United States Department of the Interior
GEOLOGICAL SURVEY
Water Resources Division
6023 Guion Road, Suite 201
Indianapolis, Indiana 46254
317-927-8640

133039

June 28, 1982

Mr. James Dragna, Attorney
U.S. Environmental Protection Agency
Mail WH527F
2nd Floor Fairchild Building
499 South Capitol Street, S.W.
Washington, D.C. 20460

Dear Mr. Dragna:

Theodore K. Greeman

I am sending you the report, "Lineament and fracture-trace analysis for the Kessler Site, Upper Merion Township, Pennsylvania." This Administrative Report was approved for release only to your agency. A copy is on record in the Publications Management Unit, Water Resources Division, U.S. Geological Survey, Reston, Virginia 22092.

This Administrative Report must not be cited as a publication. Any reference to the material in this report should be identified as written communication with the author.

Sincerely yours,

Dennis K. Stewart
District Chief

Enclosure

cc: Rob Clemens
U.S. Environmental Protection Agency
Mail WH 527
401 M. Street, S.W.
Washington, D.C. 20460

RECEIVED

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

LINEAMENT AND FRACTURE-TRACE ANALYSIS FOR THE KESSLER SITE, UPPER MERION TOWNSHIP, PENNSYLVANIA

By Theodore K. Greeman

Administrative Report

Prepared at the request of, and released to the
U.S. Environmental Protection Agency,
Office of Waste Programs Enforcement

May 1982

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CONTENTS

ILLUSTRATIONS

(Attached)

SUMMARY

The Upper Merion Reservoir near Bridgeport, Pa., furnishes an average water supply of more than 7 Mgal/d (million gallons per day) to the Philadelphia Suburban Water Company. The reservoir is in a former rock quarry that was excavated to a depth of 375 feet. Water enters the reservoir through numerous vertical and nearly vertical fractures in the massive dolomite walls. Withdrawal of water from the reservoir lowers the water table in the dolomite aquifer more than 250 feet.

Trichloroethylene was first detected in the reservoir in April 1979. To determine the possible pathways of ground-water flow to the reservoir, numerous lineaments and fracture traces were mapped in the area surrounding the reservoir. Mapping was done with 1948 and 1965 stereo-aerial photographs. Spacing between parallel sets of mapped features ranges from 125-140 feet. Two principal lineament and fracture-trace alinements were observed, west-northwest to east-southeast and north-northeast to south-southwest. These alinements correspond to those of vertical or nearly vertical bedrock features on the quarry walls. A third fracture alinement in the quarry (east-west) apparently does not correlate with lineaments or fracture traces.

Owing to withdrawals for public supply, the water level in the reservoir is lower than the water in the surrounding dolomite aquifer, therefore, water in the dolomite moves through the fractures into the reservoir. The daily inflow of ground water to the reservoir is more than 7.25 Mgal when the water level is maintained at an altitude of -125 feet. (National Geodetic Vertical Datum of 1929 is used in this report.)[1] At the Kessler site, 0.6 mile south of the reservoir, the altitude of the water table is about 75 feet or about 75 feet below the land surface, and flow is to the north toward the reservoir.

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[1]A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called "Mean Sea Level."

INTRODUCTION

The Upper Merion Reservoir, an abandoned quarry in a highly industrialized area southwest of Bridgeport, Pa., (fig. 1) has been used as a public water supply by the Philadelphia Suburban Water Company since 1969. The supply has averaged slightly more than seven (7) Mgal/d and has generally ranged from five (5) to ten (10) Mgal/d.

When quarrying was stopped in the late 1960's, approximately 17 million cubic yards of dolomite had been removed, and a pit about 1,000 feet in diameter and 375 feet deep had been excavated. During quarrying, ground water entering the pit through fractures and interconnected openings in the dolomite bedrock had to be continuously removed. Dewatering lowered the water level to -225 feet, during active quarrying. In early 1981, when the water level in the reservoir was -125 feet, ground water entered the reservoir at a rate of more than 7.25 Mgal/d.

In the late 1960's, before the Philadelphia Suburban Water Company began pumping water from the pit, the water was determined to be suitable for public supply (Fox, 1981, p. 1). Because most of the industries near the reservoir had been established for many years, the consultants concluded that the potential for future contamination was slight.

In April 1979, routine sampling and analysis of water from the reservoir indicated that organic chemicals were present. One of the organic chemicals detected is trichloroethylene, a carcinogen commonly used as a dry-cleaning agent and a metal degreaser. The source of the chemicals was unknown. In October 1979, Leggette, Brashears, and Graham, Inc., a consulting firm, was hired to identify the source(s) and to design a system to remove the chemicals from the ground water (Fox, 1981, p. 1).

To locate the source(s) of possible contamination, the consultants: (1) studied the geology of the reservoir and measured numerous vertical or nearly vertical fractures (joints) in the bedrock; (2) used sixteen wells near the reservoir to determine the ground-water-flow pattern and the gradient; and (3) compared water-quality analyses of samples collected from the reservoir, monitoring wells, streams, and an industrial cesspool.

The potentiometric surface in the dolomite aquifer near the reservoir (fig. 2) indicates that the ground-water flow gradient from the south is steeper than the gradients from the east-northeast and the west-southwest. Although no monitoring wells are located north of the reservoir, water levels near the reservoir indicate that ground-water flow is toward the reservoir from all directions.

Because of the massive texture of the dolomite, as exposed in the reservoir walls, and the large volume of water available from the reservoir, the consultants concluded that water moves through the dolomite aquifer by way of the numerous highly transmissive bedrock fractures (Fox 1981, p. 5).

