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GEOLOGY, HYDROLOGY, AND GROUND-WATER QUALITY OF CHESTER COUNTY, PENNSYLVANIA

by Ronald A. Sloto
U.S. Geological Survey

CHESTER COUNTY WATER RESOURCES AUTHORITY
Water-Resource Report 2

Prepared in cooperation with the
U.S. GEOLOGICAL SURVEY

West Chester, Pennsylvania
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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
	Length	
inch (in.)	25.4	millimeter
inch per year (in/yr)	25.4	millimeter per year
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
	Area	
square mile (mi^2)	2.59	square kilometer
	Volume	
gallon (gal)	3.785	liter
million gallons (Mgal)	3,785	cubic meter
gallon per minute (gal/min)	0.06308	liter per second
gallon per minute per foot [(gal/min)/ft]	0.207	liter per second per meter
million gallons per day (Mgal/d)	0.04381	cubic meter per second
cubic foot (ft^3)	0.02832	cubic meters
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
	Temperature	
degree Fahrenheit (°F)	°C=5/9 (°F-32)	degree Celsius

Sea level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929—geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

GEOLOGY, HYDROLOGY, AND GROUND-WATER QUALITY OF CHESTER COUNTY, PENNSYLVANIA

ORIGINAL (Red)

By Ronald A. Sloto

ABSTRACT

Chester County is a 760-square-mile area in southeastern Pennsylvania. A ground-water investigation provided basic information on the geohydrologic system and water-bearing capabilities of the geologic units, water budgets for selected surface-water basins, the relation between ground water and surface water, and statistical summaries of inorganic, organic, and radiochemical ground-water-quality data. Also included is a description for all geologic units and a new geologic map for Chester County that incorporates modern nomenclature and results of recent mapping.

Characteristics of the ground-water-flow system in Chester County, as well as aquifer hydraulic properties, are related to geology. The 41 geologic units of the county are grouped into (1) Triassic sedimentary rocks, (2) carbonate rocks, and (3) Paleozoic and Precambrian metamorphosed crystalline and sedimentary rocks. Beds of Triassic sedimentary rocks form a series of alternating aquifers and semiconfining units; each bed generally has different hydraulic properties. Most deep wells in Triassic rocks penetrate several major water-bearing zones and are multiaquifer wells. Ground water in carbonate rocks flows through a network of secondary openings enlarged by solution. Ground-water and surface-water divides in carbonate rocks commonly do not coincide, and ground water flows beneath surface-water divides to or from adjacent surface-water basins. In crystalline rocks, ground water flows through intergranular openings in the weathered zone and through a network of interconnected secondary openings in the underlying unweathered rock. The ground-water-flow system in crystalline rocks is shallow and drains to nearby streams.

Permeability in bedrock depends on the number and size of fractures and in the degree of interconnection. The number of water-bearing openings decreases with depth. Sixty-four percent of water-bearing openings are encountered within 100 feet of land surface, and 92 percent are encountered within 200 feet of land surface. The geologic units with the highest median specific capacities are the Ledger Dolomite, the Cockeysville Marble, and the Stockton Formation. The median yield of wells drilled in carbonate and Triassic sedimentary rocks is significantly higher than the median yield of wells drilled in other types of rocks.

An average water budget for 1975-88 was calculated for streams draining 46 percent of the county. The average annual precipitation was 47.5 inches. The average annual evapotranspiration was 26.2 inches, which was 55 percent of average annual precipitation. The average annual base flow was 13.5 inches, and the average annual surface runoff was 7.9 inches. Average annual recharge was 15.4 inches, which was 32 percent of average annual precipitation. The median annual base flow of streams draining Chester County ranges from 10.9 to 16.7 inches per year.

Except where adversely affected by human activities, ground water in Chester County is of good quality and suitable for most purposes. Major ions, in order of decreasing abundance are bicarbonate, sulfate, silica, calcium, chloride, sodium, magnesium, nitrate, and potassium. Water from 4 percent of wells sampled contained concentrations of total dissolved solids that exceeded the U.S. Environmental Protection Agency (USEPA) secondary maximum contaminant level (SMCL). Water from less than 1 percent of wells sampled contained concentrations of chloride and sulfate that exceeded the USEPA SMCL. Concentrations of nitrogen as nitrate in 6 percent of water samples exceeded the USEPA maximum contaminant level (MCL). No significant difference exists in the median nitrate concentration among geologic units. Of water samples analyzed, 22 percent contained concentrations of manganese and 13 percent contained concentrations of iron that exceeded the USEPA SMCL. Water from one well contained a concentration of lead that exceeded the USEPA MCL, and water from one well contained a concentration of chromium that exceeded the USEPA MCL.

Activities of radium in ground water exceeded the USEPA MCL of 5 pCi/L (picocuries per liter) for combined radium-226 plus radium-228 in water from 60 percent of the wells sampled in the Chickies Quartzite, from 17 percent of wells sampled in other quartzites, and from 18 percent of wells sampled in carbonate rocks. All ground-water samples from the Chickies Quartzite with pH less than 4.8 contained radium activities greater than 5 pCi/L. Radon-222 activities among geohydrologic groups were highest for quartzite and schist; median activities exceeded 2,000 pCi/L. Radon-222 activity exceeded 5,000 pCi/L in water from 14 percent of wells sampled.

Volatile organic compounds were detected in water samples from 32 percent of 225 wells sampled. Out of 37 compounds analyzed, 21 were detected. The most commonly detected compounds were trichloroethylene (17 percent of wells sampled) and 1,1,1-trichloroethane (13 percent of wells sampled). Phenol was detected in water from 41 percent of the wells sampled; however, concentrations exceeded 5 micrograms per liter in only 12 percent of the samples in which it was detected. Lindane (7 percent of wells sampled) and dieldrin (5 percent of wells sampled) were the most frequently detected organochlorine insecticides. Diazinon (13 percent of wells sampled) was the most frequently detected organophosphorus insecticide. The triazine herbicide alachlor was detected in 6 percent of wells sampled.

INTRODUCTION

Chester County has one of the fastest growing populations in the Commonwealth of Pennsylvania. Many areas of the county, which were formerly agricultural, are being rapidly urbanized. Approximately 60 percent of the county's residents depend on ground water as a source of water supply. As growth continues and population increases, the demand for ground water also increases.

Human activities have caused local degradation of ground-water quality. A serious consequence of industrial growth has been contamination of ground-water supplies by volatile organic compounds. Despite an intensive demand for ground water and localized contamination problems, Chester County has an abundance of high-quality ground water. Most wells yield an adequate quantity of good-quality water suitable for most domestic, commercial, and industrial uses.

This study was done by the U.S. Geological Survey (USGS) in cooperation with the Chester County Water Resources Authority and the Pennsylvania Department of Environmental Resources (PaDER), Bureau of Topographic and Geologic Survey.

Purpose and Scope

The purpose of this report is to provide basic information on the geology and the quantity and quality of ground water in Chester County, Pa. This publication supersedes a report by McGreevy and Sloto (1977). Data analysis is based on more than 1,000 additional wells and additional chemical analyses made during 1976-89. This report describes the geohydrologic system and water-bearing capabilities of the geologic units, presents water budgets for selected basins, describes the relation between ground water and surface water, and presents statistical summaries of inorganic, organic, and radiochemical ground-water-quality data. Also included is a new geologic map for Chester County that incorporates modern nomenclature and recent mapping. The report provides a description for all geologic units and summarizes relevant geologic literature to 1990. The bibliography includes all relevant references on the geology and hydrology of Chester County.

Location and Physiography

Chester County is a 760-mi^2 area in southeastern Pennsylvania (fig. 1). It lies in the Piedmont physiographic province of the Appalachian Highlands. The county is characterized by gently undulating to steeply rolling uplands, which are underlain by deeply weathered crystalline rock in most places. The uplands slope gently to the southeast. Chester Valley, which trends northeast across the middle of the county and divides the uplands, is underlain by easily eroded carbonate rock. The highest point in the county (1,071 ft above sea level) is in the northwest at the top of Welsh Mountain.

The Triassic Lowlands border the Schuylkill River in the northeastern part of the county. These lowlands were formed by erosion of the underlying sandstone and shale, which are less resistant to erosion than the crystalline rock underlying the uplands. The lowest point in the county (66 ft above sea level) is in the Triassic Lowlands where the Schuylkill River leaves the county.

Most Chester County streams have their headwaters within the county. Major drainage basins and drainage areas are shown on figure 2. The largest basin is the Brandywine Creek basin, which drains 290 mi^2 (38 percent) of the county.

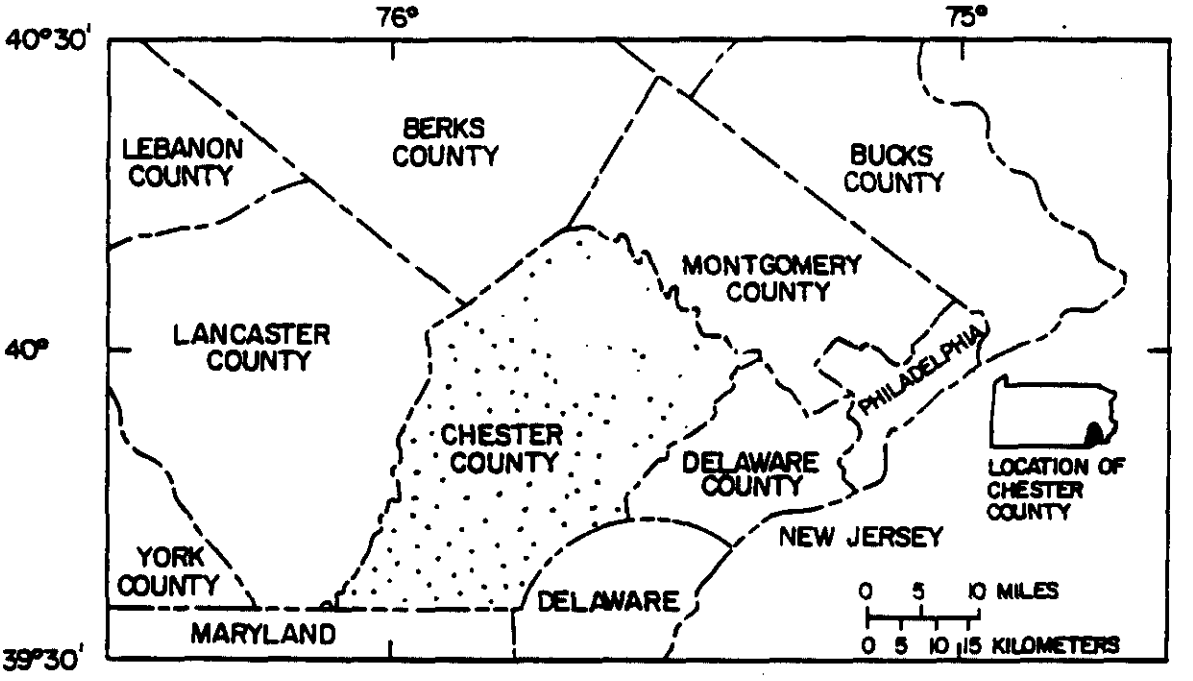

Figure 1.--Location of Chester County.

Climate

Chester County has a humid, modified continental climate characterized by warm summers and moderately cold winters. The mean annual normal (1951-80) temperature at West Chester is 52.6°F (National Oceanic and Atmospheric Administration, 1982). The mean normal (1951-80) temperature for January, the coldest month, is 29.8°F, and the mean normal temperature for July, the warmest month, is 74.8°F.

The 1951-80 annual normal precipitation at West Chester is 45.73 in. Precipitation is about evenly distributed throughout the year, with slightly more occurring during July and August.

Well-Numbering System

The well-numbering system used in this report consists of a county abbreviation prefix followed by a sequentially-assigned number. The prefix CH denotes a well in Chester County. Locations of selected wells are shown on plates 1 and 2; locations of other wells are given by Sloto (1989). Water samples from most of the wells shown on plates 1 and 2 were collected for chemical analysis during 1987-89. Data for wells shown on plates 1 and 2 are given in table 38 in the back of this report. Data on other wells are given by Sloto (1989). The prefix CH-SP denotes a spring in Chester County. Locations of selected springs are shown on plates 1 and 2. Data on springs are given by Sloto (1989). Data for springs shown on plates 1 and 2 are given in table 39 in the back of this report.

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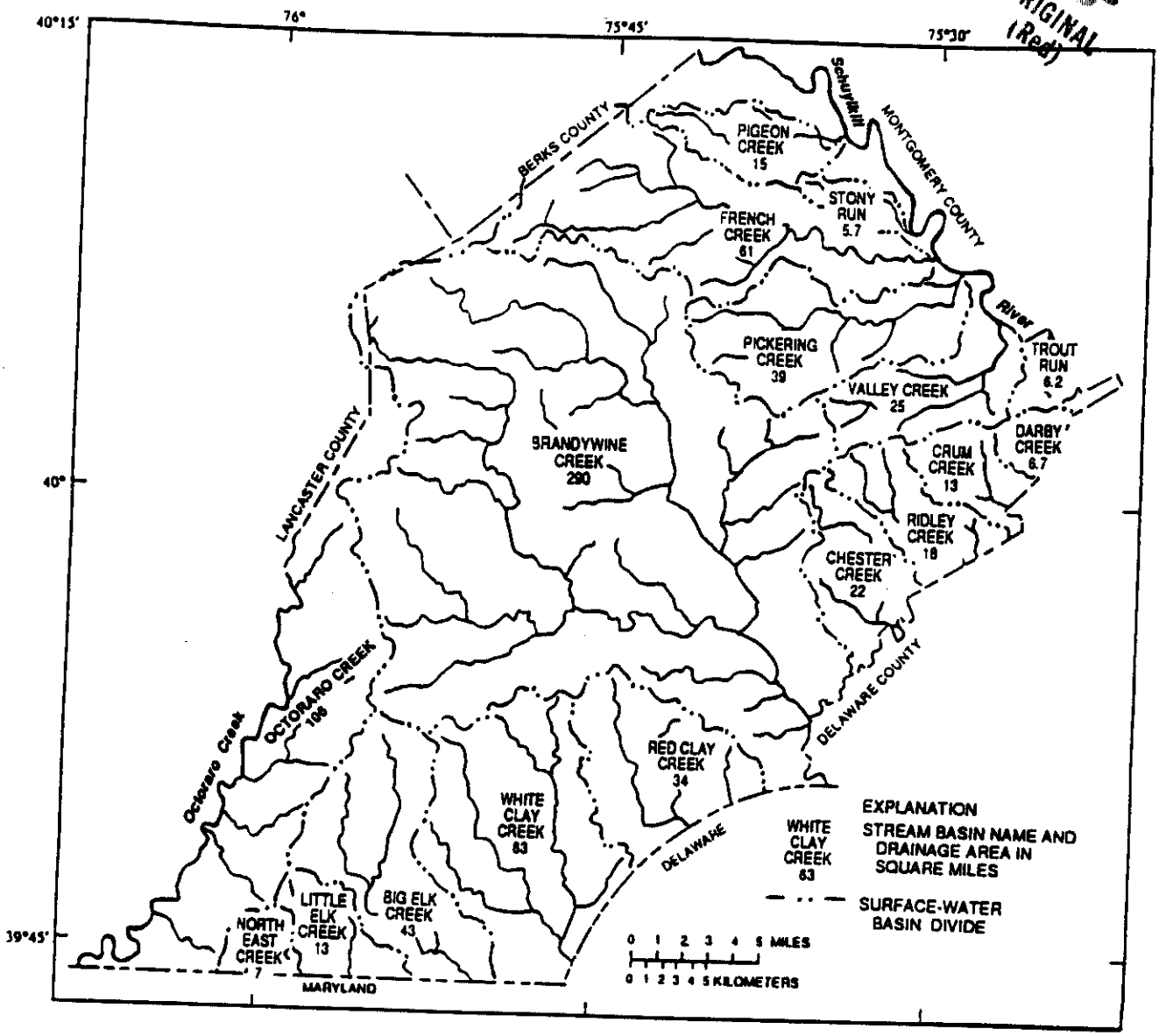


Figure 2.–Major drainage basins in Chester County, with area drained in square miles.

Previous Investigations

The geology of Chester County was mapped and described by Bascom and others (1909), Bascom and Miller (1920), Knopf and Jonas (1929), Bascom and Stose (1932 and 1938), Huntsman (1975), Demmon (1977), and Pupa (1988). Geologic quadrangle maps for Chester County were published by the Chester County Planning Commission (1973) and Berg and Dodge (1981).

Hall (1934) briefly discussed the water-bearing characteristics of the principal geological formations of southeastern Pennsylvania. The geology and hydrology of the Stockton Formation in southeastern Pennsylvania was described by Rima and others (1962). The hydrology of the metamorphic rocks of central Chester County was described by Poth (1968). McGreevy and Sloto (1977) described the ground-water resources of Chester County; this report supersedes McGreevy and Sloto (1977). The ground-water resources of the Hammer Creek Formation in southeastern Pennsylvania were described by Wood (1980). Sloto (1987) described the effect of urbanization on the water resources of eastern Chester County. Sloto (1989) presented ground-water data for Chester County.

McGreevy and Sloto (1980) simulated ground-water flow in the upper Pickering Creek basin, and Sloto (1991a) simulated ground-water flow in the Valley Creek basin.

The water table was mapped in the Cockeysville Marble by Speight (1985); in the carbonate rocks of eastern Chester Valley by Sloto (1987, pl. 2); in central Chester Valley by Wood (1984); in western Chester Valley by Wood (1985); in West Chester and East Goshen, West Goshen, Westtown, and Thornbury Townships by Garges (1986); in East Bradford and West Bradford Townships by Garges (1988), and in the Red Clay Creek basin by Vogel and others (1991). The potentiometric surface was mapped in the Triassic age rocks of northeastern Chester County by Senior and Garges (1989) and in the Triassic rocks of north central Chester County by McManus (1990).

Olmsted and Hely (1962) described the relation between ground water and surface water in the Brandywine Creek basin. Miller and others (1971) discussed the hydrology of the Pickering and upper East Branch Brandywine Creek basins.

The ground-water resources on a basin-wide scale were described for the Delaware River by Parker and others (1964) and for the Schuylkill River by Biesecker and others (1968).

Acknowledgments

The cooperation of well owners who made their wells accessible for water samples and water-level measurements is greatly appreciated. The author also acknowledges the Chester County Health Department, which contributed funding for many of the water-quality analyses, and municipal and private water purveyors, who contributed essential data. The geologic map (pls. 1 and 2) was provided by the Pennsylvania Geological Survey.

GEOLOGY

The geologic units of Chester County are combined into three terranes composed of several related structural groups (fig. 3). The stratigraphic nomenclature and geologic age used for geologic units in this report is that of the Pennsylvania Geological Survey (R.T. Faill, Pennsylvania Department of Environmental Resources, Bureau of Topographic and Geologic Survey, written commun., 1989 and 1990). Table 1 compares the stratigraphic nomenclature used in this report with nomenclature used in previous reports, such as McGreevy and Sloto (1977). Geologic units are shown on plates 1 and 2. Each unit is described below.

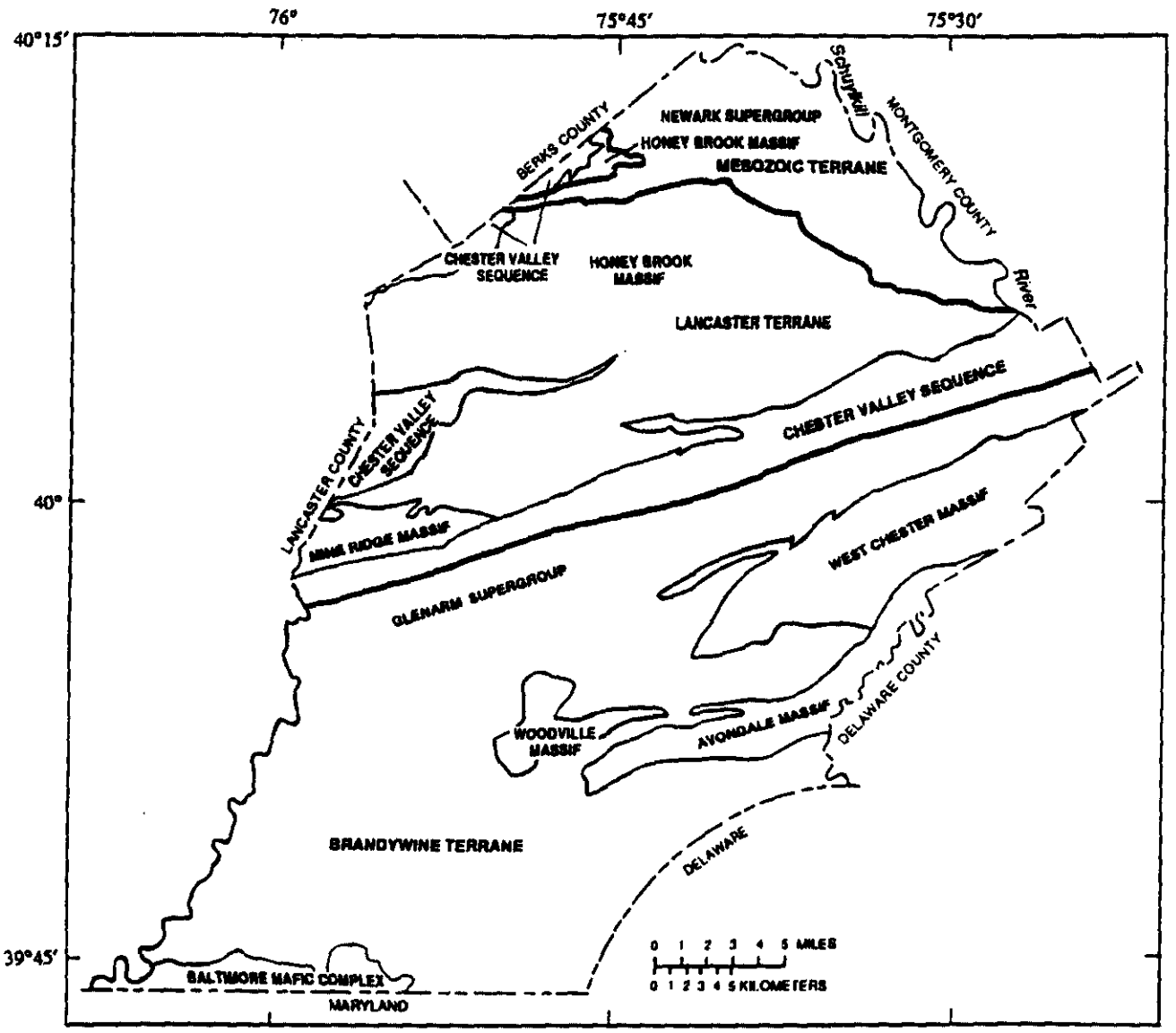


Figure 3.–Geologic terranes in Chester County.

Table 1.–Stratigraphic column

Age	Structural group	Geologic unit: This report	Geologic unit: Berg and others (1980)
Quaternary		Alluvium	
Tertiary		Pensauken and Bridgeton Formations, undivided	
		Bryn Mawr Formation	Bryn Mawr Formation
Early Jurassic	Newark Supergroup	Diabase	Diabase
Late Triassic		Brunswick Group	Brunswick Formation
		Hammer Creek Formation[1]	Hammer Creek Conglomerate
		Lockatong Formation	Lockatong Formation
		Stockton Formation	Stockton Formation
Ordovician and Cambrian	Chester Valley sequence	Conestoga Limestone	Conestoga Formation
Cambrian		Elbrook Limestone	Elbrook Formation
		Ledger Dolomite	Ledger Formation
		Kinzers Limestone	Kinzers Formation
		Vintage Dolomite	Vintage Dolomite
Cambrian and late Precambrian		Antietam and Harpers Formations, undivided	Antietam Formation, Harpers Formation
		Chickies Quartzite	Chickies Formation
Age uncertain, probably Cambrian	Baltimore Mafic Complex	Serpentinized ultramafite	Serpentine
		Gabbro and metagabbro	Gabbro and gabbroic gneiss
Late Precambrian to middle Ordovician	Glenarm Supergroup	Peters Creek Schist	Peters Creek Formation
		Octoraro Phyllite	Wissahickon Formation, albite-chlorite schist
		Wissahickon Schist	Wissahickon Formation, oligoclase-mica schist
		Cockeysville Marble	Cockeysville Marble
		Setters Quartzite	Setters Formation
Age unknown, probably late Precambrian and (or) early Paleozoic		Pegmatite	Pegmatite
		Ultramafite	Serpentinite
		Metadiabase	Metadiabase
		Metagabbro	Metagabbro
		Mafic gneiss, amphibolite facies	Mafic gneiss, hornblende-bearing
		Marble	Franklin Marble
Precambrian	Avondale, West Chester, and Woodville massifs[2]	Felsic gneiss, amphibolite facies	Felsic gneiss, hornblende-bearing
		Mafic gneiss, amphibolite facies	Mafic gneiss, hornblende-bearing
		Felsic gneiss, granulite facies	Felsic gneiss, pyroxene-bearing
		Mafic gneiss, granulite facies	Mafic gneiss, pyroxene-bearing
Precambrian	Mine Ridge massif	Felsic and mafic gneiss	Granite gneiss
Precambrian	Honey Brook massif	Anorthosite	Anorthosite
		Felsic gneiss, amphibolite facies	Graphitic gneiss
		Graphitic felsic gneiss, amphibolite facies	Granodiorite and granodiorite gneiss
		Felsic and intermediate gneiss, amphibolite facies	Gabbro and gabbroic gneiss
		Banded mafic gneiss, amphibolite facies	Quartz monzonite and quartz monzonite gneiss
		Felsic gneiss, granulite facies	
		Graphitic felsic gneiss, granulite facies	
		Mafic gneiss, granulite facies	

[1] Quartz-pebble conglomerate of the Brunswick Formation of McGreevy and Sloto (1977).

[2] Includes Baltimore gneiss and gabbro of Bascom and Stose (1932), and granite gneiss, gabbroic gneiss and gabbro, and gabbro of McGreevy and Sloto (1977).

Precambrian Crystalline Rocks of the Honey Brook Massif

The Precambrian crystalline rocks of the Honey Brook massif (fig. 3) lie north of Chester Valley. The rocks of the Honey Brook massif are described by Crawford and Hoersch (1984). These units represent a metamorphosed sequence of rocks of predominantly granitic composition overlain by a basalt-rhyolite sequence of calcic-alkaline volcanic rocks (Crawford and Hoersch, 1984). The rocks of the Honey Brook massif have undergone two episodes of burial and metamorphism, one during the Grenville orogeny and one during the Taconic orogeny (Crawford and Crawford, 1980). The geology was mapped by Huntsman (1975) and Demmon (1977). The Honey Brook massif includes amphibolite-facies gneiss, granulite-facies gneiss, and anorthosite. The amphibolite-facies gneiss is distinguished from the granulite-facies gneiss by the presence of plagioclase and dark green hornblende and by the absence of mesoperthite, hypersthene, and light green augite. A fault separates the amphibolite and granulite facies; where the fault dies out to the northeast, the amphibolite-facies gneiss to the south has a transitional contact with the granulite-facies gneiss to the north. The anorthosite is north of the fault.

The amphibolite-facies gneiss includes felsic gneiss, graphitic felsic gneiss, and felsic and intermediate gneiss mapped as separate units. The amphibolite-facies gneisses are massive and slightly foliated with granular quartz-rich layers that alternate with and grade into quartz-plagioclase layers. Clots of muscovite flakes parallel scattered biotite layers. Retrograde chlorite partly replaces garnet, biotite, muscovite, and epidote. The amphibolite-facies felsic gneiss is a quartz-plagioclase-biotite-muscovite-epidote gneiss with trace hornblende and orthoclase. The amphibolite-facies graphitic felsic gneiss is a quartz-plagioclase-epidote-graphite gneiss with minor biotite and muscovite and trace orthoclase; it differs from the amphibolite-facies felsic gneiss solely by the presence of graphite. Carbon isotope analysis by Crawford and Valley (1990) indicates that the graphite has an organic origin and that the graphitic felsic gneiss and marble are derived from sedimentary protoliths. Graphite formation in the graphitic felsic gneiss and marble is related to metamorphism of organic-rich muds and carbonates accompanied by localized fluid flow. The amphibolite-facies felsic and intermediate gneiss is a quartz-plagioclase-biotite-muscovite-epidote gneiss with or without hornblende and with trace garnet in the biotite-rich layers.

The amphibolite-facies banded mafic gneiss consists of alternating layers of quartz-plagioclase-hornblende felsic gneiss (with minor muscovite, biotite, and epidote) and hornblende-plagioclase-biotite-epidote mafic gneiss. Layer thickness generally ranges from 0.5 to 2 in. In the mafic layers, locally disseminated garnet porphyroblasts are common. Retrograde chlorite partly replaces some of the mafic minerals. Apatite, titanite, and zircon are ubiquitous.

The granulite-facies felsic and intermediate gneiss is a medium- to coarse-grained, quartz-plagioclase-mesoperthite felsic gneiss with subordinate hornblende, augite, and hypersthene. It exhibits a faint foliation caused by alinement of mafic grains and elongation of quartzo-feldspathic clusters. Intermediate gneiss contains a somewhat higher proportion of mafic minerals than does the felsic gneiss. The felsic gneiss is extensively interlayered with subordinate amounts of the mafic and intermediate gneiss. Retrograde biotite and chlorite surround the mafic minerals. Accessory minerals include apatite, titanite, and zircon.

