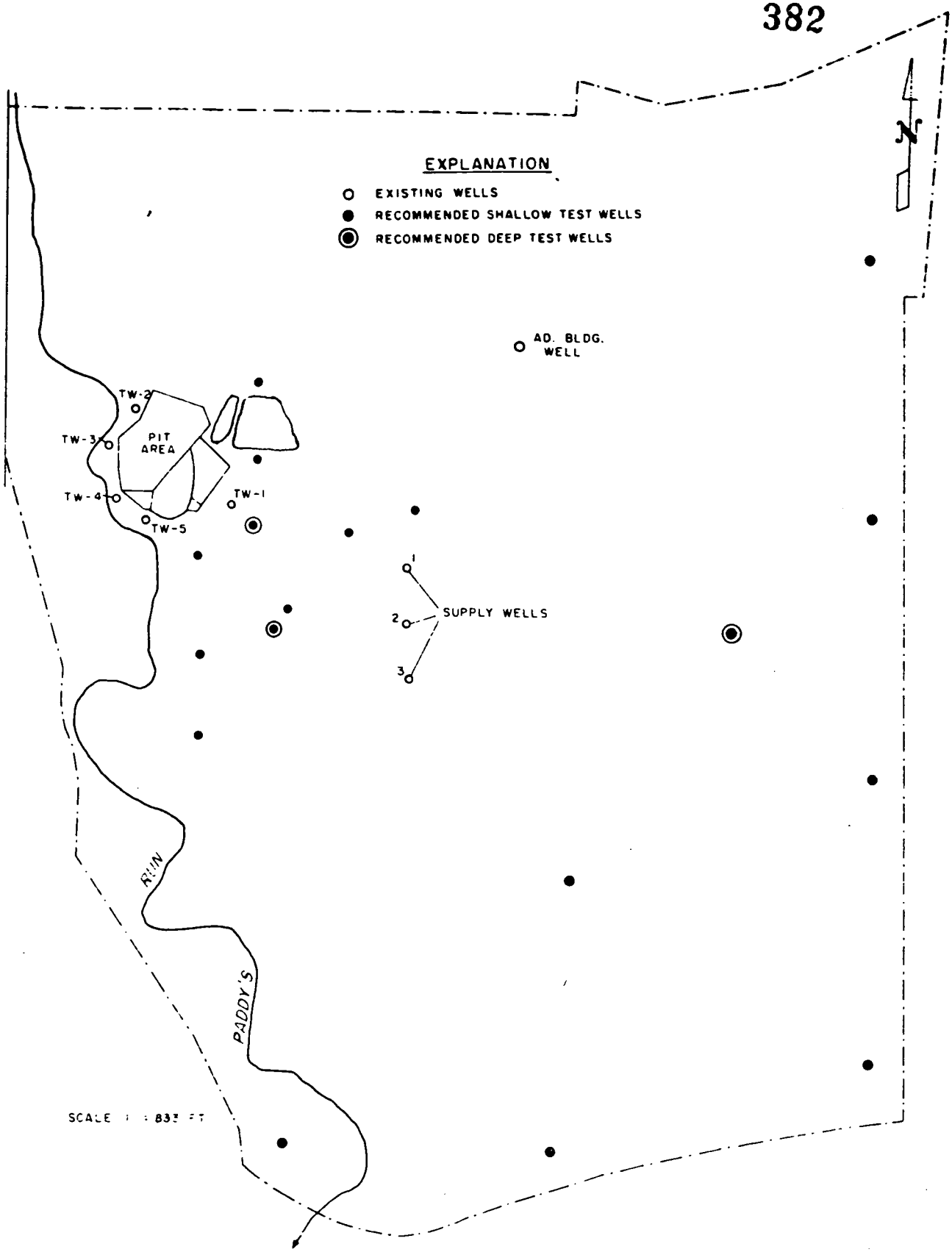


Figure 4. Map showing approximate location of existing and recommended additional wells at U. S. Government Reservation.

(4) All possible steps should be taken to prevent contaminants from continuing to enter the aquifer. This will no doubt involve more effective sealing of the bottoms of existing disposal pits. An alternate pit should be constructed so that it can be used while the existing pits are being repaired. Having an alternate pit would furthermore provide for protection in case of accidental damage to one of the existing pits.

(5) If it is determined that contaminated water in significant amount is leaving the pit area, a program of protective pumping should be instituted, and plans should be made for relocating the supply wells in the event the situation cannot be corrected by pumping. Adequate steps for safe disposal of the contaminated water must be taken.