As the Federal regulatory agency in charge of protecting public water supplies from contamination, the U.S. Environmental Protection Agency (EPA) became involved in locating the source(s) of the contaminating chemicals and preventing further contamination. Because of the connection between ground-water movement and vertical bedrock fractures, the EPA requested that the U.S. Geological Survey prepare a fracture-trace and lineament analysis of the area surrounding the Upper Merion Reservoir.

BACKGROUND

The Upper Merion Reservoir is in an east-west trending valley. This valley is underlain by tightly folded siliceous dolomite that ranges in age from Cambrian to Ordovician (approximately 500 million years). The hills to the north and south of the valley are composed of metamorphic schistose quartz-mica rock. A more recently deposited arkosic sandstone overlies the metamorphic and dolomitic rocks along the north side of the valley.

The reservoir is in a pit resulting from the quarrying of dolomite (Ledger Dolomite). The walls of the reservoir indicate the Ledger Dolomite is a massive dolomite having bedding planes dipping to the south at an angle of about 55°. Vertical and nearly vertical bedrock fractures, called joints, can be seen in the walls of the reservoir. These fractures are alined in three orientations; northeast-southwest and northwest-southeast alinements in approximately equal numbers and east-west alinements that are much less prevalent (Fox, 1981, p. 3).

The original (prequarrying) water level in the valley was probably within 50 feet of land surface. Thus, within the valley, the static water table sloped eastward from an altitude of more than 200 feet, 0.5 mile west of the reservoir site, to 45 feet at the Schuylkill River 1.5 miles east of the reservoir. The altitude of the prequarrying water level at the reservoir site was probably about 125 feet. In order to operate the quarry below this level, the owners had to dewater the pit. When quarrying was suspended, dewatering had lowered the water level to an altitude of -225 feet or about 350 feet below the original water level.

Most of the water moving through the dolomite is transmitted along bedding planes and vertical fractures while water in the pore space of the Dolomite is in storage. The considerable variability in yield of wells drilled in dolomite depends on the location of the wells in relation to bedding planes and fractures in the rock. Yields of wells drilled in dolomite can range from less than 1 gal/min (gallon per minute) to more than 2,000 gal/min (Davis and DeWiest, 1966, p. 356).

The problem of well-yield variability in bedrock aquifers attracted the interest of geologists studying linear features observed on aerial photographs. Working with carbonate rock similar to that at the Upper Merion Reservoir, Lattman and Parizek (1964, p. 79) described lineaments and fracture traces as linear to slightly curvilinear natural features consisting of topographic, vegetation, soil-tone, and drainage alinements that are visible on aerial photographs and mosaics. These features delineate underground solution zones that affect the movement and the occurrence of water in limestone and dolomite. Lattman and Parizek (1964, p. 90-91) further suggest the use of lineament and fracture-trace mapping as a significant tool for ground-water prospecting in many rock types. The difference between lineaments and fracture traces, according to Lattman (1958), is length. Lineaments are discernible for 1 mile or more and may be discerned as several segments totaling many miles. Fracture traces are less than 1 mile in length. In bedrock areas, joints visible on aerial photographs are included. Work by Moore (1976, p. 30) and Hine (1970, p. 21) has determined that lineaments and fracture traces are the mappable expressions of vertical bedrock fracture, and are preferential paths for ground-water movement. Greeman (1981) indicated that most of the ground water flowing through a dolomite aquifer follows preferential pathways toward the lowest local discharge point, which is normally a stream. However, pumping from the Upper Merion Reservoir maintains a water-level altitude in the reservoir of about -100 feet, or 150 feet below the level of the Schuylkill River. Therefore, near Bridgeport, Pa., ground-water flow in the Ledger Dolomite is toward the Upper Merion Reservoir, and preferential flow passages are the vertical and nearly vertical fractures that can be mapped from aerial photographs as lineaments and fracture traces.

PROCEDURES

Lineaments and fracture traces in the area surrounding the Upper Merion Reservoir were mapped from stereoscopic inspection of aerial photographs. Several sets of photographs representing various stages in the industrial and residential development in the area were viewed.

By definition, lineaments and fracture traces must be visible on aerial photographs. Therefore, the success of the interpreter depends on resolution, scale, and contrast of the available photographs. Owing to urban development around the reservoir, old photographs of the area are preferable to more recent ones.

Two sets of black and white photographs were used in the aerial mapping. The most recent set was taken in March and April 1965. This set, whose scale is 1:24,045, has good resolution. Urbanization of the area around the reservoir limits the use of the 1965 photographs. The second set was taken in May 1948. This set, at a scale of 1:21,000, also has good resolution. Urbanization was less extensive in 1948. Additional sets of aerial photographs taken in November 1937 and October 1942 were also examined but were not used because of poor quality.

Lineaments and fracture traces were interpreted by viewing the aerial photographs through a mirror stereoscope. This instrument gives the interpreter a three-dimensional view of the landscape. Mapping on the 1965 set of photographs was penciled directly on the prints. The 1948 photographs are transparencies. Therefore, mapping was penciled on one blue-line copy.

After the mapping was completed, map scales were adjusted and the mapped lineaments and fracture traces were transferred to mylar overlays (figs. 3 and 4) of the standard Norristown and Valley Forge, Pennsylvania Quadrangles, 7.5-minute series, topographic maps having a scale of 1:24,000 (1 inch = 2,000 feet).

RESULTS AND INTERPRETATIONS

Numerous lineaments and fracture traces were mapped in the vicinity of the Upper Merion Reservoir. Lineaments and fracture traces are abundant, well developed, and continuous, which indicates that the underlying Ledger Dolomite contains numerous vertical to nearly vertical fractures.

Although several fractures are mapped in the hills north and south of the reservoir, they are not well developed. These hills are composed of metamorphic schistose quartz-mica rock, which is more insoluble than dolomite.