The granulite-facies graphitic felsic gneiss is a medium- to coarse-grained, quartz-plagioclase-mesoperthite-hypersthene-graphite felsic gneiss with subordinate microcline, hornblende, and augite, which exhibits a faint foliation caused by alinement of mafic grains and elongation of quartzo-feldspathic clusters. The graphite is present as medium-grained rods, irregular patches, stringers, and as distinct layers up to 2 in. thick. The granulite-facies graphitic felsic gneiss is extensively interlayered with subordinate mafic gneiss. Retrograde biotite and chlorite surround the mafic minerals.

The granulite-facies mafic gneiss is a medium-grained, equigranular, hornblende-plagioclase-quartz mafic gneiss with augite and (or) hypersthene, subordinate amounts of mesoperthite, and trace amounts of garnet and biotite. The granulite-facies mafic gneiss exhibits foliation caused by alinement of mafic grains and is extensively interlayered with the dominant felsic gneiss. Retrograde biotite and chlorite surround the mafic minerals. Accessory minerals include apatite and zircon.

Anorthosite is exposed as an elliptical body within the granulite region of the Honey Brook massif. It is a stock-like body with steep to vertical boundaries. The rocks in the anorthosite suite range, with increasing mafic (predominantly hornblende) content, from anorthosite (40 percent) through leuco-hornblende gabbro (40 percent) to hornblende gabbro (20 percent). The anorthosite is described by Crawford and others (1971) and Crawford and Hoersch (1984). Plagioclase and hornblende comprise the bulk of these rocks; augite, hypersthene, and garnet are present in amounts of less than 5 percent. The anorthosite is a massive, dark bluish-gray to light gray to pinkish-gray, coarse-grained, granular plagioclase gneiss with hornblende, biotite, quartz, apatite, and magnetite. The plagioclase is altered along fractures to zoisite, clinozoisite, and sericite. The leuco-hornblende gabbro is a massive, "peppered," dark bluish-gray to light gray, coarse-grained, granular plagioclase gneiss containing less hornblende, biotite, and magnetite than is present in the anorthosite. The plagioclase is somewhat more sodium-rich than the plagioclase in the anorthosite. The hornblende gabbro is a massive, light gray to pink, very coarse-grained, very granular plagioclase gneiss with numerous lenses and layers of hornblende, biotite, and garnet. Accessory minerals include magnetite, apatite, and titanite.

Marble, formerly called Franklin Marble, is associated with the graphitic gneisses north of Chester Valley. The age of the marble is unknown, but is probably late Precambrian and (or) early Paleozoic. It is present in discontinuous lenses as a massive, white to light gray, banded marble. The marble commonly contains abundant graphite flakes. Accessory minerals include quartz, feldspar, pyrite, and muscovite.

Precambrian Crystalline Rocks of the Mine Ridge Massif

The Mine Ridge massif is south of and contiguous with the Honey Brook massif (fig. 3). The rocks of the Mine Ridge massif are described by Hoersch and Crawford (1988). The Precambrian rocks of the Mine Ridge massif consist of amphibolite-facies felsic, intermediate, and mafic gneisses that are not mapped as separate units, ultramafite, and metadiabase. The mafic rocks are intimately mixed with felsic rocks that comprise the bulk of the massif; intermediate gneiss is rare. Each gneiss consists of two types.

The felsic gneiss is divided into two types based on texture. The first type of felsic gneiss is a foliated, light gray, medium-grained, quartz-plagioclase-biotite gneiss with minor muscovite, epidote, and garnet. Biotite comprises about 10 percent of the rock. Elongated quartz grains, lepidoblastic micas, and alternating granoblastic quartzo-feldspathic and biotite-rich layers define the foliation. The second type of felsic gneiss is pegmatitic and is further subdivided into (1) a massive, granoblastic, medium- to coarse-grained potassium-feldspar-bearing gneiss with minor biotite, muscovite, and epidote; and (2) a muscovite-rich gneiss lacking potassium feldspar and containing minor epidote and garnet.

The intermediate gneiss is (1) a foliated, light gray, medium-grained, quartz-plagioclase-hornblende gneiss with minor biotite and chlorite, and (2) a quartz-plagioclase-biotite-chlorite-garnet gneiss. Both types of intermediate gneiss contain quartzo-feldspathic and ferromagnesian lenses and bands parallel to the foliation. Accessory and minor minerals include epidote, clinozoisite, muscovite, apatite, zircon, and garnet.

The mafic gneiss is (1) a dark gray, hornblende-biotite-quartz gneiss that may contain plagioclase and (or) clinozoisite and small amounts of chlorite, epidote, and titanite; and (2) a greenish-gray, epidote-chlorite-quartz-titanite gneiss with minor plagioclase. Both types of mafic gneiss are massive and unfoliated or discontinuously banded with alternating layers of ferromagnesian and quartzo-feldspathic minerals.

The ultramafite is (1) a dark greenish-gray, fine- to medium-grained, massive, granoblastic to slightly foliated rock consisting primarily of serpentine, chlorite, talc, and altered hornblende; and (2) a dark-gray, coarse-grained, granoblastic to slightly nematoblastic hornblendite containing approximately 95 percent hornblende. Chlorite, an alteration product of hornblende, makes up about 5 percent of the hornblendite. The hornblende also contains minor zircon and serpentine.

Two small lenses of metadiabase are mapped in the Mine Ridge massif. Their age is unknown, but they are probably late Precambrian and (or) early Paleozoic. The metadiabase is a bluish gray to greenish gray, fine-grained rock with ophitic texture containing plagioclase (chiefly labradorite) and pyroxene (commonly augite). Principal secondary minerals include hornblende, biotite, chlorite, epidote, zoisite, and albite.

Precambrian Crystalline Rocks of the Woodville, West Chester, and Avondale Massifs

The Woodville, West Chester, and Avondale massifs (fig. 3) are south of Chester Valley. These massifs are Precambrian gneiss and are surrounded by younger rocks of the Glenarm Supergroup. Bailey and Mackin (1937) believed the Woodville massif to be a nappe; Wagner and Srogi (1987) believe that the Avondale massif also is a nappe and that the Woodville and Avondale massifs are allochthonous, remobilized basement. The gneiss of the Brandywine terrane has undergone two episodes of burial and metamorphism, one during the Grenville orogeny and one during the Taconic orogeny (Wagner and Crawford, 1975).

These rocks are the Baltimore Gneiss of Bascom and others (1909) and Bascom and Stose (1932). They are now mapped as amphibolite- and granulite-facies felsic and mafic gneisses and are described by Wagner and Crawford (1975).

The amphibolite-facies felsic and intermediate gneiss is a light- to medium-gray, medium-grained, finely to coarsely layered, quartz-plagioclase-biotite-potassium-feldspar-garnet gneiss with or without hornblende.

The amphibolite-facies mafic gneiss is a medium- to dark-gray, medium-grained, finely to coarsely layered plagioclase-hornblende-pyroxene-biotite gneiss that may or may not contain quartz, garnet, and titanite. Metadiabase also is present.

Granulite-facies gneiss is present only in the West Chester massif. The granulite-facies felsic gneiss has a variable composition—medium- to dark-gray, coarse-grained, plagioclase-quartz-orthoclase-garnet-biotite-hypersthene/clinopyroxene gneiss (strongly lineated) to light-gray, fine- to medium-grained quartz-mesoperthite-garnet gneiss with or without biotite or hypersthene. Quartz-kyanite rocks and quartz-garnet rocks with or without kyanite are present locally.

The granulite-facies mafic gneiss is a medium- to dark-gray, medium-grained, granoblastic, plagioclase-clinopyroxene-hypersthene-garnet gneiss with or without biotite, quartz, orthoclase, and hornblende as accessory minerals.

Crystalline Rocks of Probable Late Precambrian and (or) Early Paleozoic Age

Crystalline rocks of probable late Precambrian and (or) early Paleozoic age include pegmatite, ultramafite, and metadiabase. Pegmatite and metadiabase are found in most areas of Chester County. Ultramafite mainly is found south of Chester Valley.

Pegmatite is present as numerous dikes and lenses that vary greatly in width. Few pegmatite dikes can be traced continuously for long distances. In many places, pegmatite bodies were mined for feldspar and mica. Pegmatite is a light colored, very coarse- to coarse-grained, granitic rock containing mostly alkali feldspars (microcline, orthoclase, microperthite, and sodic plagioclase) and quartz with subordinate muscovite or biotite (Bascom and Stose, 1932, p. 9). Minor garnet, tourmaline, pyrite, and corundum are present locally.

Ultramafite occurs as discontinuous pods and masses, some of which are several square miles in area. Ultramafite forms a thin, poor soil that supports a characteristic flora of scrub pine, mountain pink, and cat briar; areas underlain by ultramafite are known as "barrens." Ultramafite is a yellowish-green, grayish-green, dark green, and medium-dark gray peridotite and pyroxenite, usually altered to serpentine, steatite, talc, actinolite, tremolite, and numerous other accessory minerals.

Metadiabase forms numerous dikes from a few inches to many feet wide. The dikes are not all the same age. Metadiabase is a bluish gray to bluish- to yellowish-green, fine-grained to aphanitic rock composed of labradorite and augite (Bascom and Stose, 1938, p. 42-43). Some dikes are porphyritic and are mottled with phenocrysts of white, lath-shaped feldspar. In the bluish- to yellowish-green dikes, the labradorite is altered to zoisite, and the augite is altered to hornblende and phenocrysts of biotite.

Crystalline Rocks of the Glenarm Supergroup

The metasedimentary rocks of the Glenarm Supergroup are south of Chester Valley (fig. 3). They range in age from late Precambrian to Middle Ordovician (Berg and others, 1986). The Glenarm Supergroup was subject to intense deformation and metamorphism during the Taconic orogeny (Wagner and Crawford, 1975). McKinstry (1949) mapped the mineral isograds in the Glenarm Supergroup.

The Setters Quartzite and Cockeysville Marble are probable continental margin deposits that unconformably overlie the older felsic and mafic gneisses of the Brandywine terrane (Wagner and Srogi, 1987, p. 115). The Wissahickon Schist, Octoraro Phyllite, and Peters Creek Schist were formed as accretionary sedimentary prisms during a collision of the North American continent and a volcanic arc (the Brandywine terrane) during the early Paleozoic (Wagner and Srogi, 1987, p. 122-123).

The Setters Quartzite is the basal formation in the Glenarm Supergroup. It is present as a narrow marginal fringe on the Woodville and Avondale massifs. The Setters is a white to light-gray quartzite, quartzose schist, and potassic-feldspar-quartz-biotite-muscovite schist. The lower part of the Setters is a dark, biotite-quartz-orthoclase(?)-muscovite schist; mica constitutes about 50 percent of the rock. Accessory minerals in the Setters include hornblende, magnetite, apatite, garnet, zircon, titanite, and schorl. Bascom and Stose (1932, p. 4) estimate that the Setters is as much as 1,000 ft thick.

The Cockeysville Marble crops out adjacent to the Setters Quartzite and also in several small lenses. The Cockeysville is a white, coarse-grained, saccharoidal marble and light gray, fine-grained, banded marble. The Cockeysville commonly contains scattered, golden-brown phlogopite flakes. Bascom and Stose (1932, p. 4) estimate that the Cockeysville is less than 500 ft thick; it is probably 100 to 165 ft thick in most places.

According to the model proposed by Wagner and Srogi (1987), the Wissahickon Schist contains sedimentary rocks deposited in three different tectonic settings: (1) oceanic sediments that accumulated in an accretionary prism on the descending tectonic plate, (2) sediments originally deposited in a forearc basin on the overriding plate that later became involved in deformation, and (3) syntectonic flysch resulting from plate collision.

The Wissahickon Schist consists of metasediments metamorphosed to amphibolite grade. It conformably overlies the Cockeysville Marble; where the underlying Cockeysville and Setters are missing, the Wissahickon is in fault contact with the underlying gneiss. The Wissahickon is a light to medium gray, fine- to medium-grained, quartzo-aluminous schist and gneiss. Composition ranges from quartz-orthoclase-biotite and orthoclase-quartz-muscovite schist to quartz-biotite-plagioclase and quartz-plagioclase-biotite schistose gneiss. Garnet and (or) sillimanite are locally abundant. Foliation is generally very well developed. North of the Avondale massif, the Wissahickon contains several small ultramafic bodies. Bascom and Stose (1932) estimate the thickness of the Wissahickon Schist and Octoraro Phyllite to be 5,000 to 8,000 ft.

Amphibolite-facies mafic gneiss is interlayered with the Wissahickon Schist south of the Avondale massif. The amphibolite-facies mafic gneiss is a dark-gray, medium-grained, hornblende-plagioclase-orthoclase-quartz gneiss. Several lenses of amphibolite-facies mafic gneiss also are mapped in the amphibolite-facies felsic gneiss of the Avondale massif and may not be related to those in the Wissahickon Schist. Wagner and Srogi (1987, p. 115) interpret the origin of the amphibolite bodies in the Wissahickon as possible basalt flows interlayered with the sediments of the Wissahickon or blocks of crustal debris in a tectonic melange. The amphibolite bodies have major and minor trace element constituents similar to abyssal tholeiites (Wagner and Srogi, 1987, p. 115).

The South Valley Hills south of Chester Valley are underlain by the Octoraro Phyllite (Wissahickon Formation albite-chlorite facies of Bascom and Stose, 1938). Along the northern edge of its outcrop area, the Octoraro Phyllite may be bounded by a major thrust fault and may be thrust over the Conestoga Limestone. The Octoraro Phyllite is a bluish-gray to greenish-gray, well-foliated, quartz-muscovite-chlorite phyllite with lustrous, smooth laminae. It commonly contains quartz lenses parallel to the laminae around which the foliation wraps. The Octoraro is finer grained to the north. Locally, a purplish slate is present. Small plagioclase crystals are common in some of the layers.

The Peters Creek Schist consists of a flyschoid sequence of metagraywacke and pelite rich in quartz and magnetite (Lyttle and Epstein, 1987). The Peters Creek Schist generally is a green, fine-grained, finely-laminated, mica schist with numerous thin to thick interbeds of chlorite-bearing granular quartzite. The pelitic part is usually a quartz-muscovite-chlorite-orthoclase schist. Bascom and Stose (1932, p. 6) estimate that the Peters Creek Schist is about 2,000 ft thick.

Crystalline Rocks of the Baltimore Mafic Complex

The allochthonous Baltimore Mafic Complex straddles the State line in the southwestern part of Chester County. The Baltimore Mafic Complex consists of a basal dunite unit, a layered transitional unit, and an upper gabbro unit (Hanan and Sinha, 1989). The complex may have formed in a marginal basin originating inland from a continental margin volcanic arc or as a sub-arc plutonic complex.

The basal and transitional units are mapped as serpentinized ultramafite (pl. 2). The basal ultramafite consists of serpentized dunite and chromitite; it is in thrust fault contact with the Wissahickon Schist. Overlying the ultramafite is a transitional unit of interlayered cumulus peridotite, pyroxenite, and gabbro. Hanan and Sinha (1989) estimate that the thickness of both units is less than 3,000 ft. The upper gabbro and metagabbro unit consists of mostly metamorphosed hypersthene gabbro containing numerous cumulus peridotite layers. The upper gabbro unit also is in thrust fault contact with the Wissahickon Schist. Hanan and Sinha (1989) estimate that the Baltimore Mafic Complex is less than 6,500 ft thick.

Metamorphosed Sedimentary Rocks of the Chester Valley Sequence

Chester Valley, which cuts through the center of the county, is underlain by Cambrian and Ordovician limestone and dolomite (Chester Valley sequence, fig. 3). Basal quartzites in the sedimentary sequence underlie the North Valley Hills north of Chester Valley. These units also are present west of the Honey Brook massif. Thickness estimates for each unit given below are from Bascom and Stose (1932 and 1938).

The rocks that comprise the Chester Valley sedimentary sequence were deposited by continental margin sedimentation when the Honey Brook massif became submerged during the late Precambrian, Cambrian, and Ordovician; during that time, this area was the eastern edge of the North American continent (Rodgers, 1968, p. 141-148).

The Chickies Quartzite is a very resistant unit that forms prominent hills. Depositional environments include intertidal sand flat, subtidal channel, and tidal flat pond (Goodwin and Anderson, 1974). The Chickies Quartzite is a white to light gray, thin- to thick-bedded, cross-bedded, medium-grained quartzite with interbeds of quartzose schist and sandy mica schist. The basal Hellam Member, which is not mapped as a separate unit in Chester County, is a coarse-grained, schorl-bearing quartzite and arkosic pebble conglomerate. The Chickies Quartzite is about 500 ft thick.

The Antietam and Harpers Formations are not mapped as separate units in Chester County. In general, they consist of gray, thin- to thick-bedded, laminated quartzite, quartzose schist, and sandy micaceous schist. Kauffman and Frey (1979) interpret the Antietam Formation as a line of barrier islands fronting the early Cambrian continent. The Antietam Formation is a gray, laminated quartzite and quartzose schist that grades downward into the Harpers. The Antietam is 150 to 450 ft thick. Schwab (1970) interprets the Harpers Formation as a vertical repetition of (1) nearshore and shallow marine

platform sands, and (2) offshore, fine-grained, deep-water turbitite deposits. The Harpers Formation is a gray, sandy, micaceous schist with interbeds of quartz schist and thin-bedded quartzite. It is 500 to 1,500 ft thick.

The Vintage Dolomite crops out in a narrow band in eastern Chester Valley and in several small occurrences west of the Honey Brook massif. The Vintage is a dark gray, granular dolomite with a wavy texture. A white marble is present at the base. The lower part of the Vintage is a fine-grained, thin- to medium-bedded, argillaceous to sandy dolomite with abundant mica on the bedding planes. The upper part is a light gray, fine- to coarse-grained, thick-bedded dolomite. The Vintage grades into the underlying Antietam Formation. The Vintage is 600 ft thick west of the Honey Brook massif and 200 to 300 ft thick in Chester Valley.

The Kinzers Formation crops out in a thin band adjacent to the Vintage Dolomite. The Kinzers is a gray, micaceous limestone and calcareous mica schist with interbeds of dark gray shale, dark gray argillaceous limestone, and spotted gray to white marble. The Kinzers grades downward into the Vintage Dolomite. The Kinzers is about 130 ft thick west of the Honey Brook massif and less than 30 ft thick in Chester Valley.

The Ledger Dolomite is a white to light gray, massive to thick-bedded, granular, rather pure dolomite with a high magnesium content. The dolomite is interbedded with some siliceous beds and laminated limestone. The Ledger contains a few beds of marble with a high calcium content. The lower contact is gradational with the Kinzers Formation. The Ledger is 660 to 1,000 ft thick.

The unit mapped as Elbrook Limestone in Chester County may not be the same unit mapped as the Elbrook to the west of Chester County (R.T. Faill, Pennsylvania Department of Environmental Resources, Bureau of Topographic and Geologic Survey, written commun., 1991). It is called the Elbrook Limestone in this report. The Elbrook forms low hills in Chester Valley. The Elbrook is a light gray to white, finely laminated, fine-grained, interbedded limestone and marble. Concentrations of coarse-grained mica on parting planes are a pressure-solution residue parallel to regional cleavage. The lower contact is gradational with the Ledger Dolomite. The Elbrook is 300 to 800 ft thick.

The Conestoga Limestone is present only in Chester Valley, where it crops out along the southern edge. The Conestoga is a blue-gray, thin-bedded, argillaceous limestone with intervals of a purer, granular limestone. Mica coats most of the bedding and cleavage planes. The impure part of the Conestoga has thin-bedded alterations of dark gray, clayey, silty, slaty, micaceous layers and medium gray, argillaceous limestone that imparts a characteristic banded appearance to the rock. Some of the basal beds are a coarse limestone conglomerate containing large pebbles and irregular masses of coarse white marble in a gray limestone. It unconformably overlies the Elbrook Limestone. The upper contact of the Conestoga may be marked by a thrust fault that brings the Octoraro Phyllite over the Conestoga. The Conestoga Limestone is 500 to 800 ft thick.

Triassic Sedimentary and Jurassic Igneous Rocks of the Newark Supergroup

Late Triassic sedimentary rocks of the Newark Supergroup crop out in northern Chester County along the Schuylkill River (fig. 3). They dip about 12°. The Triassic sedimentary rocks are predominantly lacustrine sediments deposited in the extensive, closed Newark basin, which was occupied by a shallow, alkaline lake. The Newark basin was formed by crustal downwarping. Subsidence kept pace with deposition, and sediment filled the basin from all sides. The sediments are laterally and vertically transitional between depositional environments. Following deposition, the basin was tilted toward the northwest by simultaneous faulting and folding (Faill, 1973, p. 725). Toward the end of deposition, early Jurassic diabase intruded the sediments. The sedimentary formations are the Stockton, Lockatong, and Hammer Creek Formations, and the Brunswick Group.

The depositional environments of the Stockton Formation include alluvial, marginal lacustrine, and nearshore lacustrine (Turner-Peterson, 1980). The Stockton consists of light to medium gray, thin- to thick bedded, fine- to coarse-grained arkosic sandstone in the lower part and reddish brown to purplish gray, fine-grained sandstone, siltstone, shale, and mudstone in the upper part. The lower contact is

unconformable with underlying Precambrian rocks. Where the St. Peters diabase sheet intrudes the Stockton, the Stockton is an indurated, highly arkosic, fine-grained, gray conglomerate. Rima and others (1962, p. 9) estimated that the Stockton is 2,300 ft thick at Phoenixville.

The Lockatong Formation crops out in a narrow band in northern Chester County and has an average dip of 15°. Offshore lacustrine deposits formed the Lockatong (Turner-Peterson, 1980). The Lockatong Formation is predominantly a medium to dark gray, thick- to very-thick-bedded argillite with thin beds of gray to black shale, siltstone, and marlstone. The depositional sequence is composed of alternating detrital and chemical-lacustrine cycles (Van Houten, 1964). The detrital cycles, averaging 14-20 ft thick, consist of laminated, medium-dark-gray to black, calcareous, pyritic siltstone and shale overlain by dark gray, platy to massive, calcareous siltstone and fine-grained sandstone. The chemical-lacustrine cycles, averaging 8-13 ft thick, consist of medium dark gray to black, platy, dolomitic siltstone and marlstone overlain by massive, gray or red, analcime- and carbonate-rich siltstone. The lower contact of the Lockatong grades into and laterally interfingers with the Stockton Formation. The Lockatong is about 1,500 ft thick at the Schuylkill River and thins westward (Bascom and Stose, 1938, p. 72).

The Hammer Creek Formation (Brunswick Formation quartz pebble conglomerate of Bascom and Stose, 1938, p. 74) sediments were deposited in an alluvial fan. The Hammer Creek is a medium- to very-thick-bedded, fine- to coarse-grained quartz and quartzite conglomerate in a red to brown sandstone matrix interbedded with coarse-grained, red to brown sandstone and red siltstone and shale.

The Brunswick Group (Brunswick Formation of Bascom and Stose, 1938, p. 73) is late Triassic in age in Chester County. Sediments of the Brunswick were deposited in a lacustrine-nearshore environment. The Brunswick Group consists of grayish-red to reddish-brown, evenly- to irregularly-bedded, thin- to medium-bedded shale, siltstone, and fine-grained sandstone containing a few green and brown shale interbeds. Mudcracks, ripple marks, crossbeds, and burrows are common. The Brunswick contains detrital cycles of medium to dark gray and olive to greenish gray, thin-bedded shale and siltstone. Near the base are tongues of thick-bedded red argillite interbedded with dark gray argillite characteristic of the underlying Lockatong Formation. The lower contact is gradational with the Lockatong. The Brunswick laterally interfingers with the Lockatong and Hammer Formations. Bascom and Stose (1938, p. 76) estimated that the thickness of the Brunswick Group and Hammer Creek Formation together is about 8,000 ft.

Early Jurassic diabase intrudes the Triassic sedimentary rocks as dikes and sheets. It is a dark gray to black, fine- to medium-grained, intrusive igneous rock. It forms dikes up to several miles long. In northwestern Chester County, a large intrusive body, the St. Peters sheet, forms a prominent ridge. The shales and siltstones in contact with the sheet have been thermally altered.

Quaternary and Tertiary Deposits

Tertiary deposits include a few discontinuous patches of the Bryn Mawr Formation and the Pensauken and Bridgeton Formations, undivided, in northeastern Chester County. Bascom and Stose (1938, p. 78-80) considered the deposits east of Valley Creek to be Quaternary in age and interpreted them as the ancestral channel of the Schuylkill River 140 ft above its present level. These deposits are of small areal extent.

The Bryn Mawr Formation forms high-level terrace deposits consisting of reddish-brown gravel, "ironstone conglomerate," gravelly loam, sand, and sandy loam, some of which is firmly indurated.

The Pensauken and Bridgeton Formations, undivided, consist of dark reddish-brown, cross-stratified, feldspathic quartz sand with some thin beds of fine to coarse gravel and layers and lenses of clay or silt. Most of the clasts are pebbles and cobbles, but a few are boulders. The matrix is earthy and muddy; iron oxide cement imparts a considerable hardness to the deposits. Owens and Minard (1979, p. 45) consider the Pensauken and Bridgeton to be of Miocene age.

Quaternary alluvium is present as fine- to medium-grained unconsolidated material in and along stream valleys as stream-bottom and flood-plain deposits. The alluvium consists mostly of silt, sand, and pebbles mixed with locally derived cobbles.

HYDROLOGY

All geologic units in Chester County are considered to be aquifers. The terms geologic unit and aquifer are used interchangeably in this report. The geologic units are sometimes referred to as "bedrock aquifers." Nearly all wells have casing set into the upper few feet of unweathered rock and are completed as open-hole wells. A less-permeable overlying geologic unit or part of the geologic unit may be considered as a confining unit locally.

Aquifer and Well-Construction Characteristics

Aquifer and well-construction characteristics are briefly discussed in the following sections. Because of the many geologic units in Chester County, data for each geologic unit or geohydrologic group are given in tables in each section. For statistical analysis and description, the 41 geologic units mapped in Chester County have been grouped into six geohydrologic groups based on similar geologic, hydraulic, and ground-water-flow system characteristics (except for group six). These groups are (1) Triassic sedimentary rocks (Brunswick Group; Hammer Creek, Lockatong, and Stockton Formations); (2) carbonate rocks (Conestoga Limestone, Elbrook Limestone, Ledger Dolomite, Kinzers Limestone, Vintage Dolomite, Cockeysville Marble, and marble); (3) quartzite (Antietam and Harpers Formations, Chickies Quartzite, and Setters Quartzite); (4) schist (Peters Creek Schist, Octoraro Phyllite, and Wissahickon Schist); (5) gneiss (all felsic, mafic, and intermediate gneisses); and (6) all other units (diabase, ultramafite, serpentinite and pyroxenite, gabbro and metagabbro, pegmatite, metadiabase, metagabbro, and anorthosite). The last geohydrologic group (all other units) includes geologic units of small areal extent that are not important water-bearing units (such as metagabbro and ultramafite), intrusive units (such as diabase, metadiabase, and pegmatite), and units that do not fit into other categories (such as serpentinite, pyroxinite, and anorthosite).

Analysis-of-variance tests were made to determine whether statistically significant differences in hydraulic characteristics exist among the geologic units or geohydrologic groups. Nonparametric (distribution free) statistical tests were used because the data are not normally distributed. Specific capacity data for the Cockeysville Marble, for example, spans four orders of magnitude. Data were ranked from lowest to highest values; an average rank was assigned to equal values. The Kruskal-Wallis test, a nonparametric one-way analysis of variance using rank-transformed data, was used to test for statistically significant differences among groups at the 95-percent level of confidence. The null hypothesis tested by the Kruskal-Wallis test is that all groups come from the same population or from populations with equal medians. For ranked data, the median and the mean are equal. If the null hypothesis is rejected, the alternative hypothesis is that at least one group is from a different population or has an unequal median. The Kruskal-Wallis test, however, does not indicate which group is different.

If the null hypothesis of the Kruskal-Wallis test was rejected (p greater than or equal to 0.05), indicating at least one group was significantly different, further testing using a multiple comparison test (MCT) was performed to identify the geologic units or geohydrologic groups with significantly different medians. Because sample size is unequal, Tukey's studentized range test, honestly significant difference procedure (Steel and Torrie, 1960, p. 109-110), was the MCT used on the rank-transformed data to make multiple comparisons and test for significant differences at the 95-percent confidence level.

Water-Bearing Zones

Primary (intergranular) porosity below the weathered zone, except in a few Triassic sedimentary units, is virtually nonexistent in the geologic units of Chester County. Ground water flows through a network of interconnected secondary openings that comprise the water-bearing zones that provide water to wells. The number and size of the water-bearing openings determines the secondary porosity of the rock; the number, size, and degree of interconnection of the openings determines the secondary permeability. The larger and more numerous the openings, the greater the yield of a well.

The frequency of occurrence of water-bearing zones decreases with depth (fig. 4). The distribution of 3,025 water-bearing zones in 1,414 wells (143,658 ft of uncased borehole) up to 1,000 ft deep was analyzed (table 2). The data are summarized by geohydrologic group and expressed in units of water-bearing zones

per 100 ft of uncased borehole. Schist and gneiss are combined in table 2 and on figure 4 because they have nearly identical frequency distributions. Sixty-four percent of water-bearing zones for all geologic units are encountered within 100 ft of land surface, and 92 percent are encountered within 200 ft of land surface. More than three water-bearing zones per 100 ft of uncased borehole for all geologic units are encountered in the upper 100 ft, more than two water-bearing zones per 100 ft are encountered in the upper 200 ft, and less than one water-bearing zone per 100 ft is encountered below 200 ft. Fewer water-bearing zones per 100 ft of uncased borehole were encountered in carbonate rock (1.50 zones) than in the other geohydrologic groups (2.07-2.48 zones). However, the water-bearing zones in carbonate rock generally are enlarged by solution and transmit more water than do water-bearing zones in noncarbonate rock that are not enlarged by solution.