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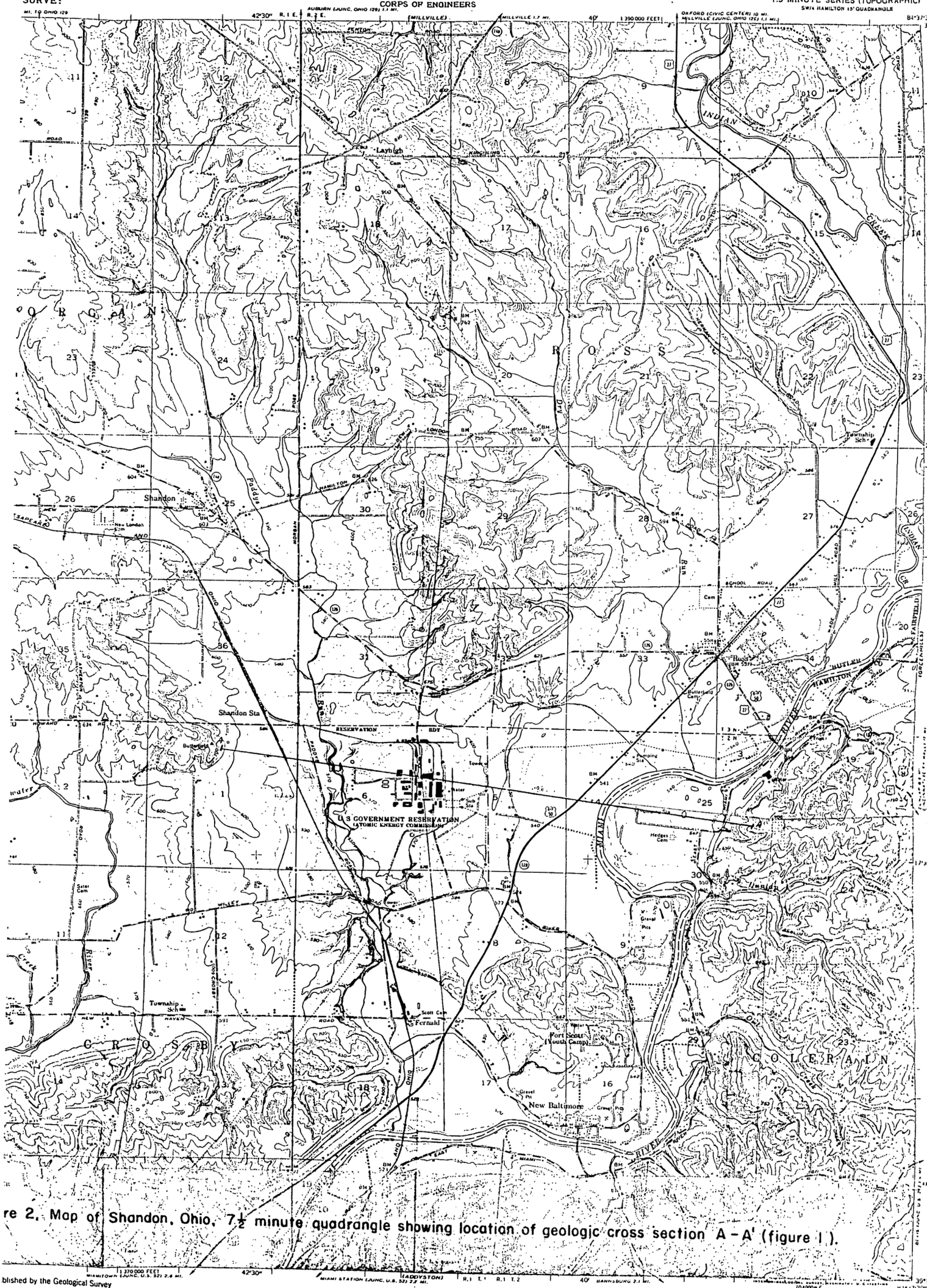
DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS

SHANDON QUADRANGLE
OHIO
7.5 MINUTE SERIES (TOPOGRAPHIC)
SW/4 HAMILTON 15' QUADRANGLE



re 2. Map of Shandon, Ohio, 7½ minute quadrangle showing location of geologic cross section A – A' (figure 1).