Mapped lineaments and fracture traces are found in two principal alinements, west-northwest to east-southeast and north-northeast to south-southwest. These alinements correspond to the principal bedrock joints measured on reservoir walls. A third east-west alinement measured on the reservoir walls was not mapped as a fracture-trace orientation on the photographs. This suggests that east-west alined joints have a minor influence on the movement of ground water.

The depression created in the water table by the removal of water from the reservoir (fig. 2) is elongated in a northeast-southwest orientation. The shape of the depression indicates that the flow of water through the dolomite aquifer is not equidimensional. The orientation of the major fractures and the combined effects of structure and lithology are the reasons for the asymmetrical flow. The ridge 1 mile south of the reservoir is composed of impermeable rock, which acts as a barrier to ground-water flow and causes the ground-water depression to spread outward in the direction of greater permeability. The ground-water depression extending more than 1.6 miles east of the reservoir indicates that part of the water reaching the reservoir comes from the Schuylkill River. At the Kessler site, south of the reservoir, the ground-water-flow gradient toward the reservoir is much steeper than those toward the reservoir from the northeast and southwest. The shape and the gradient of the ground-water depression north of the reservoir is undefined. Inflows into the northwest quadrant of the quarry (Fox, 1981, p. 3) indicate a possible connection to the arkosic sandstone in that area.

The 1948 photographs show that the quarry walls contain numerous bedrock joints spaced about 30 feet apart. Although numerous lineaments and fracture traces are mapped near the reservoir, their spacing is generally greater than 125 feet. Therefore, mapped lineaments and fracture traces tend to overlie only major bedrock joints, which are probably the principal conduits for the movement of ground water to the reservoir. Although a source of ground-water contaminants cannot be determined from aerial photographs, these photographs probably indicate the principal pathways for the movement of contaminated ground water.

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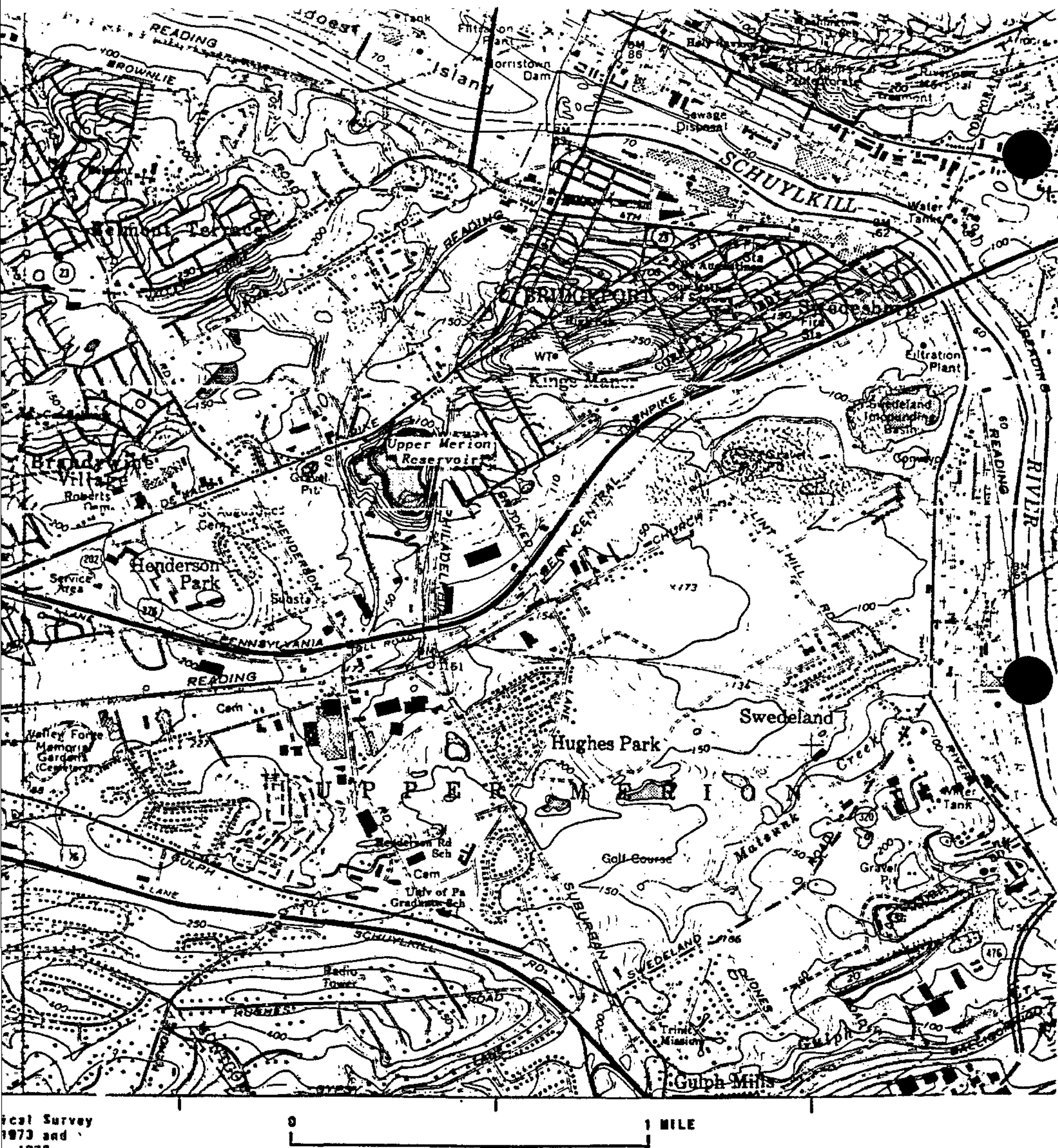

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Figure 1.— Area near the Upper Merion Reservoir, Bridgeport, Pa.