Specific Capacity

Specific capacity is a better measure of aquifer productivity than well yield because it is calculated using data from a pumped well. Specific capacity is calculated by dividing the pumping rate of a well by the drawdown. Specific capacity for a well pumped at a constant yield decreases with time. Reported specific-capacity data for wells in Chester County are given in table 3. The specific-capacity data are based on aquifer tests conducted by drillers, water purveyors, and consultants. Data given in table 3 for the Lockatong Formation, Kinzers Limestone, and Vintage Dolomite may include wells that penetrate and derive water from underlying formations. The Kinzers Limestone and Vintage Dolomite are thin in Chester Valley. Wells drilled in the low-yielding Lockatong Formation may tap more productive units below the Lockatong.

The specific capacity of nondomestic wells provides a better estimate of maximum aquifer productivity than does the specific capacity of domestic wells. Specific capacities of nondomestic wells are significantly higher than specific capacities of domestic wells at the 95-percent level of confidence. Part of the difference is because nondomestic wells generally are deeper, penetrate more water-bearing zones, and have larger diameters than domestic wells. Nondomestic wells usually are drilled for maximum yield; domestic wells usually are drilled only until an adequate yield for domestic use is obtained. Also, nondomestic wells commonly are located in valleys, and wells located in valleys generally have higher specific capacities than those in other topographic settings.

Specific-capacity data for nondomestic wells, together with data on available drawdown, provide a reasonable base for estimating yields of wells penetrating the various geologic units. This information can be used to determine which geologic units are the best water-producing units and which units are the poorest.

Based on the median specific capacity of nondomestic wells (table 3), carbonate rock is the most productive geohydrologic group, followed in order of decreasing productivity by Triassic sedimentary rocks, gneiss, schist, and quartzite. The frequency distribution of specific capacity for all wells in each geohydrologic group is shown on figure 5.

Analysis-of-variance tests using Tukey's MCT were made on specific-capacity data for nondomestic wells to test for significant differences among geohydrologic groups at the 95-percent confidence level. Tukey's MCT showed that, although the median specific capacity of nondomestic wells drilled in carbonate rocks is higher than the median specific capacity of nondomestic wells drilled in the other geohydrologic groups, the median specific capacity of nondomestic wells drilled in carbonate rocks is not significantly different than the median specific capacity of nondomestic wells drilled in Triassic sedimentary rocks or gneiss.

Based on the median specific capacity of nondomestic wells (table 3), the most productive geologic units are the Ledger Dolomite, Cockeysville Marble, and the Stockton Formation. Based on the median specific capacity of domestic wells (table 3), the least productive geologic units are the Lockatong Formation, Chickies Quartzite, amphibolite-facies graphitic felsic gneiss, and granulite-facies mafic gneiss (Brandywine terrane). If more data were available, diabase probably would be included in the group of least productive geologic units (Biesecker and others, 1968, p. 152).

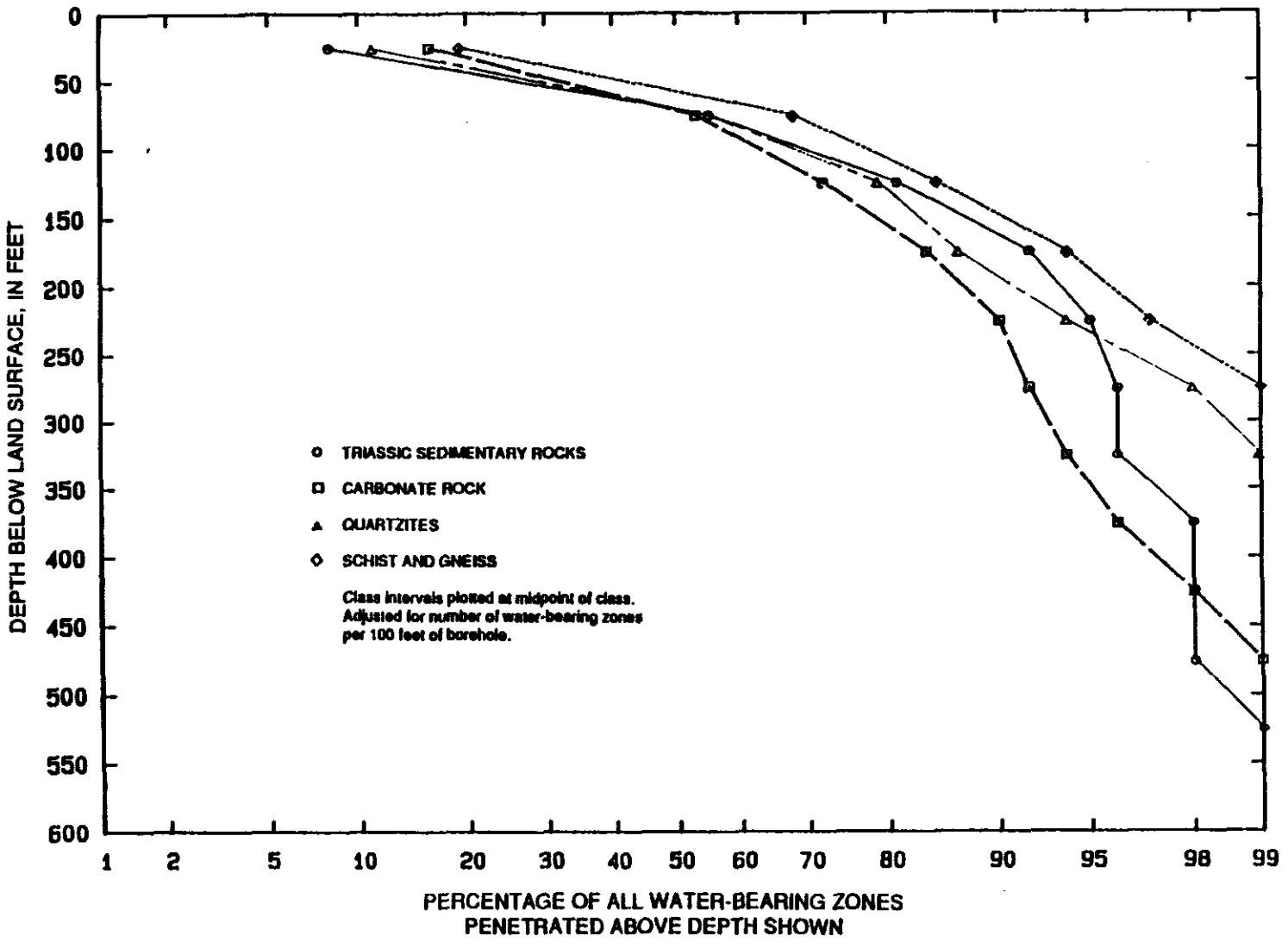


Figure 4.–Distribution of water-bearing zones with depth.

Table 2.–Number of water-bearing zones reported per 100 feet of uncased borehole drilled

[--, no data]

Interval (feet)	Triassic sedimentary rock (114 wells)			Carbonate rock (147 wells)			Quartzite (116 wells)			Schist and gneiss (1,007 wells)			All geologic units (1,414 wells)		
	Number of water-bearing zones		Footage drilled (feet)	Number of water-bearing zones		Footage drilled (feet)	Number of water-bearing zones		Footage drilled (feet)	Number of water-bearing zones		Footage drilled (feet)	Number of water-bearing zones		Footage drilled (feet)
	Pene-trated	Per 100 feet of borehole		Pene-trated	Per 100 feet of borehole		Pene-trated	Per 100 feet of borehole		Pene-trated	Per 100 feet of borehole		Pene-trated	Per 100 feet of borehole	
0-50	28	2.78	1,007	45	2.81	1,604	25	2.97	843	421	4.26	9,881	519	3.89	13,335
51-100	164	2.94	5,587	108	2.23	4,835	101	2.66	3,791	1,047	2.99	34,971	1,420	2.89	49,184
101-150	89	2.58	3,449	55	1.53	3,601	55	1.84	2,982	380	1.69	22,525	579	1.78	32,557
151-200	39	2.13	1,830	33	1.13	2,932	19	1.09	1,744	178	1.35	13,186	269	1.37	19,692
201-250	9	1.13	795	18	.91	1,989	16	1.50	1,064	71	.90	7,871	114	.97	11,719
251-300	3	.78	383	6	.42	1,434	9	1.82	495	37	.71	5,197	55	.73	7,509
301-350	1	.40	250	7	.77	914	3	2.94	102	16	.61	2,628	27	.69	3,894
351-400	6	2.58	233	4	.55	730	--	--	--	10	.68	1,478	20	.82	2,411
401-450	0	0	102	5	.94	532	--	--	--	4	.58	692	9	.68	1,326
451-500	1	1.00	100	5	1.29	389	--	--	--	1	.28	362	7	.82	851
501-550	4	4.00	100	0	0	73	--	--	--	0	0	250	4	.95	423
551-600	1	1.75	57	1	2.00	50	--	--	--	0	0	180	2	.70	287
Over 600	--	--	--	0	0	5	--	--	--	0	0	465	0	0	470
Total (mean)	345	(2.48)	13,893	287	(1.50)	19,088	228	(2.07)	11,021	2,165	(2.17)	99,686	3,025	(2.11)	143,658

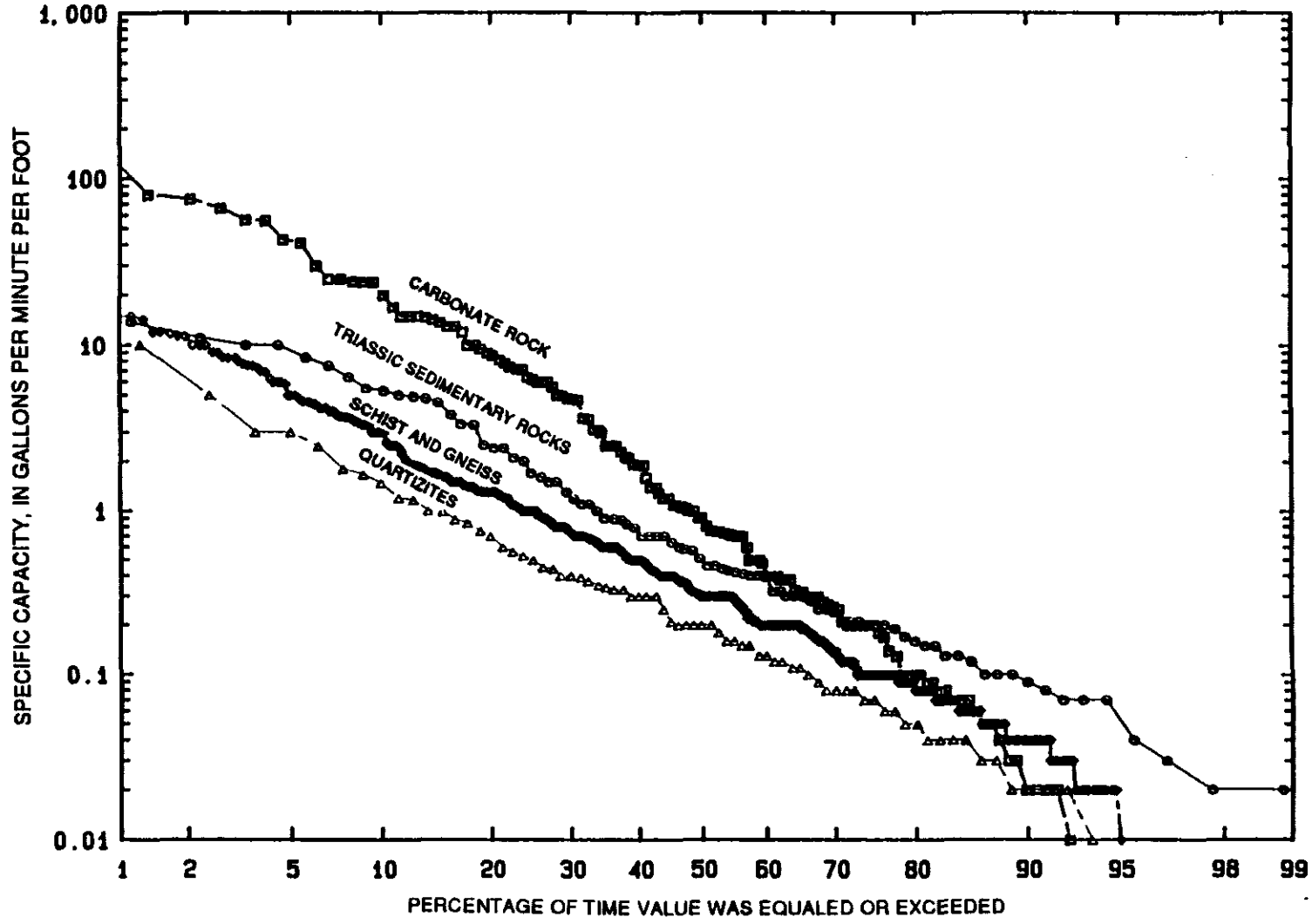


Figure 5.--Distribution of specific capacity by geohydrologic group.

Table 3.–Reported specific capacity

[Specific capacity in gallon per minute per foot of drawdown; Min, minimum; Max, maximum; P10, tenth percentile; P25, twenty-fifth percentile; Med, median; P75, seventy-fifth percentile; P90, ninetieth percentile; <, less than; --, too few data to compute statistic]

Geologic unit	Nondomestic wells								Domestic wells							
	Number of wells	Range		P10	P25	Med	P75	P90	Number of wells	Range		P10	P25	Med	P75	P90
		Min	Max							Min	Max					
Triassic sedimentary rocks	25	0.40	14	0.46	1.5	3.3	5.5	10	63	0.02	7.5	0.07	0.15	0.30	0.70	1.1
Brunswick Group	14	.40	11	.40	.70	2.4	4.9	8.4	30	.07	5	.18	.28	.44	.89	1.5
Hammer Creek Formation	0	--	--	--	--	--	--	--	1	.70	--	--	--	--	--	
Lockatong Formation	3	1.3	4.7	--	--	--	--	--	6	.02	.17	--	--	.11	--	--
Stockton Formation	8	1.5	14	--	--	5.9	--	--	26	.02	7.5	.04	.10	.21	.57	.90
Carbonate rock	54	.01	200	.10	1.2	6.7	17	56	93	<.01	41	.01	.10	.38	1.3	6.0
Conestoga Limestone	3	.01	3.6	--	--	--	--	--	23	<.01	13	.01	.01	.21	2.1	4.7
Elbrook Limestone	9	.05	24	--	--	.50	--	--	23	<.01	10	.01	.04	.20	.60	1.1
Ledger Dolomite	16	3	80	5.6	8.1	15	50	75	34	.01	41	.07	.17	.71	2.3	15
Kinzers Limestone	1	.08	--	--	--	--	--	--	2	.18	1.4	--	--	--	--	--
Vintage Dolomite	4	.07	12	--	--	--	--	--	4	.27	.91	--	--	--	--	--
Cockeysville Marble	21	.08	200	1.4	3.1	7.4	17	25	7	.13	15	--	--	2.1	--	--
Quartzites	7	<.01	3	--	--	.50	--	--	71	<.01	10	.02	.07	.20	.44	1.2
Antietam and Harpers Formations, undivided	1	.84	--	--	--	--	--	--	11	.04	3	.11	.12	.37	.53	.60
Chickies Quartzite	6	<.01	3	--	--	--	--	--	46	.01	5	.02	.06	.14	.33	.99
Setters Quartzite	0	--	--	--	--	--	--	--	14	<.01	10	.01	.13	.37	1.2	2.5
Schist	72	.02	39	.09	.25	.59	1.8	4.4	320	<.01	15	.04	.10	.30	.80	1.7
Peters Creek Schist	5	.03	2.5	--	--	--	--	--	55	<.01	11	.02	.06	.31	.80	3.4
Octoraro Phyllite	15	.10	3.7	.20	.30	.60	1.8	2.6	52	<.01	9.0	.01	.08	.30	.94	3.0
Wissahickon Schist	52	.02	39	.08	.25	.63	2.0	7.7	213	<.01	15	.06	.10	.27	.70	1.5
Gneiss	59	.04	25	.14	.36	1.4	3.6	6.9	264	<.01	62	.02	.09	.26	.73	1.8
Mafic gneiss, amphibolite facies, (late Precambrian and/or early Paleozoic)	0	--	--	--	--	--	--	--	10	.12	6.0	.15	.20	.58	1.7	5.5
Mafic gneiss, amphibolite facies (Brandywine terrane)	2	.94	1.4	--	--	--	--	--	2	.05	.19	--	--	--	--	--
Felsic gneiss, amphibolite facies (Brandywine terrane)	13	.14	12	.35	1.6	3.0	4.0	4.6	48	.01	62	.03	.09	.30	1.2	3.3
Mafic gneiss, granulite facies (Brandywine terrane)	2	.89	6.9	--	--	--	--	--	8	<.01	15	--	--	.18	--	

ORIGINAL (Red)

Geologic unit	Nondomestic wells								Domestic wells							
	Number of wells	Range		P10	P25	Med	P75	P90	Number of wells	Range		P10	P25	Med	P75	P90
		Min	Max							Min	Max					
Felsic gneiss, granulite facies (Brandywine terrane)	13	0.09	4.4	0.30	0.36	0.95	1.5	1.7	62	<0.01	8.4	0.03	0.10	0.28	0.65	1.3
Felsic gneiss, amphibolite facies (Honey Brook massif)	2	.37	25	–	–	–	–	–	3	.04	.48	–	–	–	–	–
Graphitic felsic gneiss, amphibolite facies	5	.39	12	–	–	–	–	–	41	<.01	2.1	.01	.06	.15	.30	.63
Felsic and intermediate gneiss, amphibolite facies	9	.04	1.8	–	–	.34	–	–	58	.01	12	.01	.08	.24	.47	1.9
Banded mafic gneiss, amphibolite facies	2	.25	.32	–	–	–	–	–	5	.49	2.5	–	–	–	–	–
Felsic gneiss, granulite facies (Honey Brook massif)	5	.18	25	–	–	–	–	–	19	.01	2.6	.04	.16	.79	1.0	1.7
Graphitic felsic gneiss, granulite facies	1	3.7	–	–	–	–	–	–	2	.52	1.3	–	–	–	–	–
Mafic gneiss, granulite facies (Honey Brook massif)	2	.08	3.5	–	–	–	–	–	2	.57	.79	–	–	–	–	–
Felsic and mafic gneiss	3	2.5	6.3	–	–	–	–	–	4	.40	50	–	–	–	–	–
Other geologic units																
Diabase	0	–	–	–	–	–	–	–	1	.03	–	–	–	–	–	–
Serpentine, pyroxinite, and ultramafic rocks	1	<.01	–	–	–	–	–	–	20	<.01	37	.03	.10	.20	1.3	8.4
Gabbro and metagabbro	0	–	–	–	–	–	–	–	4	.10	4.2	–	–	–	–	–
Pegmatite	1	.72	–	–	–	–	–	–	0	–	–	–	–	–	–	–
Anorthosite	1	1.9	–	–	–	–	–	–	10	.25	3.2	.37	.54	.69	1.4	2.5

ORIGINAL (Red)

Analysis-of-variance tests were made on specific-capacity data for nondomestic wells in geologic units with seven or more values using Tukey's MCT to test for significant differences among geologic units at the 95-percent confidence level. Tukey's MCT showed that although the median specific capacity of nondomestic wells drilled in the Ledger Dolomite is higher than the median specific capacity of nondomestic wells drilled in the other geologic units, the specific capacity of nondomestic wells drilled in the Ledger Dolomite is not significantly different than the median specific capacity of nondomestic wells drilled in the Stockton Formation or the Cockeysville Marble.

Well Yield

Reported well-yield data for wells in Chester County are given in table 4. The yield of nondomestic wells provides a better measure of maximum aquifer yield than the yield of domestic wells for the same reasons cited in the section on specific capacity. Data given in table 4 for the Lockatong Formation, Kinzers Limestone, Vintage Dolomite, and metadiabase may include wells that penetrate and derive water from underlying formations. The Kinzers Limestone and Vintage Dolomite are thin in Chester Valley. Wells drilled in the low yielding Lockatong Formation may tap more productive units below the Lockatong.

Analysis-of-variance tests were made on yield data for nondomestic wells in geologic units with seven or more values using Tukey's MCT to test for significant differences in yield among geologic units at the 95-percent confidence level. Tukey's MCT showed that although the median yield of nondomestic wells drilled in the Ledger Dolomite is higher than the median yield of nondomestic wells drilled in the other geologic units, the median yield of wells drilled in the Ledger Dolomite is not significantly different than the median yield of nondomestic wells drilled in the Brunswick Group, Cockeysville Marble, granulite-facies felsic gneiss (Honey Brook massif), Stockton Formation, amphibolite-facies felsic gneiss (Brandywine terrane), Conestoga Limestone, Elbrook Limestone, and the amphibolite-facies graphitic felsic gneiss.

Analysis-of-variance tests were made using Tukey's MCT on yield data for nondomestic wells to test for significant differences in yield among geohydrologic groups at the 95-percent confidence level. Tukey's MCT showed that the median yield of nondomestic wells drilled in carbonate and Triassic sedimentary rocks is significantly higher than the median yield of nondomestic wells drilled in the other geohydrologic groups. The median yield of nondomestic wells drilled in carbonate and Triassic sedimentary rocks is not significantly different from each other. The median yield of wells drilled in gneiss and schist is not significantly different from each other. The median yield of wells drilled in quartzite was lower than the median yield of all other geohydrologic groups, but was not significantly different from the median yield of wells drilled in schist.

Effect of Topography on Specific Capacity and Yield

The specific capacity and yield of a well is affected by its topographic setting. Wells were classified as drilled in hilltop, hillside, or valley (including draws) topographic settings. Specific-capacity and yield data were analyzed for wells in geohydrologic groups. In general, the median and mean specific capacity (table 5) and median and mean yield (table 6) of wells drilled in valleys are higher than the median and mean specific capacity and yield of wells drilled on hillsides or hilltops.

Analysis-of-variance tests using Tukey's MCT were made on ranked specific-capacity and yield data for nondomestic and domestic wells drilled in different topographic settings to test for significant differences in topographic setting at the 95-percent confidence level. For nondomestic wells, Tukey's MCT showed that no significant difference exists among the median specific capacities of wells drilled in valley, hillside, or hilltop topographic settings. For domestic wells, Tukey's MCT showed that the median specific capacity of wells drilled in valleys is significantly higher than the median specific capacity of wells drilled on hilltops or hillsides; no significant difference exists in the median specific capacity between wells drilled on hillsides or hilltops. Nondomestic wells are drilled for maximum yield, regardless of topographic setting; domestic wells are drilled to obtain an adequate domestic yield. For nondomestic and domestic wells combined, Tukey's MCT showed that the median yield of wells drilled in valleys is significantly higher than the median yield of wells drilled on hillsides, and the median yield of wells drilled on hillsides is significantly higher than the median yield of wells drilled on hilltops. Valleys may be formed by erosion of rock that is more highly fractured than rock underlying hilltops and hillsides.

Table 4.--Reported well yield

[Yield given in gallons per minute; Min, minimum; Max, maximum; P10, tenth percentile; P25, twenty-fifth percentile; Med, median; P75, seventy-fifth percentile; P90, ninetieth percentile; <, less than; --, too few data to compute statistic]

Geologic unit	Nondomestic wells								Domestic wells							
	Number of wells	Range		P10	P25	Med	P75	P90	Number of wells	Range		P10	P25	Med	P75	P90
		Min	Max							Min	Max					
Triassic sedimentary rocks	39	15	1,300	30	40	123	220	550	188	4	165	7	11	15	30	80
Brunswick Group	16	35	1,300	40	80	138	210	260	82	5	165	9	12	15	40	80
Hammer Creek Formation	0	--	--	--	--	--	--	--	18	6	60	8	8	12	25	50
Lockatong Formation	3	50	380	--	--	--	--	--	12	5	32	7	8	14	25	30
Stockton Formation	20	15	800	23	30	85	285	600	76	4	150	6	10	15	30	75
Carbonate rock	99	<1	1,800	10	70	136	300	600	216	<1	500	2	7	20	50	100
Conestoga Limestone	12	3	1,000	5	8	125	188	300	64	<1	175	1	3	15	36	60
Elbrook Limestone	13	5	1,200	5	13	75	450	1,000	47	<1	100	1	5	15	30	75
Ledger Dolomite	24	<1	1,120	75	127	275	450	725	57	2	500	6	15	35	100	200
Kinzers Limestone	1	17	--	--	--	--	--	--	3	10	100	--	--	--	--	--
Vintage Dolomite	4	30	275	--	--	--	--	--	9	<1	100	--	--	30	--	--
Cockeysville Marble	44	10	1,800	20	75	115	200	450	35	4	300	7	12	25	50	140
Marble	1	75	--	--	--	--	--	--	1	4	--	--	--	--	--	
Quartzites	16	<1	110	2	4	27	73	100	198	<1	110	3	6	12	20	35
Antietam and Harpers Formations, undivided	2	23	75	--	--	--	--	--	25	1	35	4	6	10	15	25
Chickies Quartzite	10	<1	96	2	4	25	40	83	131	<1	100	3	5	10	20	30
Setters Quartzite	4	2	110	--	--	--	--	--	42	1	110	4	10	18	33	60
Schist	138	3	350	8	18	40	75	180	628	<1	400	3	6	12	20	30
Peters Creek Schist	9	5	312	--	--	20	--	--	107	<1	70	3	5	10	20	30
Octoraro Phyllite	40	3	230	8	19	38	69	100	117	<1	300	1	5	10	20	35
Wissahickon Schist	89	3	350	10	20	50	90	200	404	<1	400	5	8	13	20	30
Gneiss	87	2	650	10	20	50	103	230	640	<1	400	4	7	15	30	60
Mafic gneiss, amphibolite facies, (late Precambrian and/or early Paleozoic)	0	--	--	--	--	--	--	--	22	5	100	8	10	16	20	30
Mafic gneiss, amphibolite facies (Brandywine terrane)	2	60	100	--	--	--	--	--	2	7	13	--	--	--	--	--
Felsic gneiss, amphibolite facies (Brandywine terrane)	16	5	300	6	18	153	239	300	118	<1	270	5	8	15	30	60
Mafic gneiss, granulite facies (Brandywine terrane)	3	50	150	--	--	--	--	--	12	1	40	2	4	15	21	30

ORIGINAL (Red)

Table 4.--Reported well yield--Continued

[Yield given in gallons per minute; Min, minimum; Max, maximum; P10, tenth percentile; P25, twenty-fifth percentile; Med, median; P75, seventy-fifth percentile; P90, ninetieth percentile; <, less than; --, too few data to compute statistic]

Geologic unit	Nondomestic wells								Domestic wells							
	Number of wells	Range		P10	P25	Med	P75	P90	Number of wells	Range		P10	P25	Med	P75	P90
		Min	Max							Min	Max					
Felsic gneiss, granulite facies (Brandywine terrane)	30	10	300	14	25	40	75	104	169	<1	250	4	6	15	30	75
Felsic gneiss, amphibolite facies (Honey Brook massif)	3	4	60	--	--	--	--	--	13	2	100	2	3	11	19	28
Graphitic felsic gneiss, amphibolite facies	8	2	650	--	--	83	--	--	65	<1	150	1	5	9	25	50
Felsic and intermediate gneiss, amphibolite facies	10	7	114	9	14	36	100	110	89	<1	314	3	6	12	25	40
Banded mafic gneiss, amphibolite facies	2	20	57	--	--	--	--	--	17	<1	100	2	8	18	25	80
Felsic gneiss, granulite facies (Honey Brook massif)	7	50	200	--	--	60	--	--	89	1	134	5	12	25	45	75
Graphitic felsic gneiss, granulite facies	1	95	--	--	--	--	--	--	12	2	400	12	16	50	88	200
Mafic gneiss, granulite facies (Honey Brook massif)	2	12	234	--	--	--	--	--	10	2	35	3	5	18	30	35
Felsic and mafic gneiss	3	25	80	--	--	--	--	--	22	1	50	3	5	13	30	40
Other geologic units	0	--	--	--	--	--	--	--	7	<1	100	--	--	10	--	--
Diabase	1	10	--	--	--	--	--	--	32	<1	80	4	5	12	23	45
Serpentine, pyroxinite, and ultramafic rocks	0	--	--	--	--	--	--	--	4	15	75	--	--	--	--	--
Gabbro and metagabbro	1	108	--	--	--	--	--	--	0	--	--	--	--	--	--	--
Pegmatite	0	--	--	--	--	--	--	--	1	60	--	--	--	--	--	--
Anorthosite	4	30	225	--	--	--	--	--	39	3	100	5	17	30	50	100

ORIGINAL (Red)

Table 5.--Median and mean specific capacity of wells drilled on hilltops, hillsides, and in valleys

[Specific capacity in gallons per minute per foot of drawdown; --, too few data to compute statistic]

Geohydrologic group	Hilltop			Hillside			Valley		
	Number	Median	Mean	Number	Median	Mean	Number	Median	Mean
Domestic wells									
Triassic sedimentary	9	0.12	0.41	44	0.29	0.75	10	0.37	0.50
Carbonate	3	--	--	38	.29	.96	45	.72	4.1
Quartzite	14	.23	1.1	55	.18	.44	1	--	1.5
Schist	44	.10	.42	238	.30	.89	25	.41	.90
Gneiss	31	.25	2.5	215	.20	1.2	40	.60	1.0
All rock types[1]	106	.19	1.1	584	.25	1.0	128	.60	2.2
Nondomestic wells									
Triassic sedimentary	5	4.9	5.0	7	2.0	2.8	12	4.9	5.5
Carbonate	0	--	--	16	13.5	22.8	38	5.8	22.7
Quartzite	1	--	--	5	.20	.31	0	--	--
Schist	4	--	--	38	.65	1.8	28	.56	2.6
Gneiss	4	--	--	29	1.4	2.8	24	1.6	3.7
All rock types[1]	14	1.4	2.3	98	.77	5.4	102	1.3	7.7

[1] Includes wells not in groups above.