DO NOT SCALE

blished by the Geological Survey
and City of Cincinnati
graphs by photogrammetric
taken 1954. Field check 1955
North American datum
hio coordinate system, south zone
erse Mercator grid ticks,
st Miami River Base
by private
ase
own in brown

SCALE 1:24000

CONTOUR INTERVAL 10 FEET
DATUM IS MEAN SEA LEVEL

APPROXIMATE MEAN DECLINATION, 1955

ROAD CLASSIFICATION
Heavy duty — Light duty
Medium duty — Unimproved dirt
U.S Route — State Route

QUADRANGLE LOCATION

THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U. S. GEOLOGICAL SURVEY, WASHINGTON 25, D. C.
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

SHANDON, OHIO
SW/4 HAMILTON 15' QUADRANGLE
N5915-W8437.5/7.5
1955

34

382

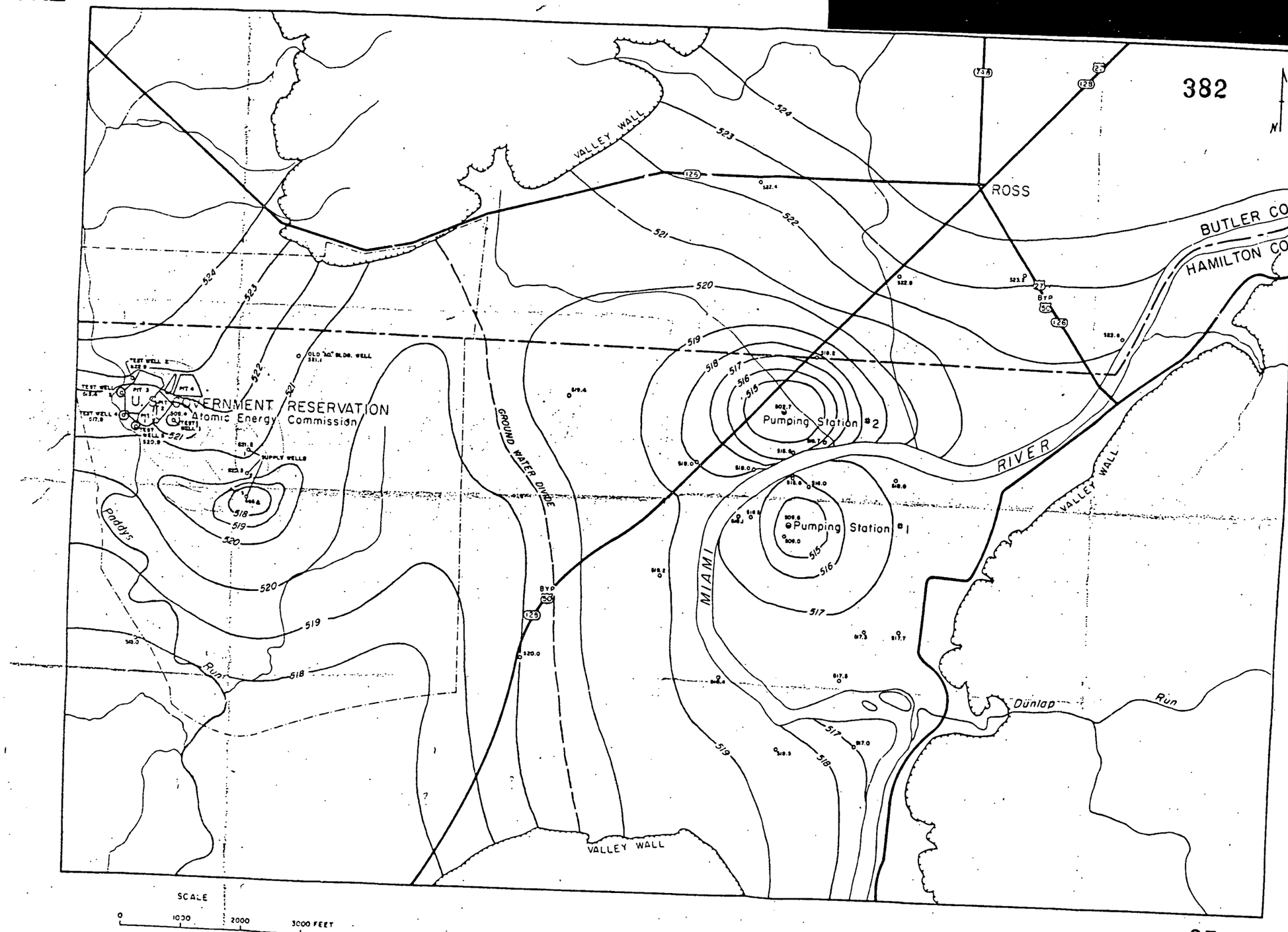


Figure 3. Map of the Miami River Valley in the vicinity of the U. S. Government Reservation showing configuration of the piezometric surface, based on Measurements made in wells on August 7-8, 1962. (Not all contours are shown around pumping wells.)