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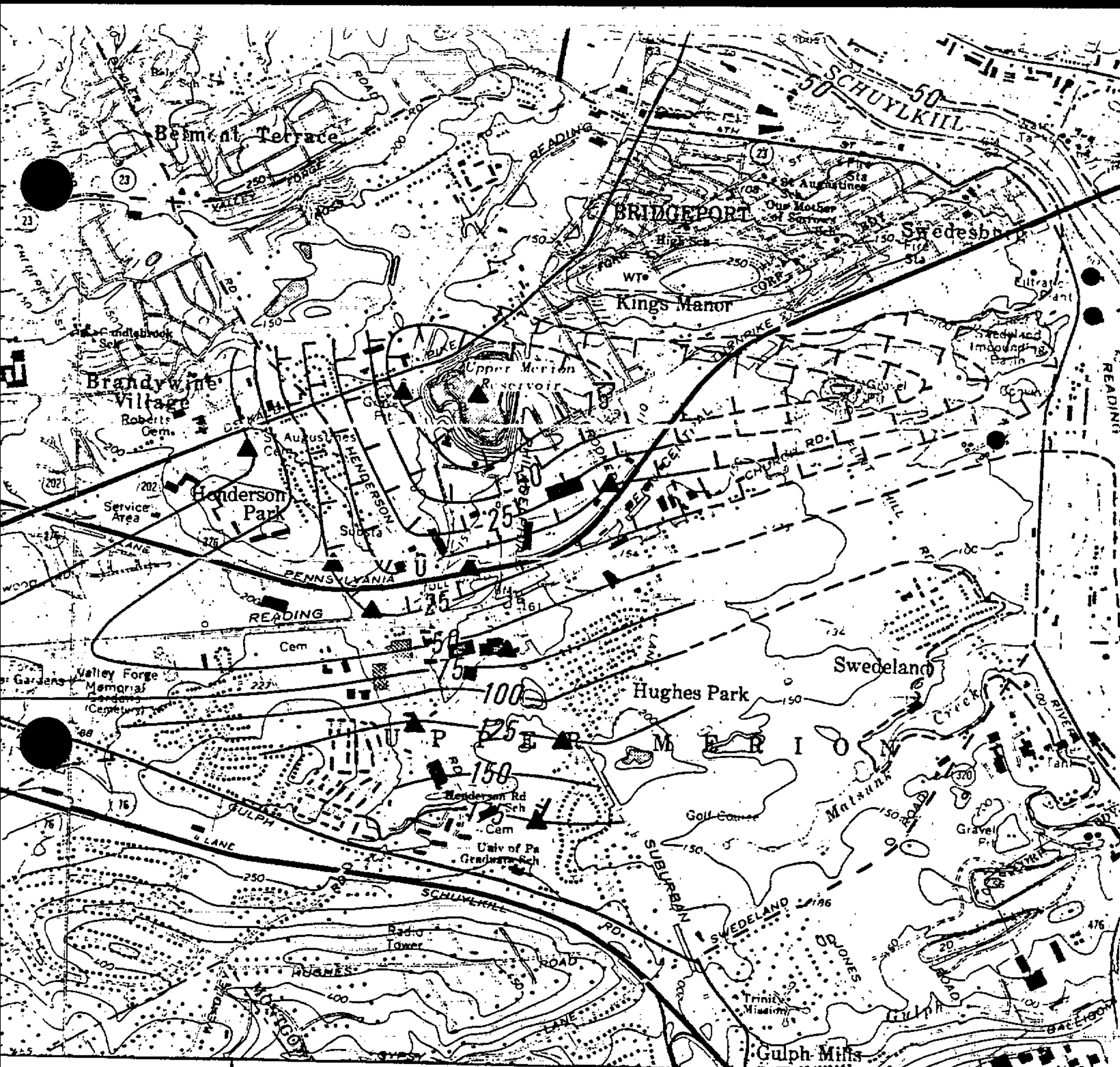

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Hydrologic data from (1981, figs.4 and 5).

EXPLANATION

—50— Line of equal potentiometric surface, dashed where approximate. Interval 25 feet

▲ Sites where water level was measured, May 8, 1981

● Sites where water level was measured, June 18, 1981

Figure 2.-- Potentiometric surface in the dolomite aquifer near the Upper Merion Reservoir, Bridgeport, Pa.