Table 6.--Median and mean yield of wells drilled on hilltops, hillsides, and in valleys

[Yield in gallons per minute; --, too few data to compute statistic]

Geohydrologic group	Hilltop			Hillside			Valley		
	Number	Median	Mean	Number	Median	Mean	Number	Median	Mean
Domestic wells									
Triassic sedimentary	23	15	18	141	15	29	23	20	38
Carbonate	6	12	22	79	15	35	120	29	52
Quartzite	40	11	12	142	11	16	0	--	--
Schist	120	10	13	403	14	20	58	12	22
Gneiss	106	12	19	420	15	23	98	30	46
All rock types[1]	295	10	15	1,185	15	23	311	20	43
Nondomestic wells									
Triassic sedimentary	9	70	80	13	100	125	15	220	351
Carbonate	0	--	--	23	200	266	75	110	252
Quartzite	1	--	--	13	23	39	1	--	--
Schist	19	25	41	70	33	52	44	51	96
Gneiss	9	15	25	37	60	96	38	59	95
All rock types[1]	39	30	47	161	52	99	172	100	174

[1] Includes wells not in groups above.

Depth to Water

Statistics on depth to water (table 7) are presented to enable the reader to estimate available drawdown and expected water levels in wells. For all geologic units, the median depth to water is between 17 and 42 ft below land surface except for the Lockatong Formation. Median depth to water in the Lockatong is 56 ft.

Under natural conditions, water levels generally are closest to land surface in valleys near streams (discharge areas) and deepest below land surface on hilltops (recharge areas). Median depth to water is greatest for quartzites (table 7), which are resistant, ridge-forming geologic units.

The greatest median depth to water is in the Lockatong Formation (table 7). The Lockatong is a low-yielding geologic unit, and wells drilled in the Lockatong may penetrate and derive water from higher-yielding geologic units beneath it. Water levels measured in wells drilled in the Lockatong may represent the composite head in water-bearing zones in the Lockatong and in water-bearing zones in a geologic unit beneath the Lockatong, which may have lower heads than water-bearing zones in the Lockatong.

Table 7.--Depth to water

[P10, tenth percentile; P25, twenty-fifth percentile; P75, seventy-fifth percentile; P90, ninetieth percentile; --, too few data to compute statistic]

Geologic unit	Number of wells	Depth to water, in feet below land surface				
		P10	P25	Median	P75	P90
Triassic sedimentary rock	224	8	16	29	46	77
Brunswick Group	96	11	19	30	47	75
Lockatong Formation	20	20	26	56	114	150
Stockton Formation	106	8	15	25	38	60
Carbonate rock	405	7	13	23	40	66
Conestoga Limestone	94	7	11	19	36	48
Elbrook Limestone	97	12	22	37	66	86
Ledger Dolomite	106	10	16	25	44	68
Vintage Dolomite	18	5	12	34	58	74
Cockeysville Marble	84	4	9	15	20	34
Quartzite	215	10	20	36	52	75
Antietam and Harpers Formations, undivided	33	15	24	41	52	82
Chickies Quartzite	132	17	30	42	60	80
Setters Quartzite	50	4	10	20	30	46
Schist	857	8	15	28	40	54
Peters Creek Schist	138	8	20	32	45	55
Octoraro Phyllite	212	10	20	33	48	67
Wissahickon Schist	507	7	14	24	36	48
Gneiss	713	6	13	24	35	49
Mafic gneiss, amphibolite facies (late Precambrian and/or early Paleozoic)	19	2	16	30	36	41
Felsic gneiss, amphibolite facies (Brandywine Terrane)	163	5	12	23	35	50
Mafic gneiss, granulite facies (Brandywine Terrane)	20	3	7	14	25	40
Felsic gneiss, granulite facies (Brandywine Terrane)	213	5	12	20	31	46
Felsic gneiss, amphibolite facies (Honey Brook massif)	12	8	14	23	30	49
Graphitic felsic gneiss, amphibolite facies	58	17	28	37	49	60
Felsic and intermediate gneiss, amphibolite facies	88	8	15	27	38	43
Banded mafic gneiss, amphibolite facies	19	1	8	21	30	47
Felsic gneiss, granulite facies (Honeybrook Massif)	60	4	14	23	30	42
Mafic gneiss, granulite facies (Honey Brook Massif)	12	7	10	17	32	41
Felsic and mafic gneiss	40	9	16	28	35	45
Other geologic units						
Diabase	7	--	--	22	--	--
Serpentine, pyroxinite, and ultramafic rocks	30	6	10	20	30	39
Anorthosite	34	8	10	18	33	45

Well Depth and Casing Length

Data on well depth and casing length are presented as a guide to help estimate well drilling costs. Well-depth data for Chester County are given in table 8. Well drilling usually stops when a sufficient yield is obtained. The median depth of wells is similar for all geohydrologic groups and ranges from 110-132 ft.

Casing-length data for Chester County are given in table 9. The median casing length is similar for wells in all geohydrologic groups and ranges from 40 to 51 ft. Wells in the Vintage Dolomite (103 ft) and granulite-facies graphitic felsic gneiss (83 ft) have the longest median casing lengths. Since 1983, Chester County regulations require a minimum of 20 ft of casing in a newly constructed well. Most wells, however, have casings longer than 20 ft.

Saturated Thickness of the Weathered Zone

In Chester County, water occupies most of the open space in the rock below the water table. This constitutes the ground-water reservoir. Most ground water is stored in the weathered rock, called saprolite, near the land surface. The average saturated thickness of the weathered zone (table 10) was estimated by subtracting depth to water from reported casing length. Casing length is an approximate indicator of depth to solid rock. However, in the Triassic sedimentary rocks, the weathered zone is thin, and casing length may not be a reliable estimate of thickness; the unconsolidated zone probably lies above the water table and is unsaturated. In carbonate rock, the median saturated thickness of the weathered zone is 30 ft; in all other geohydrologic groups, the median saturated thickness of the weathered zone is 14 to 20 ft.

The exact quantity of ground water in storage is not known, but its approximate magnitude can be determined from estimates of specific yield and the saturated thickness of the weathered zone. Specific yield is the quantity of water that will drain from saturated rock under gravity and generally is expressed as a percentage of volume. Olmsted and Hely (1962, p. 18) estimated the specific yield of the weathered zone to be 7.5 to 10 percent. McGreevy and Sloto (1980, p. 18) estimated that the specific yield of the weathered zone is 8 percent. About 3×10^{11} gal of water are stored in the weathered zone in Chester County (McGreevy and Sloto, 1977, p. 35).

Relation of Geology to Ground-Water Flow

The geologic units of Chester County are combined into three general groups based on similarity in ground-water-flow systems: (1) Triassic sedimentary rocks (sandstone, shale, and conglomerate); (2) carbonate rocks (limestone, dolomite, and marble); and (3) Paleozoic and Precambrian crystalline and metamorphosed sedimentary rocks (mainly quartzite, schist, gneiss, and anorthosite). Geologic units not falling into these groups include units of small areal extent, such as pegmatite and metadiabase, and units that are not important water-bearing units, such as diabase. The areal distribution of these general groups is shown on figure 6. Characteristics of the ground-water-flow system, as well as aquifer hydraulic properties, are related to geology. Flow systems in the Triassic sedimentary, carbonate, and crystalline rocks differ from each other.

Triassic Sedimentary Rocks

Late Triassic sedimentary rocks of the Newark Supergroup crop out in northern Chester County along the Schuylkill River (fig. 6). They form a series of layered strata that dip about 12°. The Triassic sedimentary formations are the Stockton, Lockatong, and Hammer Creek Formations and the Brunswick Group.

Ground water in the Triassic sedimentary rocks moves through the intergranular openings in the weathered zone and through a network of interconnecting secondary openings—fractures, bedding planes, and joints—in unweathered rock. In a few units, some water may move through intergranular openings in the bedrock where the cement has been removed and the permeability has increased.

ORIGINAL (Red)

Table 8.–Reported well depth

[Min, minimum; Max, maximum; P10, tenth percentile; P25, twenty-fifth percentile; P75, seventy-fifth percentile; P90, ninetieth percentile; --, too few data to compute statistic]

Geologic unit	Number of wells	Well depth (feet)						
		Range						
		Min	Max	P10	P25	Median	P75	P90
Triassic sedimentary rock	270	16	902	81	100	127	200	314
Brunswick Group	118	30	804	90	98	136	197	260
Hammer Creek Formation	21	70	265	95	108	125	137	200
Lockatong Formation	19	70	600	90	150	256	400	600
Stockton Formation	112	16	902	65	99	122	204	300
Carbonate rock	400	11	605	55	83	125	220	333
Conestoga Limestone	102	11	600	50	77	113	220	300
Elbrook Limestone	80	43	600	93	133	201	306	495
Ledger Dolomite	101	11	605	60	95	140	225	390
Kinzers Limestone	5	60	220	–	–	–	–	–
Vintage Dolomite	15	30	300	55	95	135	205	243
Cockeysville Marble	95	16	437	50	68	86	135	200
Marble	2	150	295	–	–	–	–	–
Quartzite	255	21	490	69	95	132	200	277
Antietam and Harpers Formations, undivided	34	21	216	68	100	125	175	200
Chickies Quartzite	168	38	490	70	100	143	210	278
Setters Quartzite	53	26	408	55	85	120	206	300
Schist	919	13	1,000	65	90	124	200	302
Peters Creek Schist	150	19	575	55	77	100	157	256
Octoraro Phyllite	208	15	1,000	75	102	150	260	350
Wissahickon Schist	561	13	1,000	68	90	124	198	300
Gneiss	823	10	900	55	78	110	187	286
Mafic gneiss, amphibolite facies (late Precambrian and/or early Paleozoic)	24	25	195	40	63	104	153	187
Felsic gneiss, amphibolite facies (Brandywine Terrane)	161	20	900	50	75	103	200	285
Mafic gneiss, amphibolite facies (Brandywine Terrane)	4	88	264	–	–	–	–	–
Felsic gneiss, granulite facies (Brandywine Terrane)	219	44	600	60	79	100	150	225
Mafic gneiss, granulite facies (Brandywine Terrane)	21	60	265	70	90	155	222	250
Felsic gneiss, amphibolite facies (Honey Brook massif)	16	36	340	55	83	145	212	298
Graphitic felsic gneiss, amphibolite facies	80	30	655	87	119	168	272	349
Felsic and intermediate gneiss, amphibolite facies	105	16	562	56	80	115	210	305
Banded mafic gneiss, amphibolite facies	23	42	377	50	65	93	136	280
Felsic gneiss, granulite facies (Honey Brook Massif)	102	12	432	62	80	105	183	288
Graphitic felsic gneiss, granulite facies	12	75	355	85	122	188	287	330
Mafic gneiss, granulite facies (Honey Brook Massif)	11	43	394	47	57	100	200	238
Felsic and mafic gneiss	45	10	359	27	42	60	80	135
Other geologic units								
Diabase	12	50	400	62	82	93	141	255
Serpentine, pyroxinite, and ultramafic rocks	36	40	310	53	77	100	128	246
Gabbro and metagabbro	4	57	167	–	–	–	–	–
Pegmatite	1	285	–	–	–	–	–	–
Metadiabase	1	100	–	–	–	–	–	–
Metagabbro	1	90	–	–	–	–	–	–
Anorthosite	48	14	212	60	78	91	105	163

Table 9.–Reported casing length

[Min, minimum; Max, maximum; P10, tenth percentile; P25, twenty-fifth percentile; P75, seventy-fifth percentile; P90, ninetieth percentile; --, too few data to compute statistic]

Geologic unit	Number of wells	Casing length (feet)						
		Range		P10	P25	Median	P75	P90
		Min	Max					
Triassic sedimentary rock	193	6	190	24	35	45	60	80
Brunswick Group	89	10	172	24	38	48	62	84
Hammer Creek Formation	17	31	103	38	43	50	57	84
Lockatong Formation	14	23	190	31	35	40	43	82
Stockton Formation	73	6	130	24	31	42	60	68
Carbonate rock	275	4	521	20	31	51	80	126
Conestoga Limestone	73	6	180	20	24	40	60	80
Elbrook Limestone	53	9	230	18	22	40	89	145
Ledger Dolomite	75	5	521	21	40	61	98	141
Kinzers Limestone	4	4	126	–	–	–	–	–
Vintage Dolomite	12	40	240	42	60	103	138	208
Cockeysville Marble	56	10	229	24	41	57	79	91
Marble	2	20	–	–	–	–	–	–
Quartzite	198	12	394	21	34	45	74	120
Antietam and Harpers Formations, undivided	23	20	146	21	36	48	94	120
Chickies Quartzite	141	12	282	21	32	42	70	99
Setters Quartzite	34	20	394	26	40	60	100	198
Schist	626	6	275	20	27	42	61	86
Peters Creek Schist	96	6	200	20	22	34	47	64
Octoraro Phyllite	144	6	275	19	21	32	50	78
Wissahickon Schist	386	10	261	22	35	51	70	90
Gneiss	614	6	286	22	31	40	55	75
Mafic gneiss, amphibolite facies (late Precambrian and/or early Paleozoic)	15	20	75	21	34	40	61	72
Felsic gneiss, amphibolite facies (Brandywine Terrane)	101	17	110	23	30	39	53	63
Mafic gneiss, amphibolite facies (Brandywine Terrane)	4	29	58	–	–	–	–	–
Felsic gneiss, granulite facies (Brandywine Terrane)	155	6	140	21	29	40	53	66
Mafic gneiss, granulite facies (Brandywine Terrane)	13	27	62	28	38	44	57	60
Felsic gneiss, amphibolite facies (Honey Brook massif)	14	20	186	20	27	37	45	96
Graphitic felsic gneiss, amphibolite facies	72	16	286	30	38	51	84	168
Felsic and intermediate gneiss, amphibolite facies	93	12	85	20	29	40	47	60
Banded mafic gneiss, amphibolite facies	20	10	84	22	23	40	53	61
Felsic gneiss, granulite facies (Honey Brook Massif)	90	14	160	26	38	42	54	78
Graphitic felsic gneiss, granulite facies	9	21	177	–	–	83	–	–
Mafic gneiss, granulite facies (Honey Brook Massif)	8	26	93	–	–	40	–	–
Felsic and mafic gneiss	20	20	76	20	27	37	44	48
Other geologic units								
Diabase	11	22	65	23	30	43	51	57
Serpentine, pyroxinite, and ultramafic rocks	30	9	108	13	21	40	57	84
Gabbro and metagabbro	4	30	66	–	–	–	–	–
Pegmatite	1	37	–	–	–	–	–	–
Anorthosite	43	14	88	24	40	52	67	80

ORIGINAL (Red)

Table 10.--Estimated saturated thickness of the weathered zone

Geohydrologic group	Number of wells	Range (feet)	Median (feet)
Triassic sedimentary rock	130	0-102	20
Carbonate rock	232	0-184	30
Quartzite	162	0-379	14
Schist	544	0-253	18
Gneiss	480	0-250	20

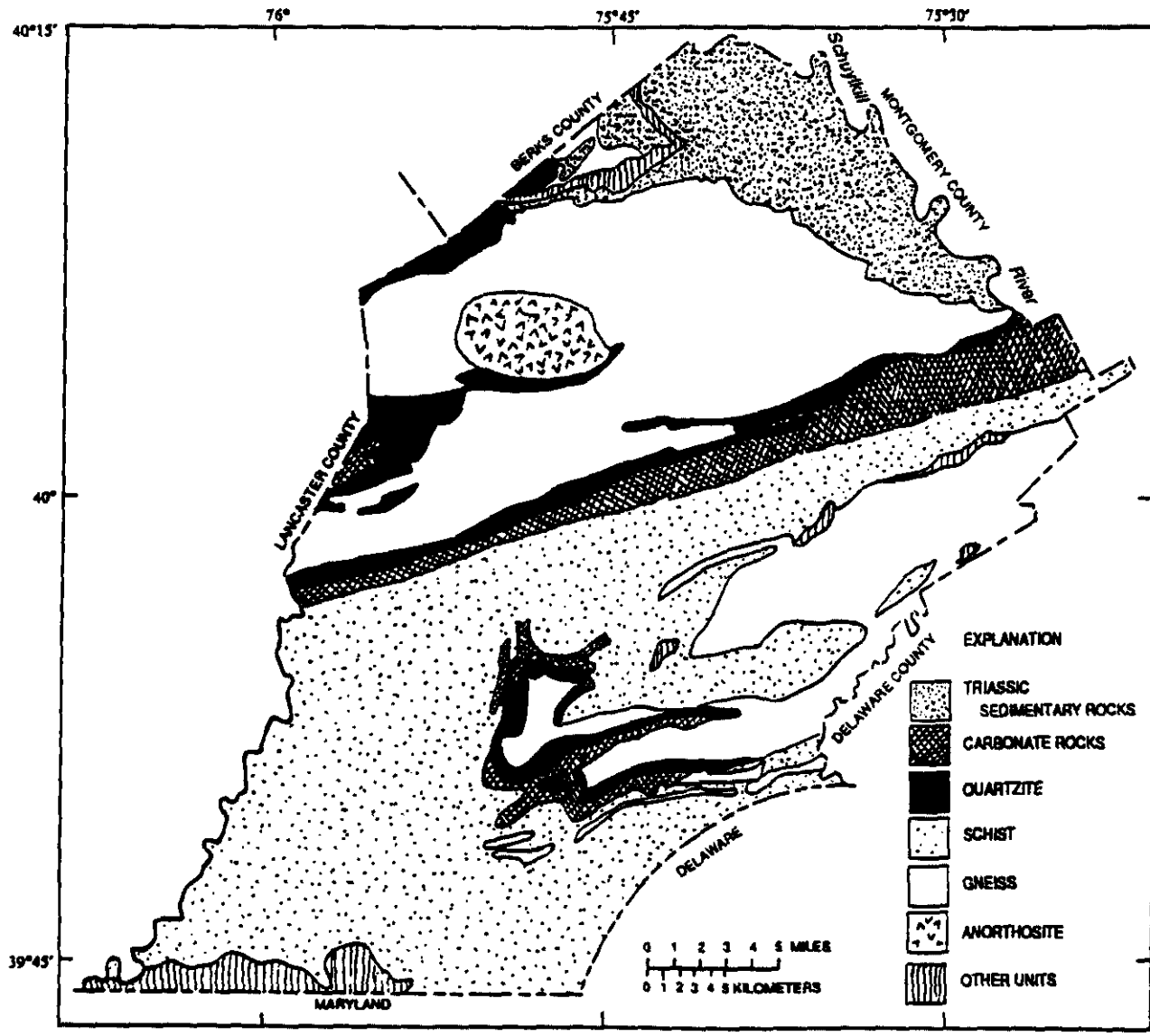


Figure 6.--Generalized geologic map of Chester County.

Triassic sedimentary beds, a few inches to a few feet thick, form a series of alternating aquifers and semi-confining units; each bed generally has different hydraulic properties. Permeability differs from one bed to another. Soft shale beds deform without breaking under stress and, as a result, have low permeability; harder sandstone beds tend to develop joints and are more permeable. Thick competent beds develop fewer joints than thin beds (Wood, 1980, p. 16) and, therefore, are less permeable.

In the Stockton Formation, the beds are lens-shaped, overlap, and pinch out. In the Brunswick Group and Lockatong Formation, beds are more continuous, and single beds generally extend downdip from a few hundred feet to as much as a few thousand feet below land surface. Commonly, beds intersect the land surface a few hundred feet updip from wells penetrating them (fig. 7).

Most deep wells are open to several major water-bearing zones and are therefore multiaquifer wells. Each zone usually has a different hydraulic head. The hydraulic head in a deep well is the composite head of the several water-bearing zones it penetrates. Water may be confined under pressure greater than atmospheric. If the hydraulic head is greater than the land-surface elevation, the well will flow.

Where differences in hydraulic head exist between water-bearing zones, water in the well bore flows under nonpumping conditions in the direction of decreasing head. This can cause water levels in some wells to be different than water levels in adjacent wells of different depths. Flow from an upper zone of higher head to a lower zone of lower head can result in locally lowered water levels in the aquifer; this can be seen on the potentiometric-surface map of Senior and Garges (1989).

Water-bearing zones generally are more continuous along strike than in the direction of dip (fig. 7); they tend to close downdip with depth because of compression. Wells drilled to the same depth several hundred feet downdip of each other rarely intersect the same water-bearing beds. Therefore, the potential for well interference is greater in wells along strike than in the direction of dip.

Ground-water flow in the Triassic sedimentary rocks has both local and regional components. Shallow ground water discharges locally to nearby streams. Deeper, regional ground-water flow is toward the Schuylkill River, the point of regional ground-water discharge. Ground-water divides may be different for each zone of ground-water flow and may not coincide with surface-water divides.

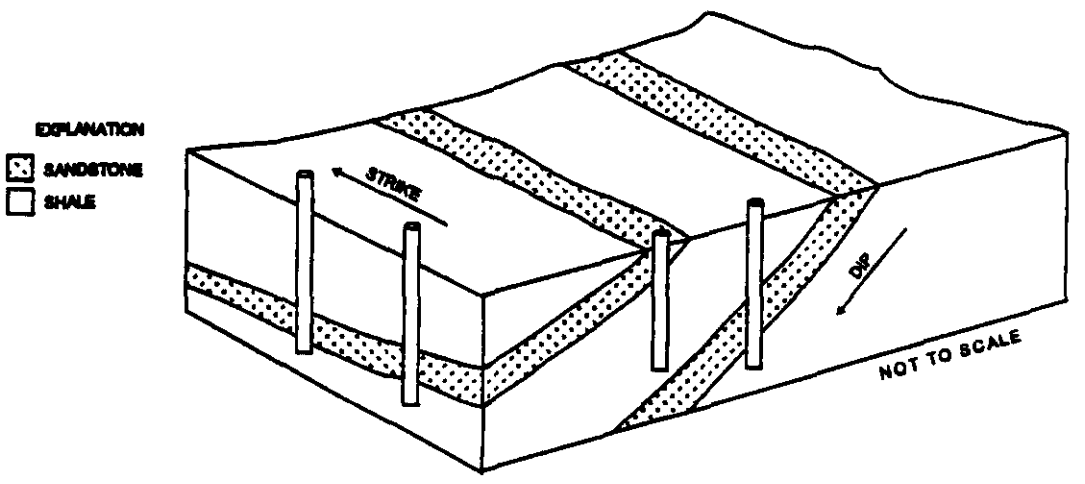


Figure 7.--Wells tapping layered sedimentary rocks.
(Modified from Biesecker and others, 1968.)

Carbonate Rocks

Chester Valley, which cuts through the center of the county, is underlain by Cambrian and Ordovician limestone and dolomite (fig. 6). The principal formations are the Ledger Dolomite, Elbrook Limestone, and Conestoga Limestone. These same formations are also present west of the Honey Brook massif (fig. 3). Marble associated with graphitic gneiss is present north of Chester Valley. The Cockeysville Marble crops out south of Chester Valley.

Ground water in carbonate rocks flows through a network of secondary openings enlarged by solution (fig. 8). Some fractures enlarged by solution are several feet wide; however, most are only a fraction of an inch wide, but they are capable of transmitting large quantities of water. Permeability of carbonate rock is predominately the result of solution-enlarged fractures. Where solution has been active, permeability may be high; elsewhere, the same unit may be nearly impermeable.

Solution is the primary weathering process in carbonate rock. Solution generally is most active above and within the zone of water-table fluctuation where water movement is relatively rapid and recharge water is acidic. Below the zone of water-table fluctuation, water movement is slower, and acidic water from recharge is neutralized. Clay and unconsolidated material sometimes move downward from the surface, plugging openings. This plugging results in decreased well yields and turbid ground-water discharge from some wells.

The depth of weathering in carbonate rocks is highly variable. Deeply weathered zones can be found adjacent to outcrops. The carbonate rock in Chester County commonly exhibits pinnacle weathering. Pinnacle weathering is caused by solution along bedding planes and fractures in dipping strata. As solution enlargement moves downward in the formation, the solid rock between the weathered areas is left as pinnacles.

Although the ground-water system generally is under water-table conditions in carbonate rock, ground water is confined locally. Confined conditions were observed in three wells in the Elbrook Limestone in the center of Chester Valley. The water level in well CH-2313 rose above land surface in the spring of 1978, 1983, and 1984; it was 1.50 ft above land surface on April 21, 1983. Well CH-2148 is a flowing well; the head was reported to be 56 ft above land surface on February 13, 1969 (Leggette, Brashears, and Graham, undated written commun.). The continuous water level recorded in observation well CH-323 shows the effect of earth tides, which is the result of confined conditions (Sloto, 1991, p. 18-19).

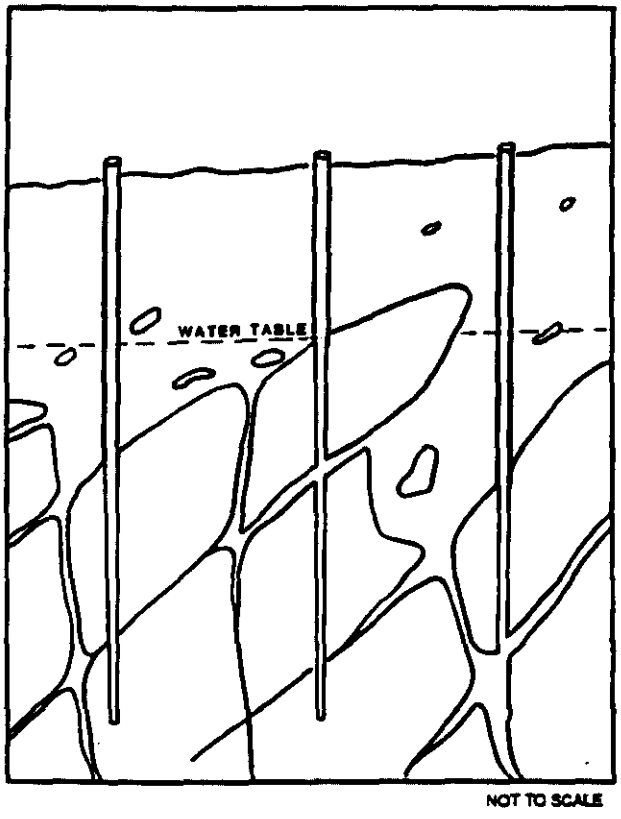


Figure 8.--Wells tapping solution openings in carbonate rock.

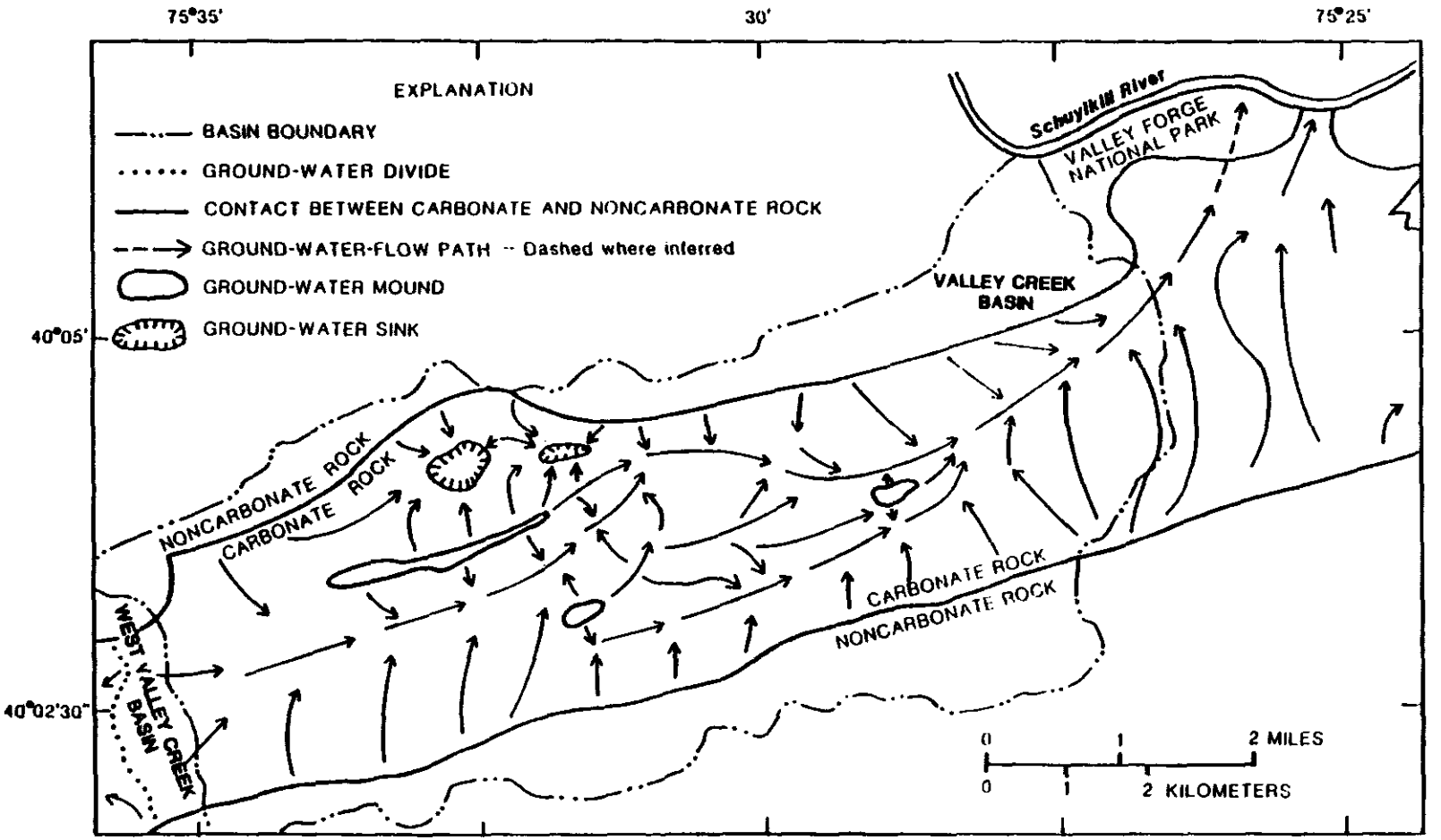


Figure 9.--Generalized direction of ground-water flow in the carbonate rocks of the Valley Creek Basin. (From Sloto, 1991a, fig. 13.)

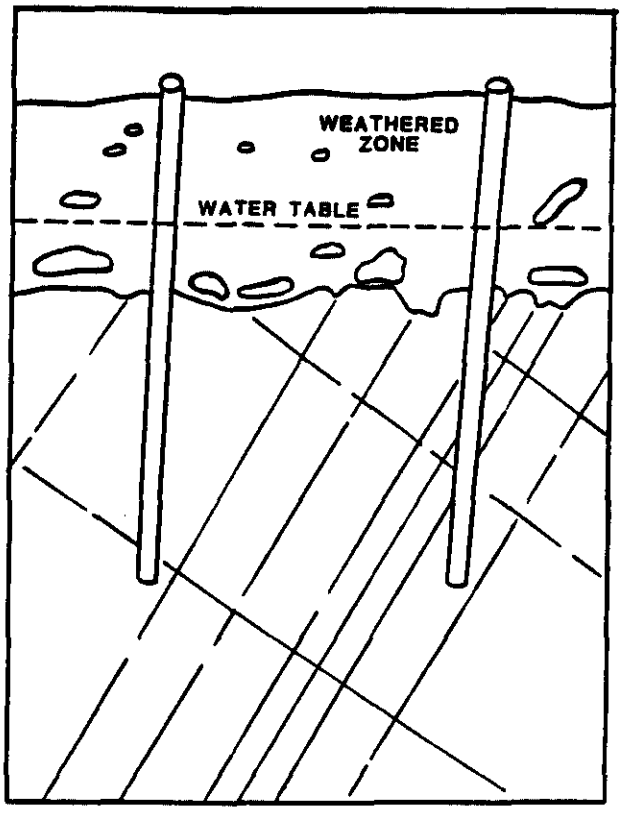
Ground-water flow in carbonate rock has both local and regional components. Locally, ground water discharges to gaining reaches of streams. Ground-water and surface-water divides often do not coincide. Ground water flows beneath surface-water divides, resulting in underflow to or from adjacent surface-water basins. For example, the Valley Creek basin in eastern Chester County does not have a ground-water divide to the east; regional ground-water flow from the Valley Creek basin discharges to the Schuylkill River (fig. 9). Computer model simulations show that wells pumping near a surface-water divide in one surface-water basin can reduce base flow in an adjacent surface-water basin (Sloto, 1991a).

Crystalline Rocks

The area underlain by crystalline rock is divided by the Chester Valley (fig. 6). The crystalline rocks north of Chester Valley are the Chickies, Antietam, and Harpers Formations and the amphibolite- and granulite-gneisses of the Honey Brook and Mine Ridge massifs. The crystalline rocks south of Chester Valley are the ultramafic rocks of the Baltimore Mafic Complex; the quartzite, schist, and phyllite of the Glenarm Supergroup; and the amphibolite- and granulite-facies gneiss of the Woodville, Avondale, and West Chester massifs.

In the crystalline rocks, ground water moves through intergranular openings in the saprolite (weathered zone) and through a network of interconnecting secondary openings—fractures and joints—in the underlying unweathered rock (fig. 10). The permeability of fractured crystalline rock depends on the number of fractures, the size of the fracture openings, and the degree of interconnection of the fractures.

The ground-water-flow system in crystalline rock is local with streams acting as drains. Flow paths are short, and ground water flows from areas of higher elevation to adjacent streams. Ground-water and surface-water divides usually coincide. The hydrologic system generally is under water-table conditions; the water-table surface is a subdued replica of the land surface. Semiconfined ground water may be present locally. A well will flow when it penetrates a water-bearing zone with a hydraulic head greater than land-surface elevation.



NOT TO SCALE

Figure 10.--Wells tapping fractures in crystalline rock.

DESCRIPTION OF MAP UNITS

Qal — **alluvium** (not field checked)--Fine- to medium-grained unconsolidated material deposited in and along stream valleys consisting mostly of silt and sand with some admixture of pebbles and locally derived cobbles.

Tpb — **Pensauken and Bridgeton Formations, undivided** -- Dark-reddish-brown, cross-stratified, feldspathic quartz sand and some thin beds of fine to coarse gravel; layers and lenses of clay or silt are also present. Most of the clasts are pebbles and cobbles, but a few reach boulder size. The matrix is earthy and muddy, imparting a significant compactness to the deposits.

Tbm — **Brys Mawr Formation**--High-level terrace deposits consisting of reddish-brown gravel, "ironstone conglomerate", gravelly loam, sand, and sandy loam, some of which is firmly indurated.

Jrd — **Diabase**--Dark-gray, fine-grained (in dikes) to medium-grained (in plutons) rock consisting mainly of plagioclase and pyroxene.

Trb — **Brunswick Group**--Reddish-brown, thin- to medium-bedded mudstone, shale, siltstone, and fine-grained sandstone containing a few green and/or brown shale interbeds. Near the base are tongues of thick-bedded, red argillite interbedded with dark-gray argillite characteristic of the underlying Lockatong Formation.

Trh — **Hammer Creek Formation**--Red to brown and light-gray, medium- to thick-bedded, fine- to medium-grained sandstone with subordinate siltstone and shale occurring between thick tongues of conglomeratic sandstone.

Trl — **Lockatong Formation**--Thick- to very-thick-bedded, medium- to dark-gray argillite interbedded with thin beds of gray to black shale, siltstone, and marlstone.

Trs — **Stockton Formation**--Light-gray, fine- to coarse-grained arkosic sandstone in the lower part; reddish-brown to grayish-purple, fine-grained sandstone, siltstone, shale, and mudstone in the upper part. The lower part is interlayered with thick beds of conglomeratic sandstone containing pebbles and cobbles of quartz and quartzite.

O€c — **Conestoga Limestone**--Blue-gray, thin-bedded, argillaceous limestone with intervals of purer granular limestone containing mica flakes on cleavage and bedding surfaces. Impure part has thin-bedded alternations of dark-gray, clayey, slaty, micaceous layers and medium-gray, argillaceous limestone. Also contains conglomeratic beds with pebbles and masses of white to gray granular marble in a gray limestone matrix.

€e — **Elbrook Limestone**--Finely-laminated, fine-grained, interbedded dolomite and limestone with muscovite and sericite on bedding and cleavage surfaces.

€l — **Ledger Dolomite**--Light-gray to white, thick-bedded, rather pure, granular dolomite, locally speckled and mottled. Contains a few beds of high-calcium marble.

€k — **Kinzers Limestone**--Gray micaceous limestone and calcareous mica schist with interbeds of dark-gray shale, dark-gray banded argillaceous limestone, and spotted white to gray marble.

€v — **Vintage Dolomite**--Dark-gray, granular dolomite with wavy, knotted texture. At the base is a white, knotted marble; in the upper part is a light-gray, coarse- to fine-grained, thick-bedded dolomite.

€Zah — **Antietam and Harpers Formations, undivided**--Gray, thin- to thick-bedded, laminated quartzite, quartzose schist, and sandy micaceous schist.

Zch — **Chickies Quartzite**--White to light-gray, thin- to thick-bedded quartzite with interbeds of quartzose schist and sandy mica schist. Conglomerate at the base contains white, colorless, and blue quartz pebbles and granules.

oct — **Octoraro Phyllite**--Bluish-gray to greenish-gray, well-foliated quartz-muscovite-chlorite phyllite with lustrous, smooth laminae; often contains quartz lenses parallel to the laminae around which the foliation wraps. Locally, a purplish slate is present.

wb — **Wissahickon Schist**--Light- to medium-gray, quartzo-aluminous schist and gneiss. Composition ranges from quartz-orthoclase-biotite and orthoclase-quartz-muscovite schist to quartz-biotite-plagioclase and quartz-plagioclase-biotite schistose gneiss. Moderately high metamorphic grade, mostly in the amphibolite facies.

pg — **pegmatite**--Light colored, very-coarse- to coarse-grained dikes and masses of granitic rock, containing mostly alkali feldspars and quartz with subordinate amounts of muscovite or biotite.

um — **ultramafite**--Yellowish-green, grayish-green, dark-green, and medium-dark-gray masses (up to hundreds of feet in size) of peridotite and pyroxenite, usually altered to serpentine, steatite, talc, actinolite, tremolite, and numerous other accessory minerals. In Mine Ridge, also includes granoblastic hornblendite containing some secondary chlorite.

md — **metadiabase**--Bluish-gray to greenish-gray, fine-grained rock with ophitic texture containing plagioclase (chiefly labradorite) and pyroxene (usually augite).

DESCRIPTION OF MAP UNITS

Ybfa — **felsic and intermediate gneiss, amphibolite facies**--Light- to medium-gray, medium-grained, finely to coarsely layered quartz-plagioclase-biotite-potassium-feldspar-garnet+/-hornblende gneiss.

Ybfg — **felsic gneiss, granulite facies**--Rather variable composition: medium- to dark-gray, coarse-grained plagioclase-quartz-orthoclase-garnet-biotite-hypersthene/clinopyroxene gneiss (strongly lineated) to light-gray, fine- to medium-grained quartz-mesoperthite-garnet+/-biotite+/-hypersthene gneiss. Quartz-kyanite and quartz-garnet+/-kyanite rocks are present locally.

Ybmg — **mafic gneiss, granulite facies**--Medium- to dark-gray, medium-grained, granoblastic plagioclase-clinopyroxene-hypersthene-garnet gneiss with or without biotite, quartz, orthoclase, and hornblende as accessory minerals.

Yhfa — **felsic gneiss, amphibolite facies**--Massive, slightly foliated quartz-plagioclase-biotite-muscovite-epidote gneiss with trace hornblende and orthoclase. Granular quartz-rich layers alternate and grade into quartz-plagioclase layers. Clots of muscovite flakes parallel scattered biotite layers.

Yhga — **graphitic felsic gneiss, amphibolite facies**--Massive, slightly foliated quartz-plagioclase-epidote-graphite gneiss, with minor biotite and muscovite and trace orthoclase. Granular quartz-rich layers alternate and grade into quartz-plagioclase layers. Clots of muscovite flakes parallel scattered biotite layers. Differs from felsic gneiss (Yhfa) solely by the presence of graphite.

Yhfs — **felsic and intermediate gneiss, amphibolite facies**--Massive, slightly foliated quartz-plagioclase-biotite-muscovite-epidote+/-hornblende gneiss with trace garnet in the biotite-rich layers. Granular quartz-rich layers alternate and grade into quartz-plagioclase layers. Clots of muscovite flakes parallel scattered biotite layers.

Yhma — **banded mafic gneiss, amphibolite facies**--Alternating layers of quartz-plagioclase-hornblende felsic gneiss with minor muscovite, biotite, and epidote and hornblende-plagioclase-biotite-epidote mafic gneiss with disseminated garnet prophyroblasts.

Yhfg — **felsic and intermediate gneiss, granulite facies**--Medium- to coarse-grained quartz-plagioclase mesoperthite felsic gneiss with subordinate hornblende, augite, and hypersthene. Intermediate gneiss contains a somewhat higher proportion of mafic minerals. The felsic gneiss is extensively interlayered with subordinate amounts of the mafic and intermediate gneiss.

DESCRIPTION OF MAP UNITS

Yhgg — **graphitic felsic gneiss, granulite facies**--Medium- to coarse-grained quartz-plagioclase-mesoperthite-hypersthene-graphite felsic gneiss with very subordinate amounts of microcline, hornblende, and augite. The graphite occurs as medium-grained rods, irregular patches and stringers, and distinct layers. Extensively interlayered with subordinate amounts of mafic gneiss.

Yhm — **marble**--White to light-gray, massive to banded, coarsely crystalline marble, dolomitic in part. Graphite is present at all localities, and each occurrence is associated with graphitic felsic gneiss.

Yhmg — **mafic gneiss, granulite facies**--Medium-grained, equigranular hornblende-plagioclase-quartz+/-augite+/-hypersthene mafic gneiss with subordinate mesoperthite and trace garnet and biotite. Extensively interlayered with the dominant felsic gneiss.

Yhan — **anorthosite suite**

anorthosite (40 percent)--massive, dark-bluish-gray to light-gray to pinkish-gray, coarse-grained, granular plagioclase with subordinate disseminated and segregated patches of hornblende, biotite, quartz, apatite, and magnetite.

leuco-hornblende gabbro (40 percent)--massive, "peppered" dark-bluish-gray to light-gray, coarse-grained, granular plagioclase with lesser amounts of disseminated and segregated patches of hornblende, biotite, and magnetite. Transitional between anorthosite and hornblende gabbro; plagioclase is somewhat more sodic than in the anorthosite.

hornblende gabbro (20 percent)--massive, light-gray to pink, very coarse-grained, very granular plagioclase with numerous lenses and layers of the mafic minerals hornblende, biotite, and garnet.

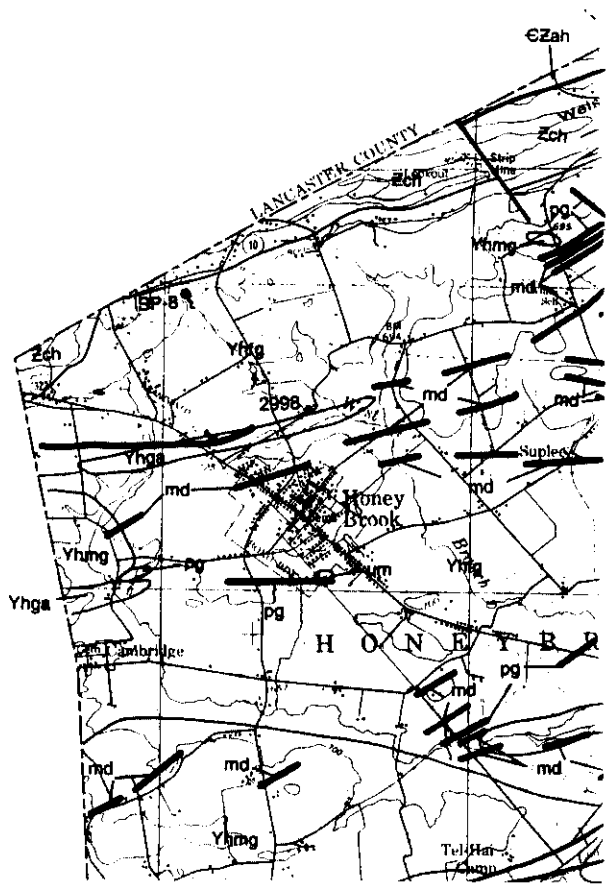
EXPLANATION

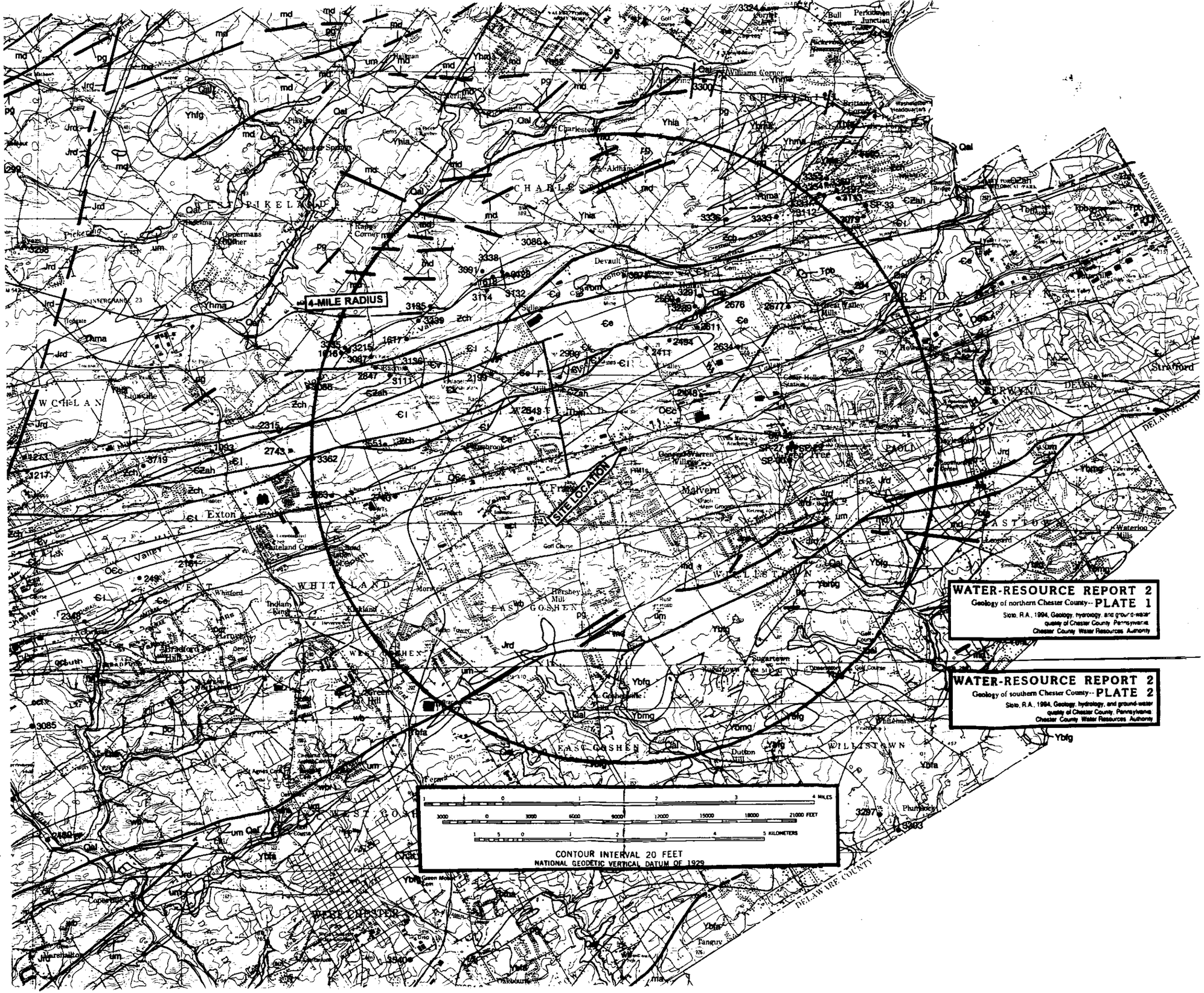
3300 ● WELL AND IDENTIFICATION NUMBER

SP-37 ● SPRING AND IDENTIFICATION NUMBER

——— CONTACT - Accuracy not stated

— — — FAULT - Dashed where approximately located. Where throw is indicated: U, upthrown side; D, downthrown side





ORIGINAL (Red)

WATER-RESOURCE REPORT 2
Geology of northern Chester County--**PLATE 1**
Sloto, R.A., 1994, Geology, hydrology, and ground-water quality of Chester County, Pennsylvania: Chester County Water Resources Authority

WATER-RESOURCE REPORT 2
Geology of southern Chester County--**PLATE 2**
Sloto, R.A., 1994, Geology, hydrology, and ground-water quality of Chester County, Pennsylvania: Chester County Water Resources Authority

ORIGINAL (Red)

REFERENCE NO. 19

ORIGINAL (Red)

GEOHYDROLOGY AND SIMULATION OF GROUND-WATER FLOW IN THE CARBONATE ROCKS OF THE VALLEY CREEK BASIN, EASTERN CHESTER COUNTY, PENNSYLVANIA

By Ronald A. Sloto

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 89-4169

Prepared in cooperation with the

CHESTER COUNTY WATER RESOURCES AUTHORITY

Harrisburg, Pennsylvania

1990

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ABSTRACT

Sixty-eight percent of the 22.6-square-mile Valley Creek basin is underlain by Cambrian and Ordovician limestone and dolomite. Ground water flows through a network of interconnected secondary openings; primary porosity is virtually nonexistent. Some of these openings have been enlarged by solution. Secondary porosity and permeability exhibit great spatial variability, and the yield and specific capacity of wells are highly variable. The number of water-bearing zones decreases with depth. Fifty percent of water-bearing zones are encountered within 100 feet of the land surface, and 81 percent are within 200 feet.

Most ground-water flow in the Valley Creek basin is local and discharges to nearby streams. Ground-water discharge comprised an average of 76 percent of the flow of Valley Creek during 1983-87, including both natural ground-water discharge and quarry pumpage discharged to Valley Creek. Discharge from the Cedar Hollow quarry comprised 21 to 26 percent of the base flow of Valley Creek; the average was 23 percent. The average natural base flow of Valley Creek would be 8 percent lower if the quarry were not operating.

Regional ground-water flow is to the northeast to the Schuylkill River. On the western side of the Valley Creek basin, the ground-water divide is 1/2 mile west of the surface-water divide. An estimated 0.75 million gallons per day of ground water flows from the adjacent West Valley Creek basin eastward into the Valley Creek basin. A ground-water divide is not present on the eastern side of the basin; the water table slopes gently eastward toward the Schuylkill River. On the northeastern side, an estimated 1.76 million gallons per day of ground water flows northeastward out of the basin to the Schuylkill River beneath the surface-water divide. On the southeastern side, an estimated 0.85 million gallons per day of ground water flows beneath the surface-water divide into the basin.

Annual water budgets and an average water budget were calculated for 1983-87 for the 20.8-square-mile area above the streamflow-gaging station. Annual precipitation for 1983-87 ranged from 40.61 to 56.55 inches and averaged 47.25 inches; annual streamflow ranged from 15.55 to 28.57 inches and averaged 22.31 inches; annual evapotranspiration ranged from 18.21 to 24.83 inches and averaged 22.90 inches; and annual recharge ranged from 15.89 to 26.84 inches and averaged 21.04 inches.

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Purpose and Scope

This report describes ground-water flow in the carbonate rocks of the Valley Creek basin. A digital model of regional ground-water flow was developed and used to simulate the average water budget in the basin and to estimate the effects of increased well and quarry pumping on base flow and underflow. Although the report primarily discusses ground-water flow in the carbonate rocks of the Valley Creek basin, it was necessary to consider noncarbonate rocks north and south of the carbonate rocks as well as the eastern and western boundaries of the hydrologic system to simulate ground-water flow. Therefore, the carbonate rocks between the Schuylkill River and the Brandywine Creek in Chester and Montgomery Counties are included in the modeled area. Data for noncarbonate rocks in these areas also are given in this report.

The report also presents a water budget for the Valley Creek basin upstream from the stream-gaging station at the Pennsylvania Turnpike bridge near Valley Forge (station 01473169), describes the development and calibration of a two-dimensional digital model of ground-water flow, and briefly discusses ground-water quality.

Location and Physiography

The Valley Creek basin is in eastern Chester County in southeastern Pennsylvania (fig. 1). Valley Creek drains 22.6 mi^2 (square miles) and is a tributary to the Schuylkill River. Streamflow from 20.8 mi^2 is measured at streamflow-gaging station 01473169, Valley Creek at Pennsylvania Turnpike Bridge near Valley Forge (fig. 2). Little Valley Creek, the major tributary to Valley Creek, drains 6.92 mi^2 and is confluent with Valley Creek above the gaging station.

The Valley Creek basin is in the Piedmont physiographic province. Sixty-eight percent of the basin is underlain by carbonate rocks; 32 percent of the basin is underlain by noncarbonate rocks. The center of the basin is underlain mostly by easily eroded limestone and dolomite, which form Chester Valley (fig. 2). Chester Valley cuts across the center of Chester County. The northern part of the Valley Creek basin is underlain by resistant quartzites that form the North Valley Hills. The southern part of the Valley Creek basin is underlain by resistant phyllite that forms the South Valley Hills.

Chester County has a modified humid continental climate characterized by warm summers and moderately cold winters. The normal annual temperature (1951-80) recorded at Phoenixville, 3 mi (miles) north of the Valley Creek basin, is 51.3 °F (degrees Fahrenheit). The normal temperature for January, the coldest month, is 30.1 °F. The normal temperature for July, the warmest month, is 74.5 °F. The average annual precipitation at Phoenixville for 81 years of record (1890-95, 1913-87) is 43.85 in. (inches). The minimum annual precipitation, 31.10 in., occurred in 1963. The maximum annual precipitation, 59.55 in., occurred in 1979. The 1951-80 normal precipitation is 43.55 in. (National Oceanic and Atmospheric Administration, 1982). Precipitation is mostly evenly distributed throughout the year, but slightly more falls in July and August than in the other months.

Acknowledgments

The cooperation of well owners for access to wells for water samples, water-level measurements, and geophysical logging is gratefully acknowledged. The author especially thanks Glasgow, Incorporated; Leggette, Brashears, and Graham, Incorporated; the Pennsylvania Department of Environmental Resources; Philadelphia Suburban Water Company; Thomas G. Keyes, Incorporated; and the Warner Company for providing data and access to their wells and property. Special thanks is given to the Philadelphia Suburban Water Company for providing aquifer-test data for their wells and to Sidney Fox of Leggette, Brashears, and Graham; Preston Leutweiller of the Philadelphia Suburban Water Company; and Joseph Pinto of the Warner Company.

GEOHYDROLOGY

Stratigraphy

The carbonate rocks of Chester Valley form the center of the Valley Creek basin. Noncarbonate rocks underlie the North Valley Hills to the north and the South Valley Hills to the south (pl. 1). The stratigraphic relationships of these units are given in table 1. Geologic descriptions were taken from Bascom and Stose (1938) and Lyttle and Epstein (1987). The nomenclature used in this report is that of Lyttle and Epstein (1987). The nomenclature of Berg and others (1986) given in table 1 is used by the Pennsylvania Geological Survey and has been used for previous reports on the ground-water resources of Chester County.

Carbonate Rocks

A sequence of carbonate rocks of Cambrian and Ordovician age underlies Chester Valley. The principal formations are the Cambrian Ledger Dolomite and Elbrook Formation and Cambrian and Ordovician Conestoga Limestone. The Cambrian Vintage Dolomite and Kinzers Formation, which crop out in a narrow band, are thin and are not important water-bearing units.

Vintage Dolomite

The Vintage Dolomite is of small areal extent in eastern Chester Valley. In the Valley Creek basin, it is present in a fault block north of Mill Lane and in a very narrow band between two parallel faults in the northeastern part of the basin. The lower part of the Vintage Dolomite is a fine-grained, thin- to medium-bedded, argillaceous to sandy dolomite with abundant mica on the bedding planes. The upper part is a fine- to medium-grained, mottled, blue limestone, grading downward into medium-grained, knotty dolomite with blebs of coarse-grained dolomite, grading downward into medium-grained, thick-bedded dolomite. It is less than 200 ft (feet) thick.

Kinzers Formation

The Kinzers Formation crops out adjacent to the Vintage Dolomite in eastern Chester Valley. The upper part is a fine- to medium-grained, irregularly bedded, argillaceous, nodular limestone containing marble lenses.

The lower part is a thin-bedded, impure limestone. The weathered limestone has the appearance of a shaley mica schist. The Kinzers Formation is less than 30 ft thick.

Ledger Dolomite

The Ledger Dolomite has been quarried in many places in Chester Valley. It is white to gray, massive to thick bedded, finely laminated, and has a high magnesium content. The dolomite is interbedded with some siliceous beds and laminated limestone, which is finely speckled in places. The lower part of the unit is characterized by alternating light and dark, porous, cherty layers. The lower contact is gradational with the Kinzers Formation. The Ledger is about 1,000 ft thick.

Table 1.--Stratigraphic section

SYSTEM AND ERA	SERIES	GEOLOGIC UNIT: Lyttle and Epstein (1987)	GEOLOGIC UNIT: Berg and others (1986)
Triassic	Upper Triassic	Stockton Formation	Stockton Formation
Ordovician	Lower Ordovician	Conestoga Limestone	Conestoga Formation
Cambrian	Upper Cambrian		
	Middle Cambrian	Elbrook Formation	Elbrook Formation
		Ledger Dolomite	Ledger Formation
	Lower Cambrian	Kinzers Formation	Kinzers Formation
		Vintage Dolomite	Vintage Formation
		Antietam Quartzite and Harpers Phyllite, undivided	Antietam Formation and Harpers Formation, undivided
		Chickies Quartzite	Chickies Formation
Late and Middle Proterozoic		Leucocratic and Intermediate Felsic Gneiss	Gneiss

Octoraro Phyllite

Wissahickon ("Octoraro") Schist

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Elbrook Formation

The Elbrook Formation forms low hills in Chester Valley and underlies the ridge south of the Catanach and Cedar Hollow quarries. The Elbrook is a light blue, thin-bedded, fine-grained limestone interbedded with white, thick-bedded, fine-grained, laminated dolomitic marble. Concentrations of coarse-grained mica are left as a pressure-solution residue parallel to regional cleavage. The lower contact is gradational with the Ledger Dolomite. The Elbrook is about 800 ft thick.