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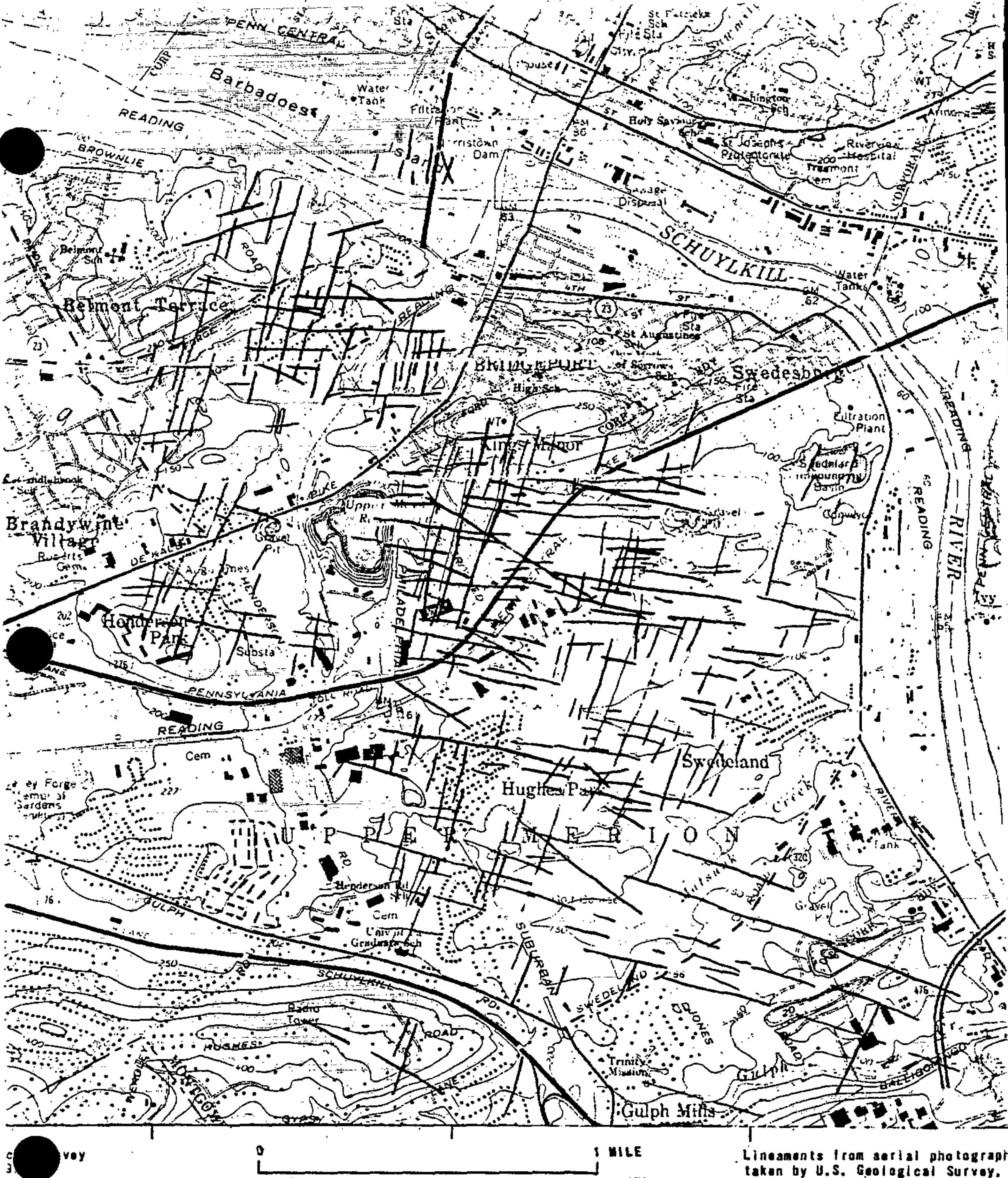
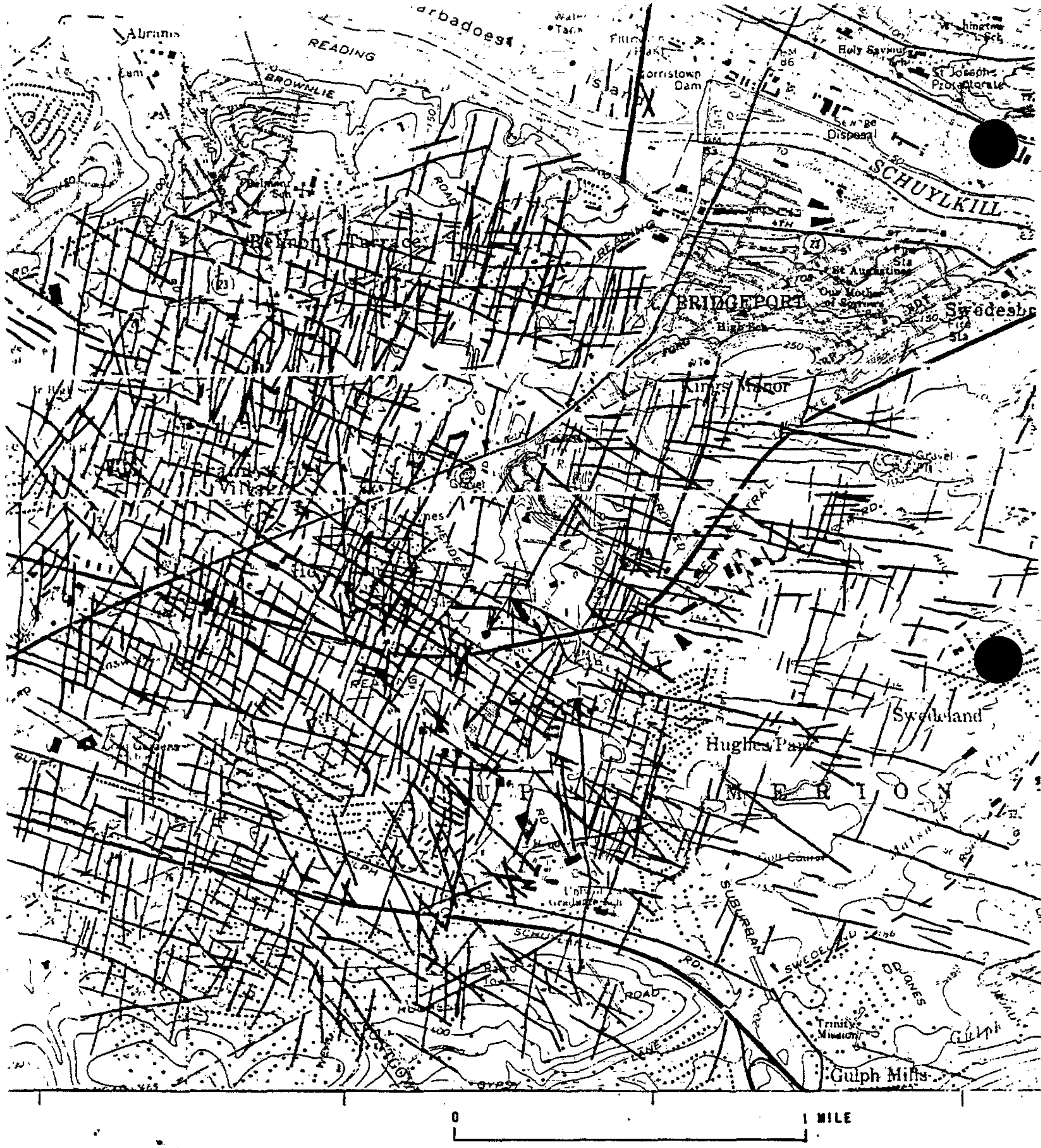
Figure 3.-- Lineaments and fracture-traces in the vicinity of the Upper Merion Reservoir, Bridgeport, Pa.