Conestoga Limestone

The Conestoga Limestone crops out along the southern edge of Chester Valley. Mica coats most of the bedding and cleavage planes. The lower part of the formation is a coarsely crystalline, light gray to white, medium- to thick-bedded dolomite interbedded with thin-bedded, medium-grained limestone and thin-bedded, fine-grained dolomite. Some of the basal beds are a coarse limestone conglomerate containing large pebbles and irregular masses of coarse white marble in a dark, argillaceous matrix. The middle part of the formation is a thin, dark, graphitic phyllite with thin, sandy schist layers that thicken eastward. It generally forms a line of discontinuous hills. The upper part is a bluish gray, thin-bedded, fine- to medium-grained, highly micaceous limestone with argillaceous, shaley partings that give it a finely laminated appearance. It unconformably overlies the Elbrook Formation. The Conestoga Limestone is 500 to 800 ft thick.

Noncarbonate Rocks

The area underlain by crystalline rock is divided by Chester Valley. North of Chester Valley, the North Valley Hills are underlain by the Cambrian Chickies Quartzite and the Antietam Quartzite and Harpers Phyllite, undivided, and Middle Proterozoic leucocratic and intermediate felsic gneiss. South of Chester Valley, the South Valley Hills are underlain by the Cambrian to Late Proterozoic Octoraro Phyllite.

Leucocratic and intermediate felsic gneiss

The Middle Proterozoic leucocratic and intermediate felsic gneiss is of small areal extent in the Valley Creek basin. It is a fine- to medium-grained, white to gray, microcline-microperthite-quartz gneiss intimately associated with biotite-oligoclase-microperthite-quartz gneiss and is interlayered with amphibolite.

Octoraro Phyllite

The South Valley Hills are underlain by the Octoraro Phyllite (which was called the albite-chlorite facies of the Wissahickon Formation by Bascom and Stose, 1938). The Octoraro Phyllite is a greenish- to silvery-gray, fine- to medium-grained phyllite and phyllonite. Grain size decreases to the north. Along the northern edge of its outcrop area, the Octoraro Phyllite is bounded by a major thrust fault and is thrust over and onto the Conestoga Limestone.

Chickies Quartzite

The Chickies Quartzite is a medium-grained, cross-bedded, massive to medium-bedded, finely-laminated quartzite and sericitic quartz schist. The basal Hellam Member, which is not mapped as a separate unit, is a coarse-grained, tourmaline-bearing quartzite and arkosic pebble conglomerate with interbeds of black slate and biotite schist. The Chickies Quartzite is about 500 ft thick.

Antietam Quartzite and Harpers Phyllite

The Antietam Quartzite and Harpers Phyllite are undivided north of Chester Valley. The Antietam Quartzite is a fine-grained, laminated quartzite that grades downward into the Harpers Phyllite. The upper beds are coarse grained and calcareous. The Antietam Quartzite is estimated to be less than 200 ft thick north of Chester Valley. The Harpers Phyllite is fine- to medium-grained, sandy, and argillaceous. It is less than 500 ft thick.

Stockton Formation

The Triassic Stockton Formation is part of the sedimentary Newark basin. The Stockton is a thick sequence of interbedded sandstone, arkosic sandstone, arkose, arkosic conglomerate, siltstone, and shale. The beds dip about 10 to 20 degrees to the northeast. The Stockton unconformably overlies older Paleozoic and Precambrian rocks. In the modeled area, the Stockton Formation is as much as 3,000 ft thick.

Hydrology

Ground water flows through a network of fractures slightly enlarged by solution. The ground-water system in Chester Valley more nearly resembles that of fractured rock than that of a classical karst terrane. A karst terrane generally is characterized by sinkholes, dry valleys, and underground drainage; regional ground-water flow is through an arterial network leading to a large main conduit that discharges through large springs. Most flow in the Valley Creek basin is local with discharge to nearby streams. Regional flow in eastern Chester Valley is to the Schuylkill River.

Dissolution is the primary weathering process of carbonate rock. Dissolution generally is most active above and within the zone of water-table fluctuation where water movement is relatively rapid and recharge water is acidic. Below the zone of water-table fluctuation, water movement is comparatively slower, and acidic recharge water becomes neutralized. Near the land surface, dissolution of carbonate rock results in the filling of voids by clay, the collapse of solution openings, and the progressive lowering of the land surface. Clay and unconsolidated material sometimes moves downward through solution openings, plugging water-bearing openings. This plugging can decrease well yields and increase turbidity of ground-water discharged from wells.

The depth of weathering is highly variable. Deeply weathered zones can be found adjacent to outcrops. Carbonate rock commonly exhibits pinnacle weathering (fig. 3). Pinnacle weathering is caused by solution along bedding planes and fractures parallel to bedding planes in steeply-dipping strata. As solution enlarges openings along the bedding planes and fractures, and enlargement moves downward in the formation, the solid rock between the weathered areas is left as pinnacles.

Figure 3.--Pinnacles of the Elbrook Formation exposed in the Cedar Hollow quarry. View looking east.

Water-Bearing Zones

Primary porosity in the carbonate rocks of Chester Valley is virtually nonexistent. Ground water flows through a network of interconnected secondary openings--fractures, joints, faults, parting planes, and bedding planes. Some of these openings have been enlarged by solution. The number and size of the openings determines the secondary porosity of the rock; the degree of interconnection of the openings determines the secondary permeability. The high permeability of carbonate rock is predominantly the result of enlargement of secondary openings by solution. Where solution has been active, permeability may be high; elsewhere, the same unit may be nearly impermeable.

Most openings enlarged by solution are only a fraction of an inch wide, but they are capable of transmitting large quantities of water. A close inspection of five active quarries in Chester Valley during this study revealed very few large solution openings. Most of the solution openings were horizontal enlargements of vertical fractures and were less than 1 ft (foot) wide (fig. 4). Most of the ground water entering the quarries flowed from very narrow fractures. Ground water was observed discharging from only one large solution opening about 15 ft above the third level of the Cedar Hollow quarry (fig. 5); the opening was less than 1 ft across.

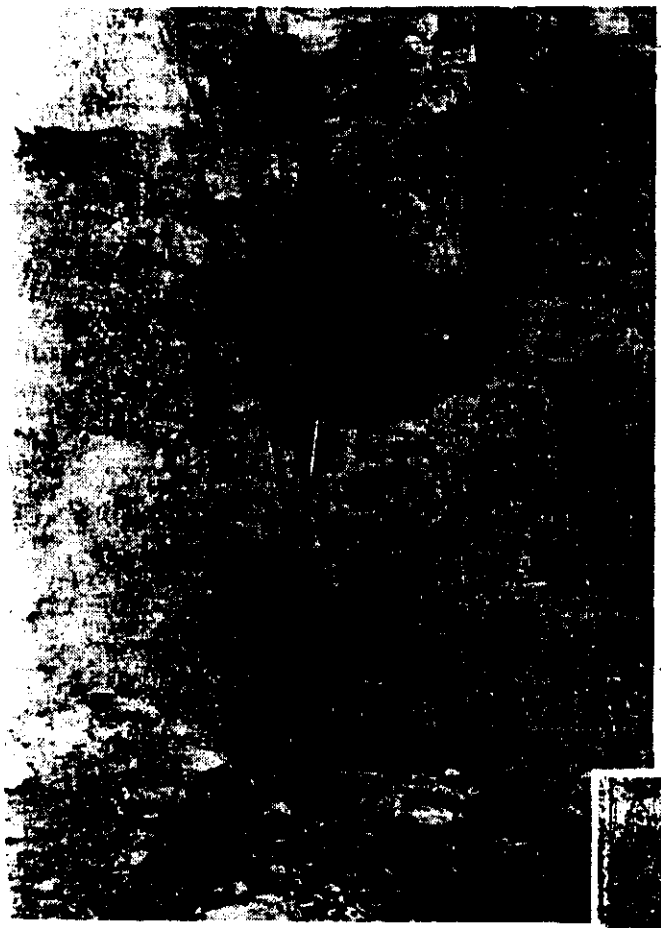

Figure 4.--Solution openings along a vertical fracture in the Cedar Hollow quarry. Scale in center of photograph is one foot long.

Figure 5.--Ground water discharging from a solution opening in the Cedar Hollow quarry. Scale on left side of photograph is two foot long.

Well CH-89, drilled south of the Cedar Hollow quarry in the Elbrook Formation, penetrated a 58-ft void from 207 to 265 ft below land surface. From 265 to 295 ft, the opening was filled with mud and rubble. Drilling was halted at 295 ft without penetrating solid rock. The void was probably an enlarged fracture similar to the one in figure 5. The well was drilled near a sinkhole area. The mud and rubble at the bottom of the opening is probably weathered surficial material that moved downward through sinkholes.

The number of water-bearing zones decreases with depth (fig. 6). The distribution of 235 water-bearing zones in 119 wells in the Vintage Dolomite, Kinzers Formation, Ledger Dolomite, Elbrook Formation, and Conestoga Limestone in Chester County was analyzed. These 119 wells represent 16,403 ft of uncased borehole; well depths are as great as 605 ft. Fifty percent of the water-bearing zones are encountered within 100 ft of the land surface, and 81 percent are encountered within 200 ft of land surface (fig. 6). Table 2 shows that more than two water-bearing zones per 100 ft of uncased borehole were encountered in the upper 100 ft of the geologic units, more than one water-bearing zone per 100 ft was encountered in the upper 200 ft, and less than one water-bearing zone per 100 ft was encountered below 200 ft. The large number of water-bearing zones per 100 ft at depths greater than 450 ft is because of small sample size.

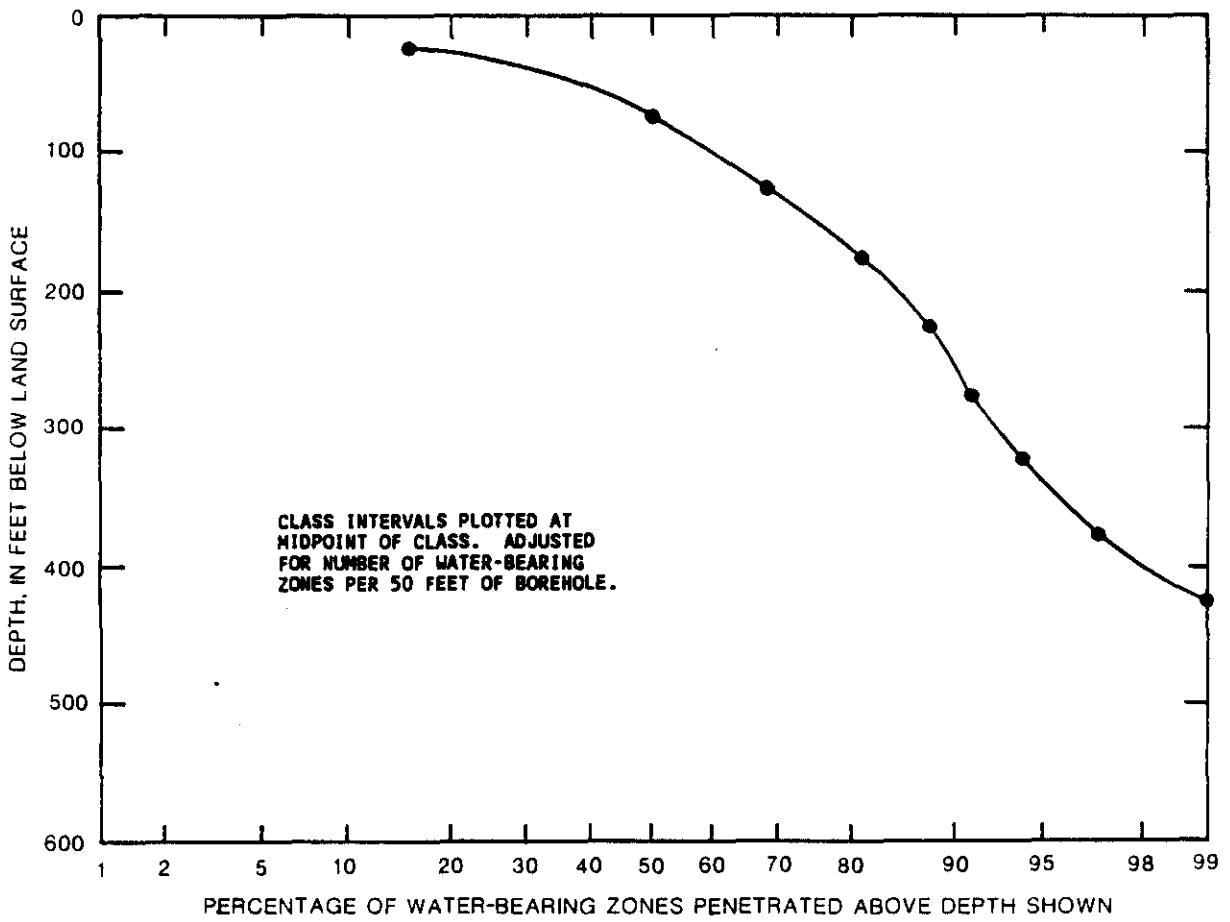

Figure 6.--Distribution of water-bearing zones with depth in carbonate rock.

Conestoga Limestone.--The Conestoga Limestone is generally a low-yield carbonate rock. Well yields range from less than 1 to 1,000 gal/min; however, only one yield exceeds 225 gal/min. The median yield of nondomestic wells is 65 gal/min. Specific capacities of four nondomestic wells in Chester County range from 0.01 to 167 (gal/min)/ft (gallons per minute per foot) of drawdown.

Transmissivities based on analysis of four aquifer tests conducted for 24 to 72 hours on wells in the modeled area in Chester and Montgomery Counties ranged from 1,250 to 1,680 ft^2/d (feet squared per day); the median was 1,540 ft^2/d. The specific capacities of the four wells ranged from 15 to 27 (gal/min)/ft.

Elbrook Formation.--The Elbrook Formation is the least productive carbonate rock in Chester Valley. Yields range from less than 1 to 1,200 gal/min; however, only two yields exceed 500 gal/min. The median yield of nondomestic wells is 75 gal/min. The specific capacities of 10 nondomestic wells in Chester County range from 0.02 to 24 (gal/min)/ft; the median specific capacity is 0.83 (gal/min)/ft.

Transmissivities based on analysis of five aquifer tests conducted for 6.5 to 96 hours on wells in the modeled area in Chester County ranged from 13 to 2,740 ft^2/d; only one transmissivity exceeded 350 ft^2/d. The median was 211 ft^2/d. The specific capacities of the five wells ranged from 0.16 to 15 (gal/min)/ft.

Ledger Dolomite.--The Ledger Dolomite is the most productive aquifer in Chester County. Yields range from less than 1 to 1,120 gal/min. The median yield of nondomestic wells is 100 gal/min. Specific capacities of 14 nondomestic wells in Chester County range from 0.5 to 155 (gal/min)/ft; the median specific capacity is 20 (gal/min)/ft.

Transmissivities based on analysis of six aquifer tests conducted for 63 to 315 hours on wells in the modeled area in Chester and Montgomery Counties ranged from 600 to 15,430 ft^2/d; the median transmissivity was 1,680 ft^2/d. The specific capacities of the six wells ranged from 8 to 74 (gal/min)/ft.

Kinzers Formation and Vintage Dolomite.--Few data are available for wells in the Kinzers Formation and Vintage Dolomite in Chester County. These geologic units crop out together in a narrow band and are thin and of small areal extent. Because they are so thin, wells drilled into the Kinzers and Vintage probably derive water from underlying units, making the Kinzers and Vintage difficult to evaluate. Data on well yield and specific capacity for the few wells identified with these geologic units are summarized in tables 3 and 4.

Yields of four wells in the Kinzers Formation range from 10 to 100 gal/min. The specific capacity of three wells range from 0.08 to 1.4 (gal/min)/ft.

Yields of 13 wells in the Vintage Dolomite range from less than 1 to 665 gal/min; however, only one yield exceeds 100 gal/min. The median yield is 50 gal/min. Specific capacities of four nondomestic wells range from 0.71 to 29 (gal/min)/ft.

Noncarbonate rocks

Well yields in the Stockton Formation range from 4 to 800 gal/min. The median yield of nondomestic wells is 70 gal/min. Specific capacities of four nondomestic wells range from 2.5 to 14 (gal/min)/ft.

Well yields in the Antietam Quartzite and Harpers Phyllite (undivided) range from 1 to 75 gal/min; the median yield is 12 gal/min. Specific capacities of three wells range from 0.04 to 0.19 (gal/min)/ft.

Well yields in the Chickies Quartzite range from less than 1 to 100 gal/min. The median yield of nondomestic wells is 25 gal/min. Specific capacities of seven nondomestic wells range from less than 0.01 to 3 (gal/min)/ft; the median specific yield is 0.55 (gal/min)/ft.

Well yields in the leucocratic and intermediate felsic gneiss range from less than 1 to 165 gal/min. The median yield of nondomestic wells is 55 gal/min. Specific capacities of 14 nondomestic wells in Chester County range from 0.04 to 25 (gal/min)/ft; the median specific yield is 0.4 (gal/min)/ft.

Well yields in the Octoraro Phyllite range from less than 1 to 300 gal/min. The median yield of nondomestic wells is 40 gal/min. Specific capacities of 14 nondomestic wells range from 0.12 to 3.8 (gal/min)/ft; the median specific capacity is 1.3 (gal/min)/ft.

Water-Level Fluctuations

The carbonate rocks of Chester Valley form a complex, heterogeneous water-table aquifer. The water table fluctuates in response to recharge from precipitation, discharge from pumped wells and quarries, evapotranspiration, and discharge to streams. The water table generally rises during the fall and winter when evapotranspiration is at a minimum and recharge is at a maximum; it declines during the spring and summer when evapotranspiration is at a maximum and recharge is at a minimum. Wells in different parts of Chester Valley have similar hydrographs (fig. 9).

Shallow and deep wells have similar water levels and similar responses to precipitation. Two wells in the Conestoga Limestone 200 ft apart--one shallow and one deep--were equipped with continuous water-level recorders. Well CH-80 is 57 ft deep, and well CH-2448 is 300 ft deep. The water-level altitude was about the same in both wells (fig. 10). The water levels in both wells had a similar response to precipitation and similar fluctuations (fig. 11).

Although the ground-water system is generally under water-table conditions, confined ground water is present locally. In carbonate rocks, ground water can be confined by the relatively impermeable sides of a fracture or solution channel. Confined conditions were observed in three wells in the Elbrook Formation in the center of the Valley Creek basin. The water level in well CH-2313 rose above land surface in the spring of 1978, 1983, and 1984; it was 1.50 ft above land surface on April 21, 1983. Well CH-2148 is a flowing

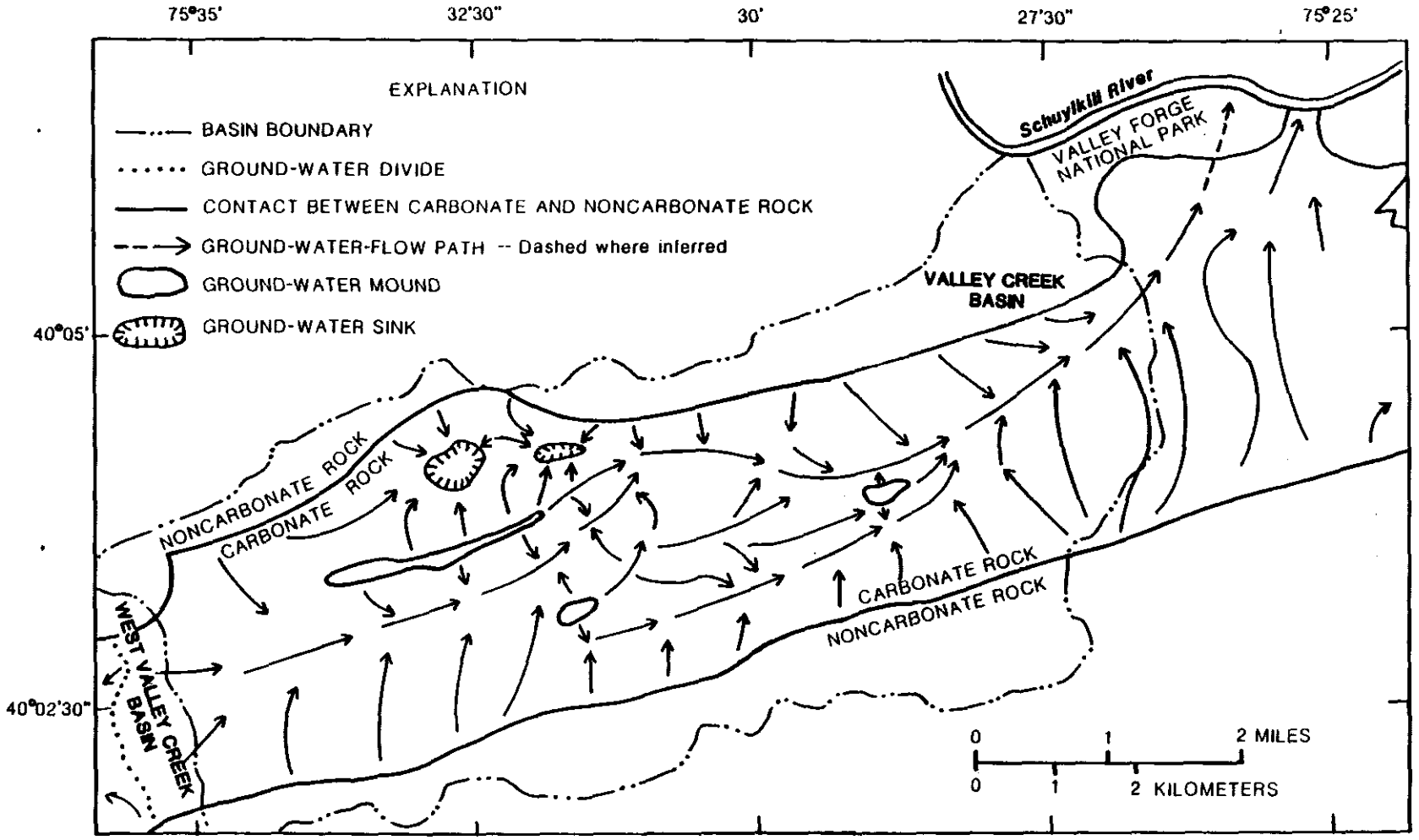

Figure 13.--Generalized direction of ground-water flow in the carbonate rocks of the Valley Creek basin.

1.78 in/yr. On the southeastern side of the Valley Creek basin, some ground-water flows beneath the surface-water divide into the basin. Based on Darcy's law and the water-table map of Sloto (1987, pl. 2), estimated ground-water inflow to the basin from the southeast is 0.85 Mgal/d or 0.86 in/yr.

During low streamflow when the water table is low, Valley Creek loses water between the streamflow-gaging station and the contact between the carbonate and crystalline rocks where Valley Creek leaves Chester Valley. The measured loss in this reach was 3.23 Mgal/d on October 10, 1984, and 0.94 Mgal/d on July 1, 1985. The streamflow measured at the bridge on Wilson Road (station number 01473170 on pl. 1) was 20.1 and 17.7 ft^3/s (cubic feet per second), respectively. An increase in streamflow between these points was measured on April 28, August 13, and November 11, 1975, when the streamflow at the bridge on Wilson Road was 50, 38.1, and 34.5 ft^3/s, respectively.

Water Budget

A water budget is an estimate of water entering and leaving a basin plus or minus changes in storage for a given time period. Water enters as precipitation and leaves as ground-water flow, streamflow, evapotranspiration, and diversions, such as ground-water pumpage. Water also is taken into or released from ground-water and soil-moisture storage.

Annual water budgets for 1983-87 and an average water budget for those years were calculated for the 20.8-mi^2 part of the basin above the streamflow-gaging station. The streamflow gage measures the quantity of water leaving the basin above the gage as streamflow. Water-level records from observation well CH-323 were used to estimate the annual change in ground-water storage. Ground-water withdrawals from the basin are calculated from pumpage data supplied by the Philadelphia Suburban Water Company; estimated commercial, industrial, and domestic pumpage (Sloto, 1987, p. 22); and water pumped by the Catanach quarry not returned to the ground-water system. These ground-water withdrawals are consumptive use or are removed from the Valley Creek basin as exported ground water. Records of pumpage from the Cedar Hollow quarry were supplied by the Warner Company. Precipitation was measured at a rain gage maintained in the basin by the U.S. Geological Survey.

The annual change in ground-water storage was estimated using water-level data from observation well CH-323. Specific yield was calculated from the change in water level in well CH-323 for six periods between August 24, 1984, and June 10, 1986. The selection criteria for these periods were:

(1) Streams were at base flow. No rain fell immediately prior to the start of the period.

(2) No recharge was observed in the hydrograph of well CH-323. Little or no rain fell during the period; any precipitation that fell went to satisfy the soil-moisture deficit.

(3) The period was longer than 10 days.

(4) Streamflow, water-level, rainfall, and quarry-pumpage data were available preceding and during the period.

Simplified Conceptual Model

Continuum methods of ground-water-flow analysis, including modeling, assume laminar flow through a medium with primary porosity and permeability (porous media). The geologic units in Chester Valley have low primary porosity or permeability; ground water flows mainly through secondary openings. However, to permit analysis by continuum methods, the geologic units in Chester Valley are assumed to approximate porous media because of the regional scale of analysis. Secondary-opening density is sufficiently great at a regional scale to permit the use of a porous-media model. A block of aquifer material is assumed to have the equivalent properties of the same-size block of porous media. Water-table maps of Chester Valley (Sloto, 1987, pl. 2; Wood, 1984; Wood, 1985) indicate that ground-water flow is continuous on a regional scale.

In order to analyze ground-water flow with a digital model, a simplified conceptual model of the complex physical system was developed. The conceptual model includes the following assumptions:

(1) The geologic units in Chester Valley act together as a single heterogeneous water-table aquifer.

(2) Hydraulic properties of each geologic unit differ spatially, but are averaged for model simulation. The average is considered representative of the geologic unit. An average hydraulic conductivity is specified for each geologic unit.

(3) The ground-water system is recharged by precipitation. Recharge to noncarbonate rocks is half of recharge to carbonate rocks because the noncarbonate rocks have much steeper slopes, are much less permeable, and accept recharge at a lower rate than carbonate rocks. Recharge is distributed evenly over each rock type.

(4) Streams are in direct hydraulic contact with the aquifer.

(5) The lower limit of ground-water flow is 600 ft below land surface based on analysis of water-bearing zones. Ground-water flow below 600 ft is considered negligible.

(6) Secondary permeability is a function of topography and generally increases down gradient from hilltop to valley bottom (Gerhart and Lazorchick, 1984, p. 11-13). Hydraulic conductivity is a function of secondary permeability; therefore, hydraulic conductivity in the same unit is greater in valley-bottom areas than in hilltop areas. The effect of topography is approximated by adjusting hydraulic conductivity for the topographic position of each cell.

Discretization

Because ground-water and surface-water divides do not coincide in Chester Valley, the Valley Creek basin cannot be modeled separately. The area between the Brandywine Creek and the Schuylkill River was modeled to include the natural hydrologic boundaries of the ground-water-flow system (pl. 2). The

Table 10.--Aquifer hydraulic conductivity used for steady-state simulation

[Initial estimates of hydraulic conductivity based on transmissivity calculated from specific-capacity data by the method of Theis (1963, p. 332). Final estimates of hydraulic conductivity are values used in the model after adjusting the initial estimates.]

Geologic unit	Hydraulic conductivity (feet per day) Initial	Final
Stockton Formation	1.9	8.0
Conestoga Limestone	32	10
Elbrook Formation	6.7	7.0
Ledger Dolomite	44	45
Kinzers Formation and Vintage Dolomite	53	6.0
Antietam Quartzite, Harpers Phyllite, Chickies Quartzite, and leucocratic gneiss	2.6	3.0
Octoraro Phyllite	5.2	5.0

Calculation of hydraulic conductivity using specific capacity data from aquifer tests gave values similar to those in table 10. The hydraulic conductivity of the Ledger Dolomite calculated from specific-capacity data was 58 ft/d, the hydraulic conductivity of the Elbrook Formation was 6.2 ft/d, and hydraulic conductivity of the Conestoga Limestone was 20 ft/d.

Hydraulic conductivity of consolidated-rock aquifers is affected by topography (Poth, 1968, p. 21-23). Generally, hydraulic conductivity is less on hilltops and greater in valley-bottom areas. On hilltops, fractures are widely spaced, and the unit is more resistant to weathering. In valley-bottom areas, fractures are closely spaced, and the unit is less resistant to weathering.

Cells were classified as hilltop, hillside, or valley bottom from their topographic position on 7.5-minute topographic maps. The hydraulic conductivity for each cell was multiplied by a topography-adjustment coefficient (table 11) using the method of Gerhart and Lazorchick (1984, p. 27) to adjust hydraulic conductivity for topographic position. The distribution of final hydraulic conductivity is shown on plate 3.