Lineaments from aerial photographs taken by U.S. Geological Survey, March and April 1985

AR100015

F... Lineaments and Fracture-traces in the vicinity of the Upper Merion Reservoir, Bridgeport, Pa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Holy Saviour Sch
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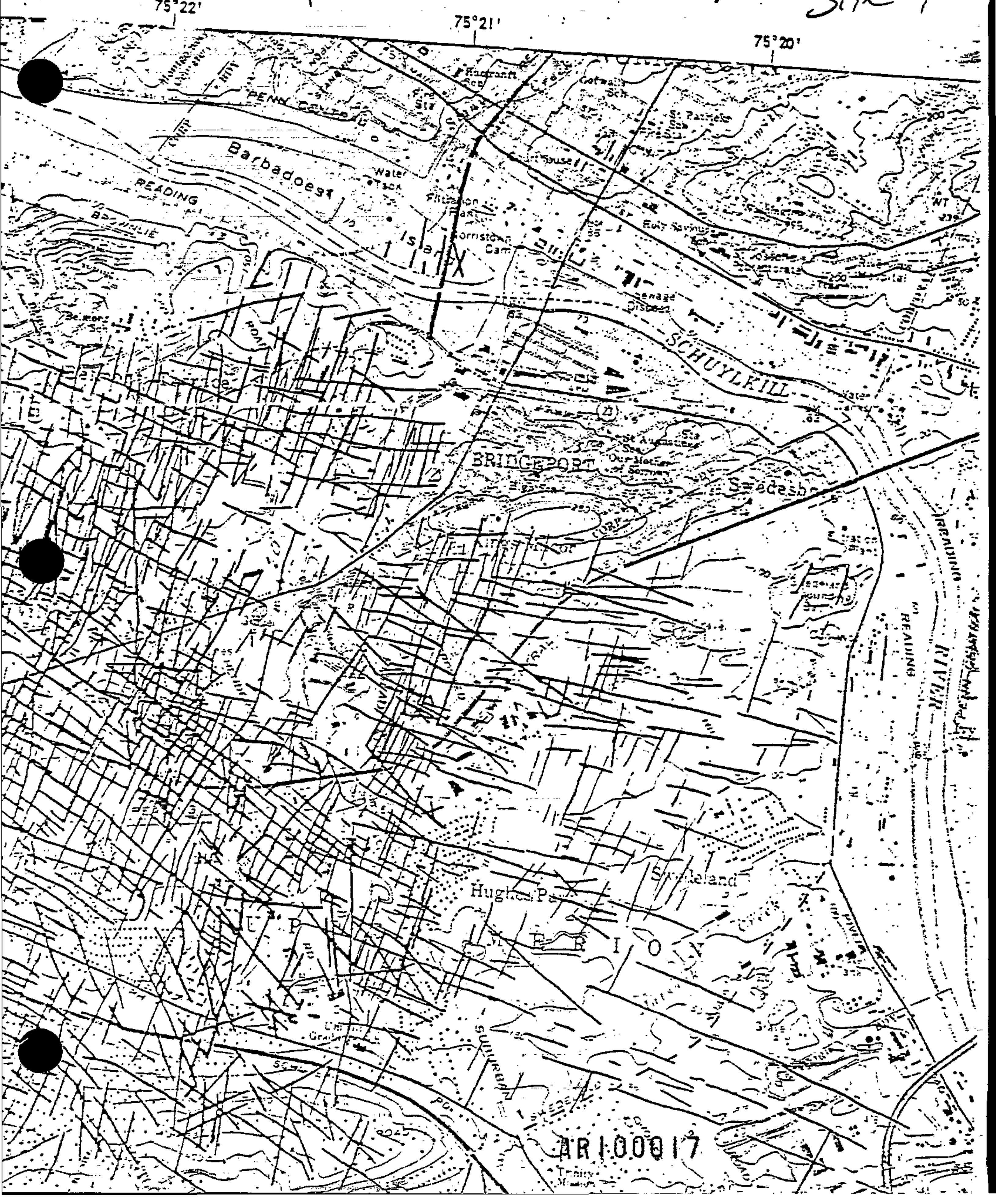
Fracture Trace Analysis TDI Site Area



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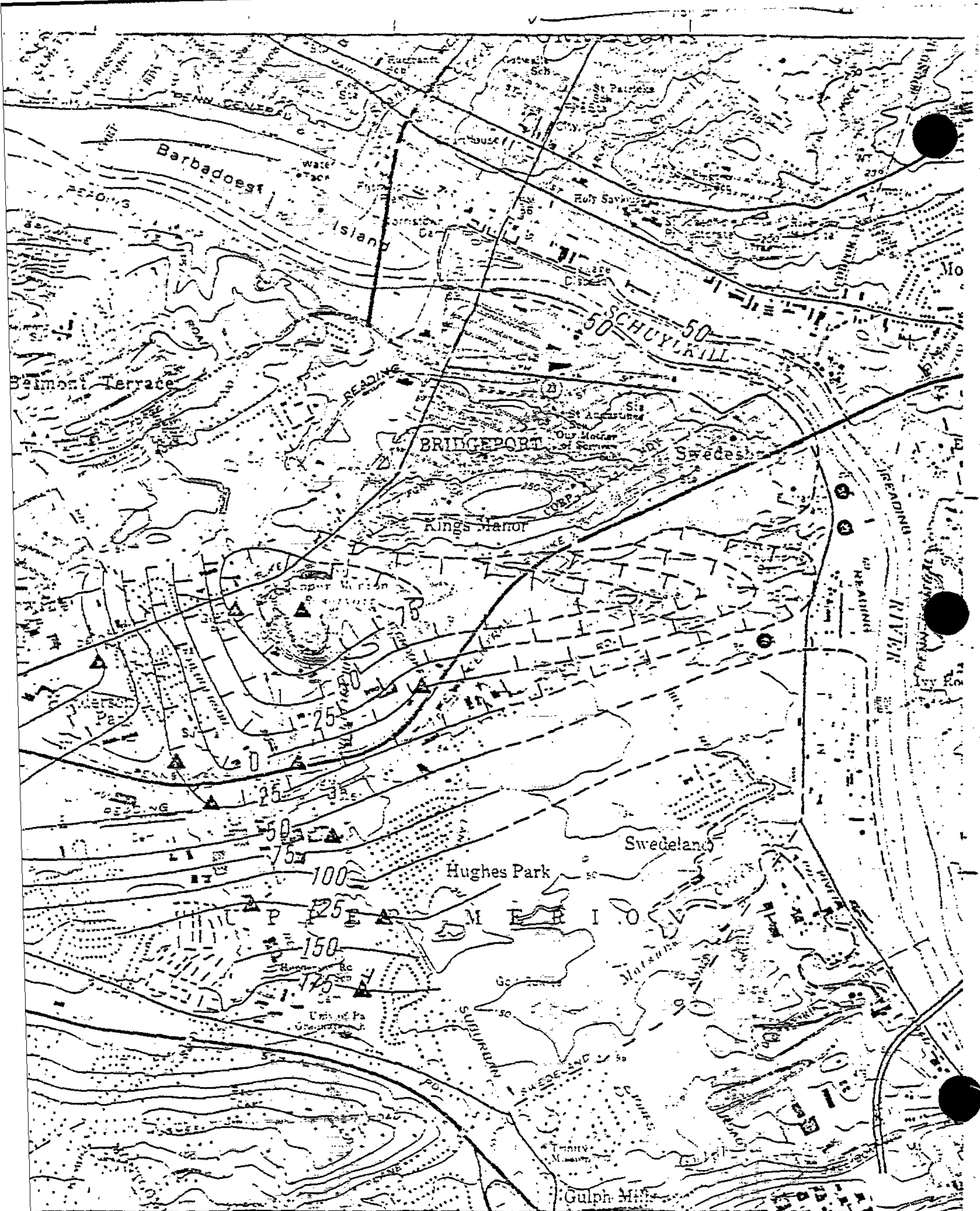