The water-table aquifer system is anisotropic. The preferential direction of ground-water flow in Chester Valley is parallel to bedding along strike. The strike of the geologic units in Chester Valley is northeast. The model grid is oriented parallel to strike. A column-to-row anisotropy multiplication factor of 0.2, based on simulated regional ground-water flow directions, was used, resulting in hydraulic conductivity along strike being five times greater than hydraulic conductivity across strike.

Table 13.--Simulated average water budget for the Valley Creek basin

[in., inches]

Water-budget component	Water budget Simulated (in.)	Calculated (in.)
Recharge	21.05	21.04
Base flow	13.06	13.04
Evapotranspiration	1.59	2.00
Ground-water withdrawals	[1]1.92	2.13
Cedar Hollow quarry pumpage	3.96	3.96
Underflow into basin:		
from east	.71	[2].86
from west	.26	[3].76
Underflow out of basin:		
to east	2.04	[2]1.78

[1]Does not include small commercial, industrial, and domestic pumpage.
[2]Estimated by Darcy's Law from October 1983 water-table map (Sloto, 1987, pl. 2).
[3]Estimated by Darcy's Law from October 1983 (Sloto, 1987, pl. 2) and May-June 1984 (Wood, 1984) water-table maps.

Sensitivity Analysis

A sensitivity analysis of model variables involves varying the value of a single model variable while holding the others constant. The effect of varying the value of a particular model variable on the simulated water budget was determined by varying the value of the variable being tested over a reasonable range, while the values of the rest of the variables remained fixed. Then, any changes in the simulated water budget are caused only by the change in the value of the variable being tested. If the change in the value of a variable causes a large change in the simulated water budget, the model is said to be sensitive to that variable. Conversely, if changes in the simulated water budget are slight, the model is insensitive to that variable.

Many sensitivity analyses were made during model calibration. The variables tested for sensitivity are aquifer hydraulic conductivity, streambed hydraulic conductance, recharge rate, ground-water evapotranspiration rate, aquifer thickness, and aquifer anisotropy. The results of a final sensitivity analysis, made when model calibration was completed, is presented below. Model variables were varied over a range from half to double the calibrated value. The effects of changing the value of a model variable on base flow and RMSE are shown on figures 20 and 21, respectively. The effects of changing aquifer anisotropy on base flow and RMSE are shown on figures 22 and 23, respectively. In figures 20 and 21, slope is directly proportional to sensitivity. A low slope indicates low sensitivity (or insensitivity); a high slope indicates high sensitivity.

SUMMARY

Valley Creek, a tributary to the Schuylkill River, drains 22.6 mi^2 in eastern Chester County. Streamflow from 20.8 mi^2 is measured at a streamflow-gaging station on Valley Creek at the Pennsylvania Turnpike Bridge near Valley Forge. The Valley Creek basin is mostly underlain by easily eroded Cambrian and Ordovician limestone and dolomite, which form Chester Valley. Resistant quartzites form the North Valley Hills to the north, and resistant phyllite forms the South Valley Hills to the south.

Ground water flows through a network of interconnected secondary openings--fractures, joints, faults, parting planes, and bedding planes; primary porosity is virtually nonexistent. Some of these openings are enlarged by solution. Most openings enlarged by solution are only a fraction of an inch wide, but they are capable of transmitting large quantities of water.

Secondary porosity and permeability have large spatial variation in carbonate rock; therefore, the yield and specific capacity of wells are highly variable. Well yield depends on the number and size of openings below the water table. The frequency of water-bearing zones decreases with depth; fifty percent of water-bearing zones are within 100 ft of the land surface, and 81 percent are within 200 ft of the surface.

The carbonate rocks form a complex, heterogeneous water-table aquifer. The water table fluctuates in response to recharge from precipitation, discharge from pumped wells and quarries, evapotranspiration, and discharge to streams. Although most of the ground-water system is under water-table conditions, the water is confined locally.

Most ground-water flow in the Valley Creek basin is local with discharge to nearby streams. Regional ground-water flow is to the northeast to the Schuylkill River. In most areas, the ground-water discharge to streams comprises the base-flow component of streamflow. Ground-water discharge comprised 73 to 84 percent of the flow of Valley Creek measured at the gaging station during 1983-87. The average ground-water discharge was 76 percent of streamflow. Ground-water discharge includes both natural discharge and quarry pumpage for dewatering. For 1983-87, the base flow of Valley Creek ranged from 11.56 to 21.87 in.; the average was 17.00 in.

For 1983-87, discharge from the Cedar Hollow quarry comprised 21 to 26 percent of the base flow of Valley Creek; the average was 23 percent. The discharge from the Cedar Hollow quarry sustains a greater-than-natural base flow in Valley Creek. The average natural base flow of Valley Creek would be 8 percent lower if the quarry were not operating.

On the western side of the Valley Creek basin, the ground-water divide is about 1/2 mi west of the surface-water divide. An estimated 0.75 Mgal/d of ground water flows from the adjacent West Valley Creek basin eastward into the Valley Creek basin. A ground-water divide does not exist on the eastern side of the Valley Creek basin; the water table slopes gently eastward toward the Schuylkill River. On the northeastern side of the basin, an estimated 1.76 Mgal/d of ground water flows northeasterly out of the basin beneath the

surface-water divide to the Schuylkill River. On the southeastern side of the basin, an estimated 0.85 Mgal/d of ground water flows beneath the surface-water divide into the basin.

Annual water budgets for 1983-87 and an average water budget for those years were calculated for the 20.8-mi^2 part of the basin above the streamflow gaging station. The average water budget approximates long-term or steady-state conditions. Annual precipitation ranged from 40.61 to 56.55 in. and averaged 47.25 in., annual streamflow ranged from 15.55 to 28.57 in. and averaged 22.31 in., and annual evapotranspiration ranged from 18.21 to 24.83 in. and averaged 22.90 in. Annual recharge ranged from 15.89 to 26.84 in. and averaged 21.04 in. For 1983-87, average base flow was 81 percent of average recharge.

Ground-water flow in the Valley Creek basin was simulated using a digital computer model. The basin was modeled as a two-dimensional water-table aquifer. Recharge to, ground-water flow through, and discharge from the rocks of Chester Valley was simulated. Input to the modeled hydrologic system is areally varied recharge and pumpage from quarry dewatering discharged to a sinkhole. Output of the modeled hydrologic system is withdrawal from wells and quarries, ground-water discharge to streams, and ground-water evapotranspiration.

In order to analyze ground-water flow with a digital model, the following assumptions were made: (1) the geologic units in Chester Valley act as a single heterogeneous water-table aquifer; (2) hydraulic properties differ spatially, but are averaged for model simulation; (3) recharge to noncarbonate rocks is half of recharge to carbonate rocks; (4) streams are in direct hydraulic contact with the aquifer; (5) the lower limit of ground-water flow is 600 ft below land surface; and (6) hydraulic conductivity increases down gradient from hilltop to valley bottom.

The 66.4-mi^2 area between the Brandywine Creek and the Schuylkill River was modeled to include the natural hydrologic boundaries of the ground-water-flow system. On the northwestern and southern sides of the modeled area, the surface-water divide in the noncarbonate rocks, which coincides with the ground-water divide, is a no-flow boundary. The western boundary is the Brandywine Creek, which is a regional ground-water sink. On the northeastern and eastern sides of the modeled area, the Schuylkill River is a specified-head boundary. The lower model boundary is a no-flow boundary 600 ft below land surface. The upper model boundary is the water-table surface and streams. The modeled area was discretized into a variably-sized grid of 16 rows and 52 columns.

The ground-water-flow model of the Valley Creek basin was calibrated under steady-state conditions using average recharge rates of 5.67×10^{-3} ft/d (24.84 in/yr) for carbonate rocks and 2.83×10^{-3} ft/d (12.40 in/yr) for noncarbonate rocks; this produced a recharge rate of 4.91×10^{-3} ft/d (21.05 in/yr) for the Valley Creek basin. The average evapotranspiration rate, 5.23×10^{-3} ft/d (22.90 in/yr), produced a simulated ground-water evapotranspiration rate of 1.59 in/yr. Pumping rates used in model simulations are 1983-87 average rates.

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REFERENCE NO. 20

GROUND-WATER RESOURCES
OF CHESTER COUNTY, PENNSYLVANIA

By Laurence J. McGreevy and Ronald A. Sloto

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations 77-67

Open-File Report

Prepared in cooperation with the

Chester County Water Resources Authority

September 1977

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GROUND-WATER RESOURCES OF CHESTER COUNTY, PENNSYLVANIA

By Laurence J. McGreevy and Ronald A. Sloto

ABSTRACT

Chester County is an area of about 760 square miles (1,970 square kilometers) in the Piedmont of southeastern Pennsylvania. Rocks of the county include: (1) Precambrian metamorphic and igneous rocks; (2) upper Precambrian to lower Paleozoic metamorphic rocks, predominantly metamorphosed sedimentary rocks; (3) upper Precambrian and lower Paleozoic sedimentary rocks that are moderately metamorphosed; and (4) Upper Triassic sedimentary and igneous rocks. Overlying the bedrock is a generally thick zone of unconsolidated weathered rock.

Most wells derive water from fractured rock. Intergranular permeability is present only in the weathered zone and in some of the sedimentary rock. Solution of carbonate rock and weathering increase the permeability.

Reported yields range from 0 to 1,800 gallons per minute (114 liters per second). Yields from carbonate rock, particularly the Cockeysville Marble and Ledger Formation, are generally higher than yields from other units. The difference in yield between nearby wells in the same unit, however, may be greater than the difference in yield between wells in different units. Exceptionally high yields of 100 gallons per minute (6 liters per second) or more were reported in almost all parts of the county and from almost all units, as were exceptionally low yields of 5 gallons per minute (0.3 liters per second) or less.

The estimated number of wells that would be needed in an area to yield 1 million gallons per day (0.04 cubic meters per second) continuously are indicated on a map. The estimates are based on evaluation of data on reported yields of more than 1,900 wells, on specific capacity for almost 900 wells, and on estimates of long-term specific capacity from 97 pumping tests. Yields that might be obtained by intensive exploration of an aquifer were estimated. These yields were then reduced by half to approximate the long-term average yield.

Aerial imagery of various kinds was evaluated as a potential aid in the study. The imagery included: side-scanning radar, infrared scanning, Skylab photography, Landsat imagery, and aerial photographs from various altitudes. These provided images at scales of 1:1,000,000; 1:250,000; 1:100,000; 1:60,000; and 1:24,000. The Landsat and Skylab images give an overview of the geology and structure of the area that is not available from other sources.

Straight or gently curved linear features are visible on all scales of aerial imagery that were examined, and most have geologic and hydrologic significance. Many linear features indicate fracture zones where fractured rock might be tapped by wells. Linear features were mapped from Landsat imagery and from 1:60,000 aerial photos. The mapped features are generally topographic lows, and most indicate zones of weakness in the rock.

Most ground water moves from where it enters the ground in upland areas and hillsides to the nearby valleys, where it is discharged to streams. Ground-water levels fluctuate in response to precipitation and evapotranspiration. Water levels generally decline during the growing season and recover during the rest of the year.

A water-budget analysis for the county indicates that an average of about 1,650 million gallons of water per day or 72 cubic meters per second enter and leave the area. The basin yield from the county during a near-average water year (1968) was 620 million gallons per day (27 cubic meters per second). Base flow, ground-water outflow, accounts for about 420 million gallons per day (18 cubic meters per second) and direct (storm) runoff about 200 million gallons per day (9 cubic meters per second).

The dissolved-solids concentration of most ground water in the county is less than 500 milligrams per liter. Chemical-quality problems are predominantly caused by acidity, iron and manganese, or nitrate. Hardness is sometimes a problem.

About 7 billion gallons (26 cubic hectometers) of water was withdrawn from the ground in Chester County in 1974. Almost 60 percent of this water was for self-supplied domestic users. Public supplies accounted for another 30 percent. In all, almost two-thirds of the residents of the county depend upon ground water for household use.

GEOLOGIC SETTING

The bedrock formations of Chester County are Precambrian, lower Paleozoic, and Triassic in age and are mapped and described on plate 2. They may be divided into four general groups: (1) Precambrian metamorphic and igneous rocks, which are mostly gneiss and igneous rock of similar composition; (2) upper Precambrian to lower Paleozoic metamorphic rocks, which are predominantly metamorphosed sedimentary rocks, mostly schist; (3) upper Precambrian and lower Paleozoic sedimentary rocks, some of which may correlate with group (2) above. These are mostly moderately metamorphosed limestone, dolomite, and quartzite; and (4) Upper Triassic sedimentary and igneous rocks, which are mostly shale, sandstone, conglomerate, argillite (indurated siltstone or mudstone), and diabase.

The bedrock is generally deeply weathered, and a zone of unconsolidated weathered rock covers most of the area. Minor alluvial and slope-wash deposits are present locally, but in this report they are not distinguished from the unconsolidated weathered rock.

The geologic structure consists of a series of extremely complicated anticlines and synclines that trend northeast, approximately parallel to Chester Valley. Major faults also trend northeast and may be normal, reverse, or thrust. Minor normal faults generally trend north or northeast. Triassic sedimentary rocks unconformably overlie older rocks in the northern part of the county. They generally strike east to southeast and dip north to northeast 10° to 20°.

Except for slight modification, the terminology used for the geologic units in this report are those of the Pennsylvania Topographic and Geologic Survey (Gray and others, 1960) and the Chester County Planning Commission (1973). The nomenclature does not necessarily follow the usage of the U. S. Geological Survey.

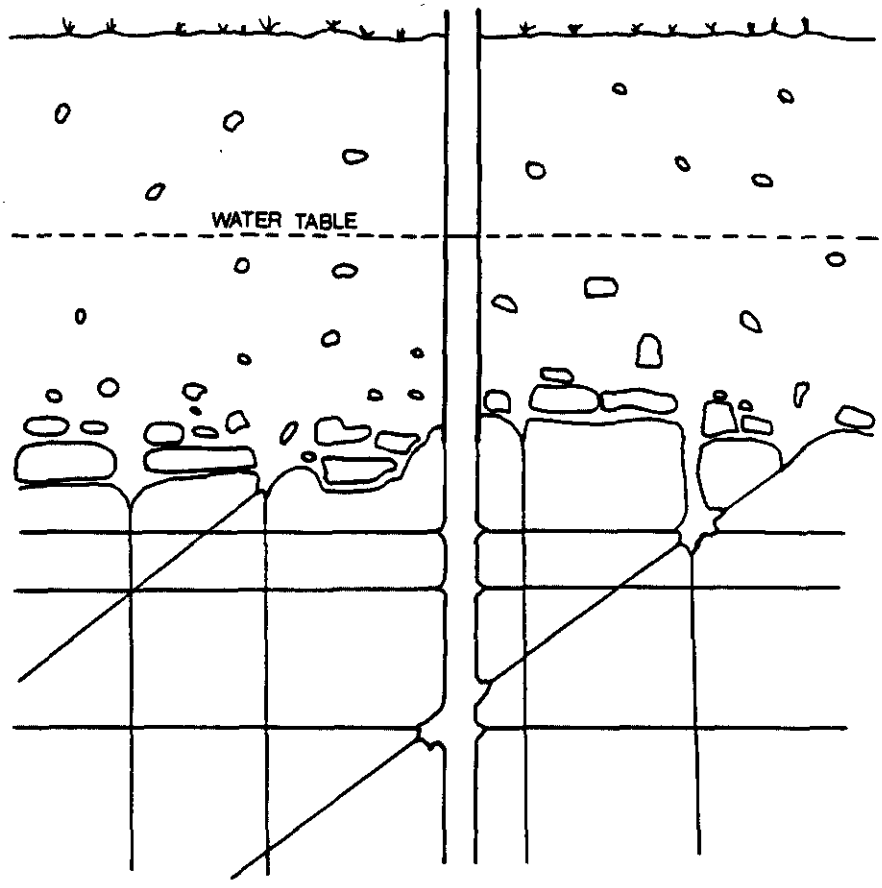

Figure 3.--Sketch of well tapping fractured rock.

GROUND WATER

Water-Bearing Units

All the geologic units in Chester County are water bearing. The units are composed of crystalline rock or highly indurated sedimentary rock and contain water where the rock has been fractured, decomposed by weathering, or dissolved. Intergranular permeability is present only in intensely weathered rock, in some of the Triassic sedimentary rock, and in some of the quartzitic rock. The water-bearing units and their reported yields are listed in table 1.

Fracturing

Most wells in Chester County obtain water from fractured rock. (See fig. 3.) Fractures are common as a result of various natural stresses. Permeability of fractured rock depends on the number of fractures per unit area, the size of the fracture opening, and the interconnection of the fractures.

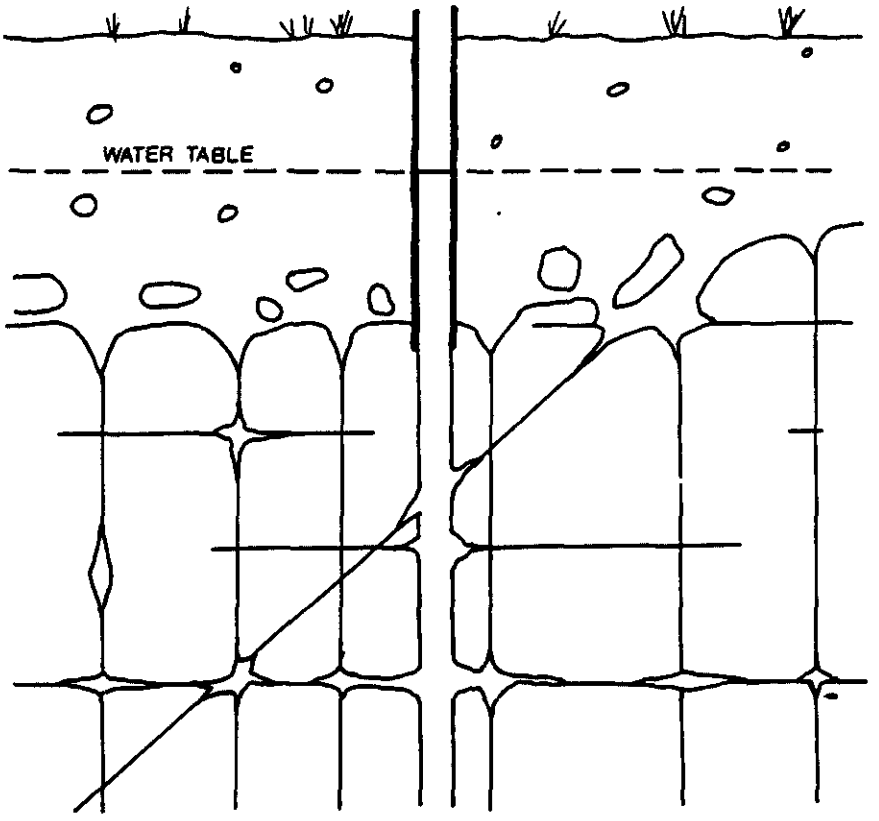

Figure 5.--Sketch of well tapping solution openings in fractured carbonate rock.

Solution of Carbonate Rock

Permeability of carbonate rock is predominantly a result of solution. As water moves through carbonate rock along fractures or other openings, it dissolves the rock and enlarges the openings. (See figures 4 and 5.) Where solution has been active, as in a fractured zone, permeability may be high; elsewhere, the same unit may be nearly impermeable.

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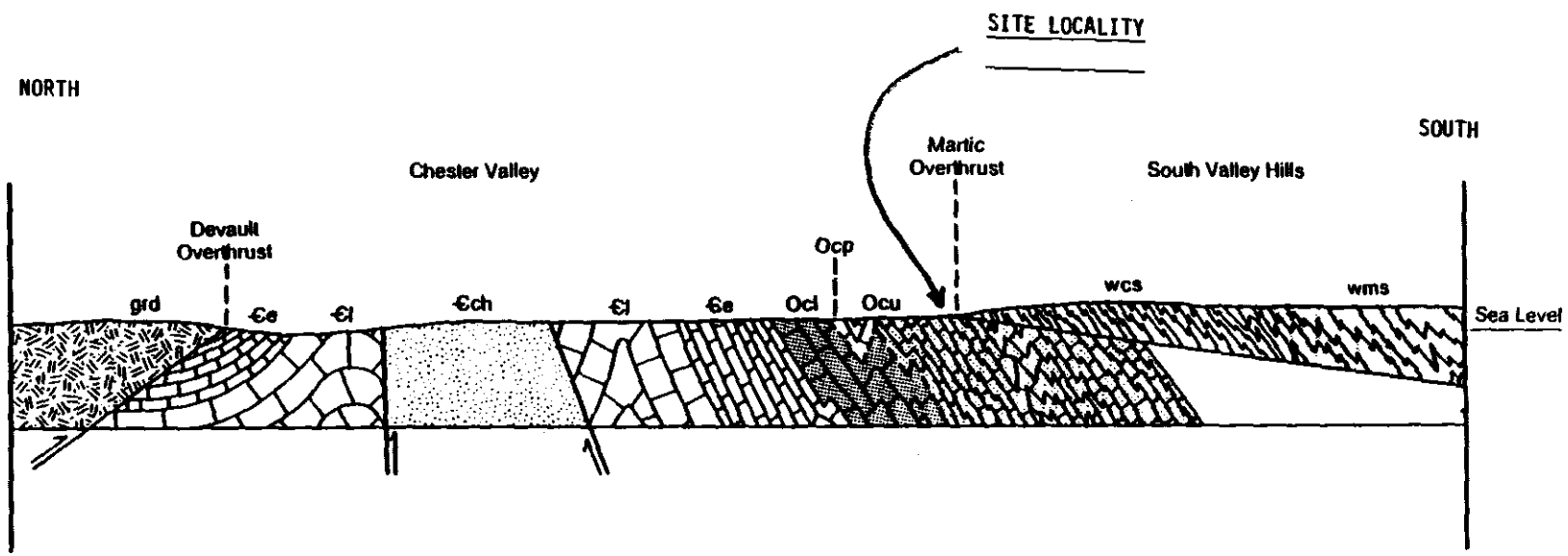
September 1988

WESTON W.O. 0087-08-01

WESTON
MANAGERS DESIGNERS/CONSULTANTS



Source: Bascom and Stose, 1938

Legend

Ocu	Conestoga Formation - Thin-Bedded Impure Limestone
Ocp	Conestoga Formation - Graphitic Phyllite and Mica Schist
Ocl	Conestoga Formation - Crystalline Micaceous Limestone
€e	Elbrook Formation - Thin-Bedded Siliceous Limestone
€l	Ledger Formation - Thick-Bedded Granular Dolomite
€ch	Chickies Formation - Massive Quartzite
grd	Granodiorite
wcs	Wissahickon Formation - Albite-Chlorite Schist
wms	Wissahickon Formation - Oligoclase-Mica Schist

0 1/2 1 Mile
Scale

FIGURE 2-3 CHESTER VALLEY GEOLOGIC CROSS SECTION

ORIGINAL (Red)

REFERENCE NO. 22

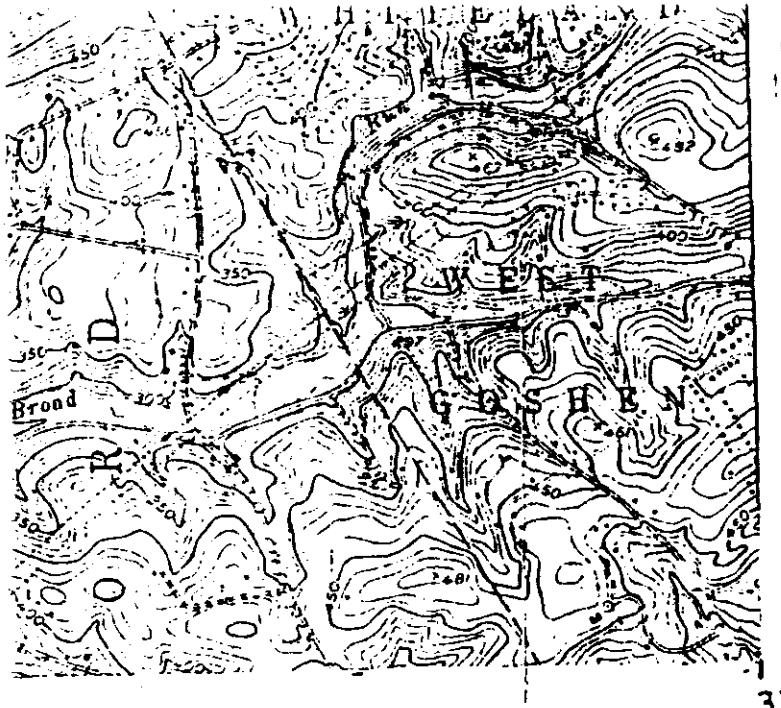
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

OPEN-FILE REPORT 84-715

GROUND-WATER LEVELS IN THE CARBONATE ROCKS OF CENTRAL CHESTER COUNTY, PENNSYLVANIA, MAY 18 TO JUNE 15, 1984

By CHARLES R. WOOD

1984



37′30″

= GEOLOGIC FORMATION BOUNDARY ADDED BY MNDS

SCALE: 1:24,000

Hydrology mapped in 1984

EXPLANATION

GEOLOGIC CONTACT -- shows location of the contact between carbonate and noncarbonate rocks.

—300— WATER-TABLE CONTOUR -- shows altitude of water table. Dashed where approximately located. Contour interval 20 feet. National Geodetic Vertical Datum of 1929.

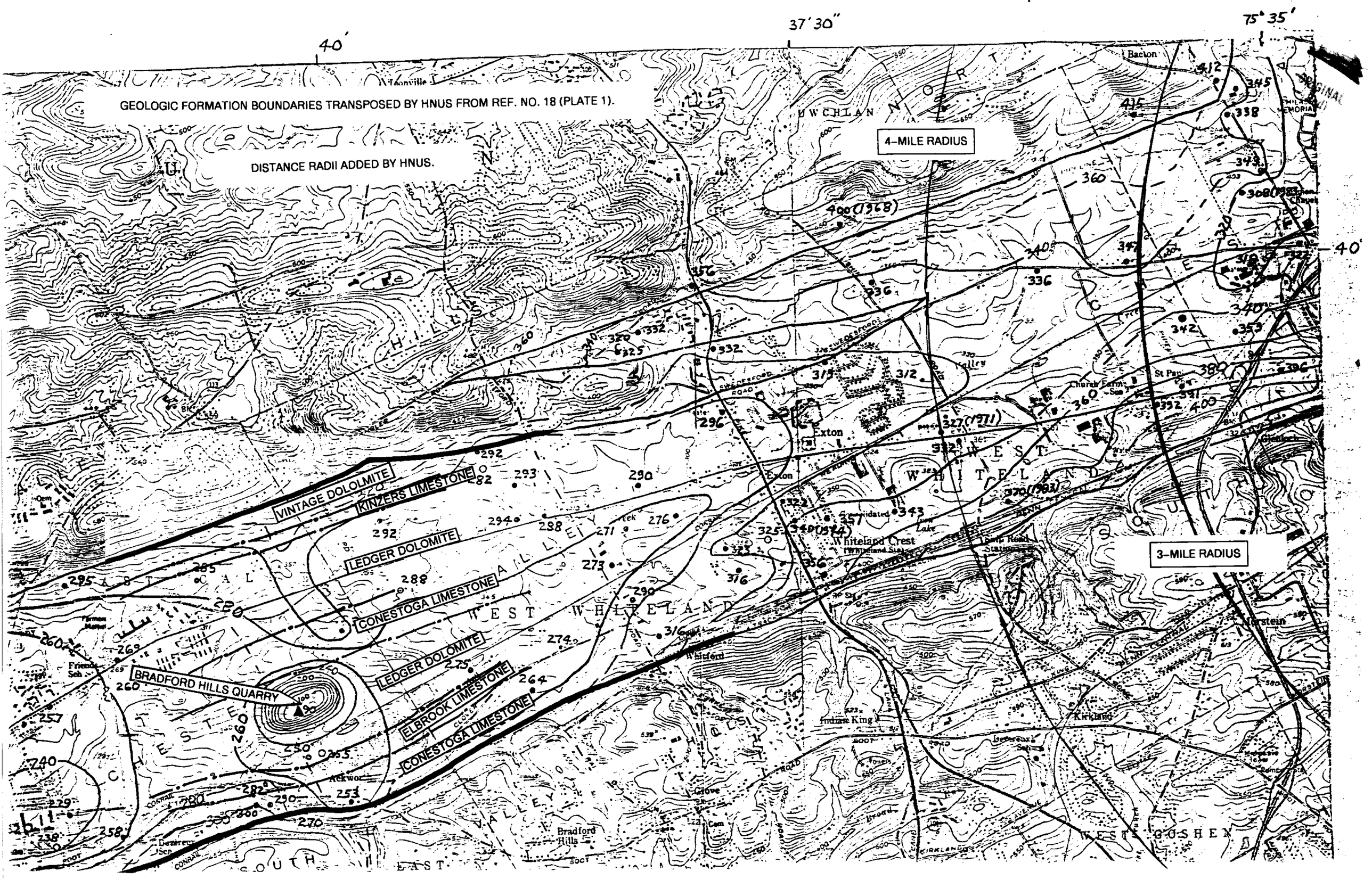
SITE USED FOR WATER-TABLE ALTITUDE -- Symbol gives location of site. Number gives altitude of water table.

320(1925) Static water-table altitude measured in drilled or dug well and year of water-level observation (in parenthesis) measured or reported for a period other than May 18 to June 15, 1984.

o322 Water-level altitude measured in a pumping drilled well.

236 Altitude of spring.

▲ 90 Water-table altitude in quarry.