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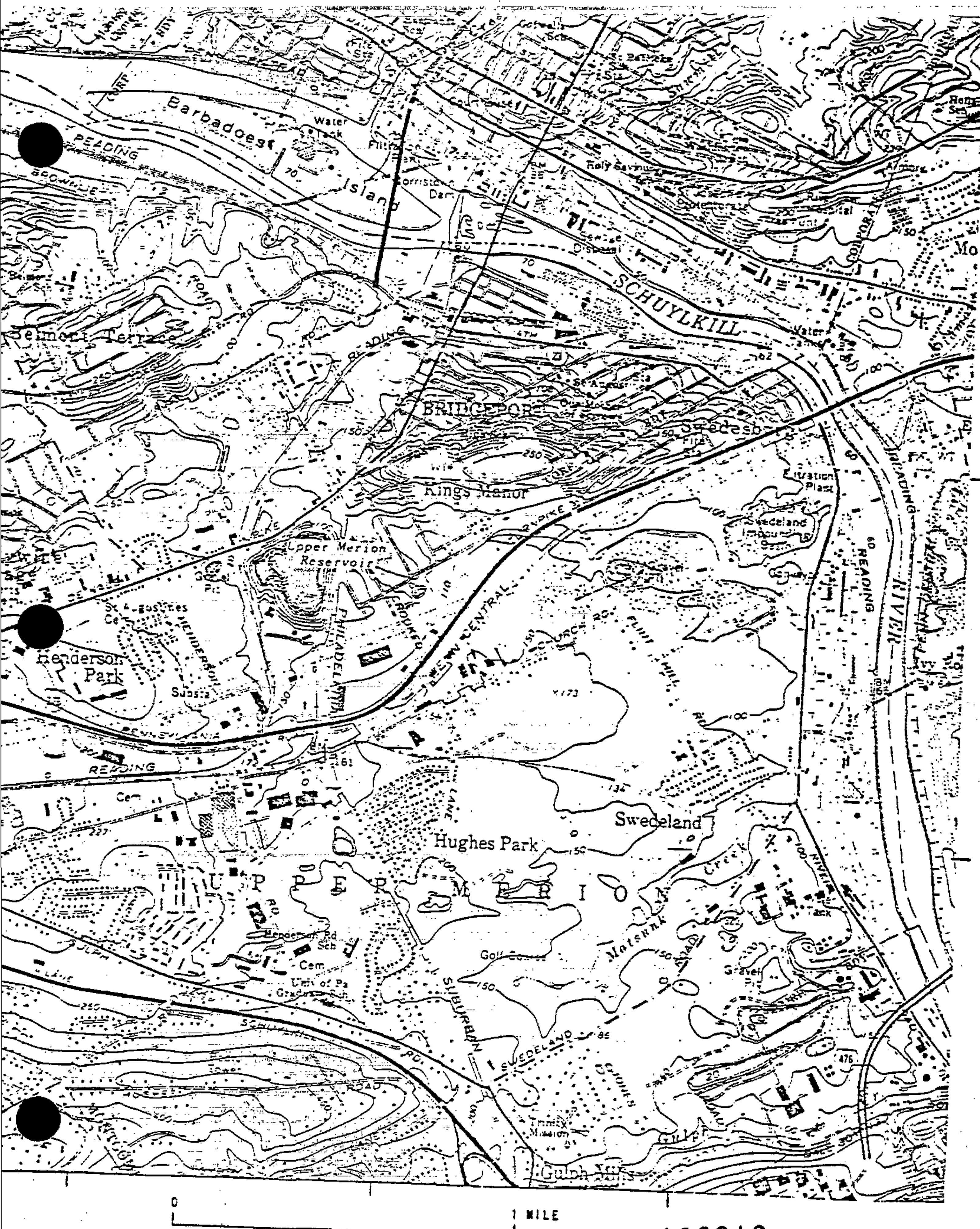
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CHURCH RD
FLINT HILL
READING
RIVER
Hughes Park
Swedeland
UPPER MERION
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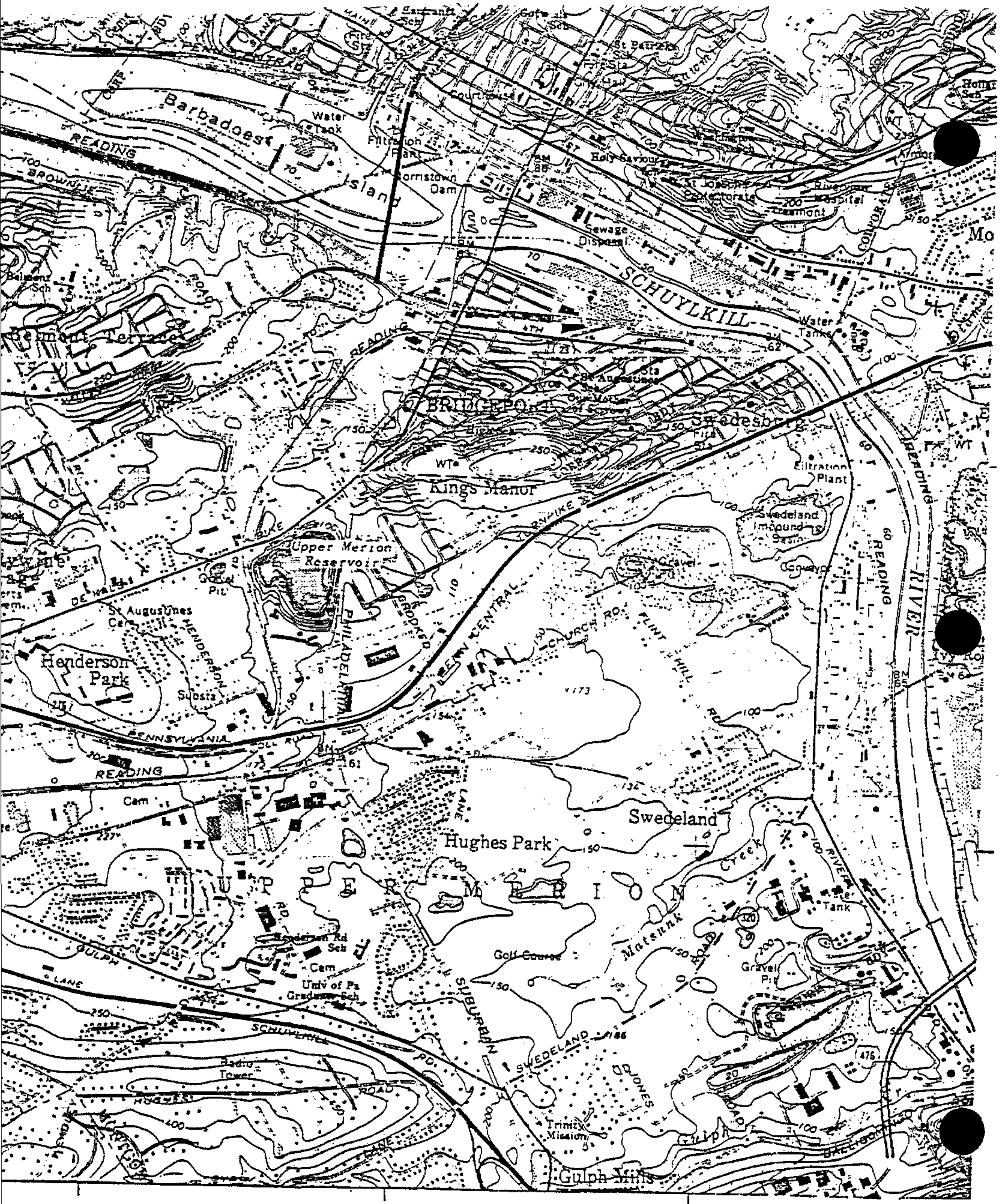
Barbadoes Island
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SCHUYLKILL
RIVER
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Filtration Plant
Water Tank
Courthouse
Holy Saviour
Sewage Disposal
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Swedesburg
Kings Manor
Upper Merion Reservoir
St Augustines Cem
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TURNPIKE
CHURCH RD
FLINT HILL RD
Filtration Plant
Swedeland Impound Basin
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Hughes Park
U P P E R M E R I O N
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