GEOLOGIC FORMATION BOUNDARIES TRANSPOSED BY HNUS FROM REF. NO. 18 (PLATE 1).
DISTANCE RADII ADDED BY HNUS.
4-MILE RADIUS
3-MILE RADIUS
VINTAGE DOLOLMITE
KINZERS LIMESTONE
LEDGER DOLOMITE
CONESTOGA LIMESTONE
LEDGER DOLOMITE
ELBROOK LIMESTONE
CONESTOGA LIMESTONE
BRADFORD HILLS QUARRY
40'
37'30"
75°35'
40'
Exton
Whiteland Crest
Whitford
Indian King
Kirkland
Morstein
Bradford Hills
Glove
Bacton
Church Farm Sch
St Paul
Friends Sch
Ackwor
Dezereux Sch
WEST WHITELAND
WEST GOSHEN

REFERENCE NO. 23

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

ORIGINAL (Red)

GROUND-WATER LEVELS IN THE LOWER PALEOZOIC AND PRECAMBRIAN CRYSTALLINE ROCKS, OF EAST BRADFORD AND WEST BRADFORD TOWNSHIPS, CHESTER COUNTY, PENNSYLVANIA, JULY AND AUGUST 1987

By JOHN A. GARGES

Prepared in cooperation with the
CHESTER COUNTY WATER RESOURCES AUTHORITY

WATER RESOURCES INVESTIGATIONS REPORT 88-4052

EPA REGION III
SUPERFUND DOCUMENT MANAGEMENT SYSTEM

DOC ID # 401695
PAGE #

IMAGERY COVER SHEET
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REPORT OR DOCUMENT TITLE Reference # 18-57 (Volume III of III).

DATE OF DOCUMENT 01-01-01

DESCRIPTION OF IMAGERY Site Map.

NUMBER AND TYPE OF IMAGERY ITEM(S) 1 Oversized Map

ORIGINAL (Red)

REFERENCE NO. 24

RECORD OF COMMUNICATION

[XX] PHONE CALL [ ] DISCUSSION [ ] FIELD VISIT [ ] CONFERENCE
[ ] OTHER (SPECIFY)

(Record of item checked above)

TO:	FROM:	DATE
Ron Sloto Hydrologist USGS-Malvern PA	Mindi Snoparsky Geologist US EPA Region III	11-9-87 TIME 9:05 AM

SUBJECT
Hydrogeology in the vicinity of AIW Frank/Mid-County Mustang

SUMMARY OF COMMUNICATION

Ground-water modeling and hydrologic studies performed by Ron Sloto for the USGS, as well as USGS water table contour information, indicate that ground-water in the vicinity of AIW Frank/Mid-County Mustang flows from the North Valley hills (granodlorite outcrop area north of the carbonate units) into the carbonate units, and from the South Valley hills (Wissahickon outcrop area south of the carbonate units) into the carbonate units.

The studies have also indicated that the geologic faults in the area are not hydrologic boundaries.

CONCLUSIONS, ACTION TAKEN OR REQUIRED

INFORMATION COPIES
TO:

ORIGINAL
(Red)

REFERENCE NO. 25

9006-28-20

NUS CORPORATION AND SUBSIDIARIES **TELECON[redacted]**

CONTROL NO:	DATE:	TIME:
9006 - 28	OCTOBER 19, 1990	7:45 am

DISTRIBUTION:
AQUIFER INTERCONNECTION : FOOTE MINERAL FRAZER FACILITY

BETWEEN:	OF:	PHONE:
(b) (4) [redacted]	U.S.G.S. MALVERN, PA	(215) 647 - 9008

AND:
(b) (4) [redacted], NUS FIT 3

DISCUSSION:
MR. SLOTO SAID THAT IN GENERAL, WITHIN THE CHESTER VALLEY AREA, GROUNDWATER FLOWS FROM THE NORTH AND SOUTH VALLEY HILLS INTO THE CHESTER VALLEY, AND THAT THE ROCK UNITS OF THE CHESTER VALLEY ACT AS A SINGLE INTERCONNECTED AQUIFER. HE AGREED TO ALLOW ME TO STOP BY THEIR OFFICES AFTER 1:00 PM THIS AFTERNOON TO OBTAIN ADDITIONAL INFORMATION.

(b) (4) [redacted]

10-19-90

DIRECTIONS TO USGS MALVERN:

SOUTH 202 TO 29 — STRAIGHT THRU 1ST & 2nd LIGHTS UP HILL ON TECHNOLOGY DRIVE TO STOP — LEFT ON GREAT VALLEY PKWY — .60 APPX ½ MILE AROUND LOOP OR CURVE TO # 111 GREAT VALLEY PKWY

(b) (4) [redacted]

10-19-90

ACTION ITEMS:

NUS 087 REVISED 0986

ORIGINAL (Red)

REFERENCE NO. 26

7006-28-21

NUS CORPORATION AND SUBSIDIARIES — **TELECON NOTE**

CONTROL NO:	DATE:	TIME:
9006 - 28	OCTOBER 18, 1990	9:15 am

DISTRIBUTION:
AQUIFER INTERCONNECTION : FOOTE MINERAL, FRAZER FACILITY

BETWEEN:	OF:	PHONE:
CHARLES WOOD	USGS, MALVERN, PA.	(215) 647-9008

AND: (b) (4) [redacted], NUS FIT 3

DISCUSSION:
THERE IS FLOW ACROSS FORMATION CONTACTS FROM THE FORMATIONS OF THE NORTH AND SOUTH VALLEY HILLS INTO THE FORMATIONS OF THE CHESTER VALLEY. THIS FLOW IS SOMEWHAT LIMITED, BUT IS PRESENT. THE HYDROGEOLOGIC RELATIONSHIPS BETWEEN THE NORTH AND SOUTH VALLEY HILLS AND THE CHESTER VALLEY ARE SIMILAR ALONG THE ENTIRE LENGTH OF THE CHESTER VALLEY. THE ELBROOK FORMATION WITHIN THE CHESTER VALLEY MAY SOMETIMES ACT AS A BARRIER TO GROUNDWATER FLOW, BUT IS BREACHED IN OTHER AREAS. THERE IS EVIDENCE FOR CONDUIT FLOW WITHIN THE ELBROOK FORMATION. THERE IS A REPORT OR STUDY BY RON SLOTO, GROUNDWATER MODEL OF THE VALLEY CREEK BASIN, WATER RESOURCES INVESTIGATIONS REPORT 89-4169; APPROVED BUT NOT YET PUBLISHED. IT SHOULD CONTAIN HYDRAULIC CONDUCTIVITY NUMBERS FOR VARIOUS FORMATIONS. MODEL EXTENDS FROM

~~ACTION ITEMS:~~
SCHUYLKILL TO BRANDYWINE IN CHESTER VALLEY. HE WILL REFER MY REQUEST FOR INFORMATION TO RON SLOTO AND WE WILL TRY TO SET UP A TIME FOR ME TO VISIT THEIR OFFICES TO OBTAIN MORE INFORMATION. THEY (USGS) MAY BE ABLE TO GIVE OR LOAN COPIES OF SOME OF THEIR REPORTS TO US (NUS FIT 3) OR WE CAN GET A BIBLIOGRAPHY AND ORDERING INFORMATION.

NUS 067 REVISED 0686

(b) (4) [redacted]

ORIGINAL (Red)

REFERENCE NO. 27

NUS CORPORATION
SUPERFUND DIVISION

PROJECT NOTES

TO: FOOTE MINERAL FILE, 9006-28 DATE: OCTOBER 19, 1990

FROM: (b) (4) [redacted] NUS FIT 3 COPIES:

SUBJECT: GEOLOGY & HYDROLOGY (AQUIFER INTERCONNECTION)

REFERENCE: MEETING w/ RONALD A. SLOTO, U.S.G.S., MALVERN PA, 10/19/90, 1:00 pm.

I met with Ron Sloto, hydrologist, USGS, Malvern, PA at his office and obtained the following information.

1.) All the geologic formations of the North Valley Hills, Chester Valley, and South Valley Hills have average hydraulic conductivities within two orders of magnitude.

2.) These average hydraulic conductivity values were determined from well test results for specific capacity, etc.

3.) The hydraulic conductivity at specific locations within a given formation may vary up to a maximum of seven orders of magnitude.

4.) This information was determined as part of an investigation currently in press — Sloto, R.A., [In Press]. Geohydrology and simulation of ground-water flow in the carbonate rocks of the Valley Creek Basin, eastern Chester County, Pennsylvania: U.S. Geological Survey Water Resources Investigations Report 89-4169. — This report will be published by January 1991 at the earliest.

5.) A revised Chester County Ground-Water Resources Study is currently undergoing review, eventually to be published by the Pennsylvania Geological Survey. However, their publishing backlog is up to seven years and the revised study will probably be published first as an Open File report; earliest possible date, December 1991.

6.) Thesis reports concerning the geology of the crystalline rocks of parts of Chester County are from the Bryn Mawr College Geology Department Library.

NUS CORPORATION
SUPERFUND DIVISION

PROJECT NOTES

TO: DATE:

FROM: COPIES.

SUBJECT:

REFERENCE:

7.) Check with Dave Yeack, Director, Chester County Water Resources to possibly obtain a copy of Sloto, R.A., 1987. Effect of urbanization on the Water Resources of eastern Chester County, Pennsylvania; U.S. Geological Survey Water Resources Investigations Report 87-4058. If not available from this source, order from U.S.G.S. Open File Series.

8.) Check U.S.G.S. Open File Series for availability and ordering of other useful references or reports

9.) Many of the tributary stream reaches to Valley Creek in the Chester Valley reflect the level of perched water table in the weathered overburden, not the true water table of the carbonate aquifer.

10.) Mr. Sloto provided me with a copy of a bibliography containing most of the geologic and hydrologic references available for Chester County (Attached).

NUS 443A 58 1182

SELECTED REFERENCES

Anderson, T.H., Drake, D.E., and Wise, D.U., 1965, Megapetrofabric of the Coatesville-Doe Run area, Penna.: Proceedings Pennsylvania Academy Natural Science, v. 38, no. 2, p. 174-182.

Baily, E.B., and Mackin, J.H., 1937, Recumbent folding in the Pennsylvania piedmont-preliminary statement: American Journal of Science, 5th ser., v. 33, no. 195, p. 187-190.

Bascom, Florence, 1905, Piedmont district of Pennsylvania: Geological Society America Bulletin, v. 16, p. 286-328.

Bascom, Florence, Clark, W.B., Darton, N.H., Kummel, H.B., Salsbury, R.D., Miller, B.L., and Knapp, G.M., 1909, Description of the Philadelphia district (Pennsylvania-New Jersey-Delaware): U.S. Geological Survey Geological Atlas, Folio 162, 24 p.

Bascom, Florence, and Miller, B.L., 1920, Description of the Elkton and Wilmington Quadrangles, Maryland, Delaware, New Jersey, Pennsylvania: U.S. Geological Survey Geologic Atlas, Folio 211, 22 p.

Bascom, Florence, and Stose, G.W., 1932, Description of the Coatesville and West Chester quadrangles: U.S. Geological Survey Geologic Atlas, Folio 223, 15 p.

-----, 1935, The Pre-Cambrian igneous rocks of eastern Pennsylvania and Maryland: Transactions American Geophysical Union, 16th Annual Meeting, part 1, p. 328.

-----, 1938, Geology and mineral resources of the Honeybrook and Phoenixville quadrangles, Pennsylvania: U.S. Geological Survey Bulletin 891, 145 p.

Berg, T.M., and Dodge, C.M., 1981, Atlas of preliminary geologic quadrangle maps of Pennsylvania: Pennsylvania Geological Survey, 4th ser., Map 61, 636 p.

Berg, T.M., and others, 1980, Geologic map of Pennsylvania: Pennsylvania Geological Survey, 4th ser., Map 1, 3 plates, scale 1:250,000.

Berkheiser, S.W. Jr., 1983, Reconnaissance survey of potential whiting sources in Pennsylvania: Pennsylvania Geological Survey, 4th ser., Mineral Resources Report 83, 53 p.

-----, 1985, High-purity silica occurrences in Pennsylvania: Pennsylvania Geological Survey, 4th ser., Mineral Resources Report 88, 67 p.

Biesecker, J.E., Lescinsky, J.B., and Wood, C.R., 1968, Water resources of the Schuylkill River basin: Pennsylvania Department of Forests and Waters Water Resources Bulletin 3, 198 p.

Bliss, E.F., and Jonas, A.I., 1917, Relation of the Wissahickon mica gneiss to the Shenandoah limestone and Octoraro schist of the Doe Run and Avondale region, Chester County, Pennsylvania: U.S. Geological Survey Professional Paper 98, p. 9-34.

Cecil, L.D., Smith, R.C. II, Reilly, M.A., and Rose, A.W., 1987, Radium-228 and radium-226 in ground water of the Chickies Formation, southeastern Pennsylvania IN Graves, Barbara, ed., Radon, radium, and other radioactivity in ground water: Chelsea, Michigan, Lewis Publishers, p. 437-447.

Chester County Planning Commission, 1963, Chester County-Natural environment and planning, landforms, geology, soils, woodlands, climate: West Chester, Pennsylvania, 70 p.

-----, 1973, Chester County Geology: West Chester, Pennsylvania, 95 p.

Chester County Planning Commission, 1982, Eastern Chester County Region Water Resources Inventory Update (1980): West Chester, Pennsylvania. 123 p.

-----, 1985, County facilities Inventory, Chester County, Pennsylvania. Volume 1, Sewer facilities: West Chester, Pennsylvania, 252 p.

-----, 1985 County facilities Inventory, Chester County, Pennsylvania, Volume 2, Water facilities: West Chester, Pennsylvania, 209 p.

Council on Environmental Quality, 1981, Contamination of ground water by toxic organic chemicals: Washington, U.S. Government Printing Office, 84 p.

Crawford, M. L., and Crawford, W. A., 1980, Metamorphic and tectonic history of the Pennsylvania piedmont: Journal of the Geological Society of London, v. 137, p. 311-320.

Crawford, W.A., and Hoersch, A.L., 1984: The Geology of the Honey Brook upland, southeastern Pennsylvania: Geological Society America Special Paper 194, p. 111-125.

Crawford, W.A., Robelen, P.G., and Kalmbach, J.H., 1971, The Honey Brook anorthosite: American Journal Science, v. 271, p. 333-349.

Crowe, C., Gaffar-Adley, R., and Shank, J.C., 1962, Geophysical Surveys in the Triassic basin, northern Chester County, Pennsylvania-A progress report: Proceedings Pennsylvania Academy Science, v. 36, p. 225-231.

Demmon, F.E. III, 1977, Investigations of the origin and metamorphic history of Pre-Cambrian gneisses, Downingtown 7 1/2-minute quadrangle, southeastern Pennsylvania: unpublished M.S. thesis, Bryn Mawr College.

Dufor, C.N., and Becker, Edith, 1964, Public water supplies of the 100 largest cities in the United States, 1962; U.S. Geological Survey Water-Supply Paper 1812, 364 p.

Faill, R.T., 1973, Tectonic development of the Triassic Newark-Gettysburg basin in Pennsylvania: Geological Society America Bulletin, v. 84, no. 3, p. 725-740.

Federation of Northern Chester County Municipalities, 1988, Water Resources management study: West Chester, Pennsylvania, 147 p.

Fletcher, W.W., 1974, The pest war: New York, John Wiley and Sons, 218 p.

Garges, J.A., 1986, Ground-water levels in lower Paleozoic and Precambrian crystalline rocks, southeastern Chester County, Pennsylvania, July and August 1986: U.S. Geological Survey Water Resources Investigations Report 86-4352, 1 plate, scale 1:24,000.

Garges, J.A., 1988, Ground-water levels in lower Paleozoic and Precambrian crystalline rocks of East Bradford and West Bradford Townships, Chester County, Pennsylvania, July and August 1987: U.S. Geological Survey Water Resources Investigations Report 88-4052, 1 plate, scale 1:24,000.

Goodwin, P.W., and Anderson, E.J., 1974, Associated physical and biogenic structures in environmental subdivision of a Cambrian tidal body: Journal of Geology, v. 82, p. 779-794.

Grauert, Berwin, Crawford, M.L., and Wagner, M.E., 1973, U-Pb isotopic analysis of zircons from granulite and amphibolite facies rocks of the West Chester prong and the Avondale anticline, southeastern Pennsylvania: Carnegie Institute Washington, Yearbook 72, p. 290-293.

Grauert, Berwin, and Wagner, M.E., 1975, Age of the granulite-facies metamorphism of the Wilmington complex, Delaware-Pennsylvania piedmont: American Journal Science, v. 275, p. 683-691.

Grauert, Berwin, Wagner, M.E., and Crawford, M.L., 1974, Age and origin of amphibolite-facies rocks of the Avondale anticline (southeastern Pennsylvania) as derived from U-Pb isotopic studies on zircon: Carneige Institute Washington, Yearbook 73, p. 1000-1003.

Hall, G.M., 1934, Ground water in southeastern Pennsylvania: Pennsylvania Geological Survey, 4th ser., Water Resources Report 2, 255 p.

Hanan, B.B., and Sinha, A.K., 1989, Petrology and tectonic affinity of the Baltimore mafic complex, Maryland: Geological Society America Special Paper 231, p. 1-18.

Hartwig, N.L., Gesell, S.G., and Dum, S.A., 1980, Pesticide use survey for agronomic crops in Pennsylvania: State College, Pennsylvania State University, 36 p.

Hem, J.D., 1985, Study and interpretation of the chemical characteristics of natural water: U.S. Geological Survey Water-Supply Paper 2254, 263 p.

Higgins, M.W., 1982, Age, origin, regional relations, and nomenclature of the *Glenarm series, central Appalachian Piedmont: a reinterpretation*: Geological Society America Bulletin, v. 83, p. 989-1026.

Hoersch, A.L., and Crawford W.A., 1988, The mine ridge of the SE Pennsylvania piedmont: Northeastern Geology, v. 10, no. 3, p.181-194.

Huntsman, J.R., 1975, Crystalline rocks of the Wagontown 7.5 minute quadrangle: unpublished M.A. thesis, Bryn Mawr College.

Jonas, A.I., 1923, Rocks of the Quarryville quadrangle, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Bulletin 75, 9 p.

-----, 1937, Tectonic studies in the crystalline schists of southeastern Pennsylvania and Maryland: American Journal Science, 5th ser., v. 34, p. 364-388.

Kauffman, M.E., and Frey, E.P., 1979, Antietam sandstone ridges-exhumed barrier islands or fault-bound blocks [ABS]: Geological Society America Abstracts with Programs, Northeastern Section, v. 11, no. 1, p. 18.

Knopf, E.B., and Jonas, A.I., 1923, Stratigraphy of the crystalline schists of Pennsylvania and Maryland: American Journal Science, v. 5, p. 40-62.

-----, 1930, Geology of the McCalls Ferry-Quarryville district: U.S. Geological Survey Bulletin 799, 156 p.

Lapham, D.M., 1967, The tectonic history of multiply deformed serpentinite in the piedmont of Pennsylvania IN Wyllie, P. J., ed., Ultamafic and related rocks: New York, John Wiley and Sons, p. 174-183.

Lapham, D.M. and Basett, W.A., 1964, K-Ar dating of rocks and tectonic events in the piedmont of southeastern Pennsylvania: Geological Society America Bulletin, v. 75, p. 661-668.

Lapham, D.M., and McKague, H.W., 1964, Structural patterns associated with the serpentinites of Pennsylvania: Geological Society America Bulletin, v. 75, no. 7, p. 639-659.

Leitman, P.L., Ward, J.R., and Behrendt, T.E., 1983, Effects of specific land uses on non-point sources of suspended sedimennt, nutrients, and herbicides--Pequea Creek basin, Pennsylvania: U.S. Geological Survey Water-Resources Investigations Report 83-4113, 88 p.

Lium, B.W., 1976, Limnological data for the major streams in Chester County, Pennsylvania: U.S. Geological Survey Open-File Report, 219 p.

-----, 1977, Limnological studies of the major streams in Chester County, Pennsylvania: U.S. Geological Survey Open-File Report 77-462, 37 p.

Lyttle, P.T., and Epstein, J.B., 1987, Geologic map of the Newark 1°x2° quadrangle, New Jersey, Pennsylvania, and New York: U.S. Geological Survey Miscellaneous Investigations Series I-1715, 2 plates, scale 1:250,000.

Mackin, J.H., 1935, The problem of the Martic overthrust and the age of the Glenarm series: Journal Geology, v. 43, p. 356-380.

-----, 1962, The structure of the Glenarm series in Chester County, Pennsylvania: Geological Society America Bulletin, v. 73, no. 3, p. 403-409.

Maclachlan, D.B., 1983, Geology and mineral resources of the Reading and Birdsboro quadrangles, Berks County, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Geologic Atlas 187cd, 1 plate, scale 1:24,000.

Mahan, I., and Mahan, E., 1977, Mercury retention in untreated water samples in the parts-per-billion level: Analytical Chemistry, v. 49, p. 662-664.

McGreevy, L.J., 1974, Seepage study of streams crossing Chester Valley, Chester County, Pennsylvania: U.S. Geological Survey Open-File Report, 12 p.

McGreevy, L.J., and Sloto, R.A., 1976, Selected hydrologic data, Chester County, Pennsylvania: U.S. Geological Survey Open-File Report, 138 p.

-----, 1977, Ground-water resources of Chester County, Pennsylvania: U.S. Geological Survey Water-Resources Investigations Report 77-67, 76 p.

-----, 1980, Development of a digital model of ground-water flow in deeply weathered crystalline rock, Chester County, Pennsylvania: U.S. Geological Survey Water-Resources Investigations Report 80-2, 42 p.

McKinstry, H.E., 1949, Mineral isograds in southeastern Pennsylvania: American Mineralogist, v. 34, p. 874-892.

-----, 1961, Structure of the Glenarm series in Chester County, Pennsylvania: Geological Society America Bulletin, v. 72, p. 557-578.

McManus, B.C., and Wood. C.R., [IN REVIEW], Altitude and configuration of the potentiometric surface in the Triassic sandstones and shales, northern Chester County, Pennsylvania, October 1989 through March 1990: U.S. Geological Survey Water Resources Investigations Report _____, 1 plate, scale 1:24,000.

Miller, R.A., Troxell, John, and Leopold, L.B., 1971, Hydrology of two small river basins in Pennsylvania before urbanization: U.S. Geological Survey Professional Paper 701-A, 57 p.

Moore, C.R., 1987, Determination of benthic-invertebrate indicies and water-quality trends of selected streams in Chester County, Pennsylvania: U.S. Geological Survey Water-Resources Investigations Report 85-4177, 62 p.

-----, 1989, Physical, chemical, and biological data for selected streams in Chester County, Pennsylvania, 1969-80: U.S. Geological Survey Open-File Reptort 85-686, 289 p.

National Oceanic and Atmospheric Administration, 1982, Monthly normals of temperature, precipitation, and heating and cooling degree days, 1951-80, Pennsylvania: Climatography of the United States No. 81, National Climatic Center, Asheville, North Carolina.

Newell, W.L., and Wise, D.U., 1965, Independent joint system superimposed on metamorphic fabric of Glenarm series near Coatesville, Penna.: Proceedings Pennsylvania Academy Science, v. 38, no. 2, p. 150-153.

O'Brien, R.D., 1967, Insecticides, action and metabolism: New York, Academy Press, 332 p.

Olmsted, F.H., and Hely, A.G., 1962, Relation between ground water and surface water in Brandywine Creek basin, Pennsylvania: U.S. Geological Survey Professional Paper 417-A, 21 p.

Owens, J.P., and Minard, J. P., 1979, Upper Cenozoic sediments of the lower Delaware Valley and the northern Delmarva Peninsula, New Jersey, Pennsylvania, Delaware, and Maryland: U.S. Geological Survey Professional Paper 1067-D, 47 p.

Parker, G.C., Hely, A.G., Keighton, W.B., Olmsted, F.H., and others, 1964, Water resources of the Delaware River basin: U.S. Geological Survey Professional Paper 381, 200 p.

Parsons, F., Wood, P.R., and DeMarco, J., 1984, Transformation of tetrachloroethene in microcoms and ground water: Journal American Water Works Association, v. 56, no. 2, p. 56-59.

Petura, J.C., 1980, TCE in ground water--a problem assessment: The Weston Way, v. 6, no. 2.

Poth, C.W., 1968, Hydrology of the metamorphic and igneous rocks of central Chester County, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Water Resources Report 25, 84 p.

Pupa, D.M., 1988, Crystalline rocks of the Honey Brook 7 1/2 minute quadrangle, southeastern Pennsylvania: unpublished M.A. thesis, Bryn Mawr College.

Reith, J.G., Brinton, E.G., and Abele, R.J., 1979, Water resources inventory study, Vol. 3, Clay & Elk sub-basin: West Chester, Pennsylvania, Chester County Water Resources Authority and Chester County Planning Commission, 105 p.

Reith, J.G., Brinton, E.G., and Abele, R.J., 1979, Water resources inventory study, Vol. 4, Brandywine sub-basin: West Chester, Pennsylvania, Chester County Water Resources Authority and Chester County Planning Commission, 83 p.

-----, 1980, Water resources inventory study, Vol. 5, Octoraro sub-basin: West Chester, Pennsylvania, Chester County Water Resources Authority and Chester County Planning Commission, 83 p.

Reith, J.G., Brinton, E.G., and Stern, J.R., 1978, Water resources inventory study, Vol. 1, Delaware sub-basin: West Chester, Pennsylvania, Chester County Water Resources Authority and Chester County Planning Commission, 97 p.

-----, 1979, Water resources inventory study, Vol. 2, Schuylkill sub-basin: West Chester, Pennsylvania, Chester County Water Resources Authority and Chester County Planning Commission, 115 p.

Richards, H.G., 1956, Geology of the Delaware Valley: Mineralogical Society Pennsylvania, ___ p.

Riese, A.C., 1982, Adsorption of radium and thorium onto quartz and kaolinite: a comparison of solution equilibria models: unpublished Ph.D. Dissertation, Colorado School of Mines, 292 p.

Rima, D.R., Meisler, Harold, and Longwill, S.M., 1962, Geology and hydrology of the Stockton Formation in southeastern Pennsylvania: Pennsylvania Geological Survey, 4th ser., Water Resources Report 14, 111 p.

Rodgers, John, 1968, The eastern edge of the North American continent during the Cambrian and early Ordovician IN Zen, E., White, W.S., Hadley, J.B., and Thompson, J.B., Jr., Studies of Appalachian Geology: New York, Intersience Publishers, p. 141-149.

Schawb, F.L., 1970, Petrology, paleocurrents, and depositional environment of the Harpers Formation in the central Appalachians [ABS]: Geological Society America Abstracts with Program, Northeast Section, v. 2, no. 1, p. 35.

Senior, L.A., and Garges, J.A., 1989, Altitude and configuration of the potentiometric surface in the Triassic sandstones and shales, northeastern Chester County, Pennsylvania, September 1987 through January 1988: U.S. Geological Survey Water Resources Investigations Report 89-4043, 1 plate, scale 1:24,000.

Senior, L.A., and Vogel, K.V., [IN PRESS], Geochemistry of radium-226, radium-228, and radon-222 in ground water of the Chickies Quartzite, Southeastern Pennsylvania: Proceedings of conference on ground water in the piedmont of the eastern United States, Charlotte, North Carolina, October 16-18, 1989.

-----, [IN REVIEW], Radium and radon in the ground water of the Chickies Quartzite, Southeastern Pennsylvania: U.S. Geological Survey Water Resources Investigations Report.

Sloto, R.A., 1982, A stormwater management model for the West Branch Brandywine Creek, Chester County, Pennsylvania: U.S. Geological Survey Water Resources Investigations Report 81-73, 34 p.

-----, 1984, Water-table contour map of the carbonate rocks of eastern Chester County, Pennsylvania: U.S. Geological Survey Open-File Report 84-235, 1 plate, scale 1:24,000.

-----, 1985, Effects of flood controls proposed for the Sucker Run basin, Chester County, Pennsylvania: Chester County Water Resources Report 1, 30 p.

Sloto, R.A., 1985, Effects of flood controls proposed for the West Branch Brandywine Creek, Chester County, Pennsylvania: U.S. Geological Survey Water Resources Investigations Report 86-4054, 28 p.

-----, 1987, Effect of urbanization on the water resources of eastern Chester County, Pennsylvania: U.S. Geological Survey Water Resources Investigations Report 87-4098, 131 p.

-----, 1988, Effects of urbanization on storm-runoff volume and peak discharge of Valley Creek, eastern Chester County, Pennsylvania: U.S. Geological Survey Water Resources Investigations Report 87-4196, 32 p.

-----, 1989, Selected ground-water data, Chester County, Pennsylvania: U.S. Geological Survey Open-File Report 87-217, 198 p.

-----, [IN PRESS], Geohydrology and simulation of ground-water flow in the carbonate rocks of the Valley Creek basin, eastern Chester County, Pennsylvania: U.S. Geological Survey Water Resources Investigations Report 89-4169.

-----, [IN REVIEW], A computer method for estimating ground-water contribution to streamflow using hydrograph-separation techniques: Proceedings of the U.S. Geological Survey National Computer Technology Meeting, U.S. Geological Survey Water Resources Investigations Report.

Speight, D.W., 1985, Ground-water levels in the Cockeysville marble of southern Chester County, Pennsylvania, 1983-84: U.S. Geological Survey Water Resources Investigations Report 85-4341, 1 plate, scale 1:24,000.

Steel, R.G.D., and Torrie, J.H., 1960, Principles and procedures of statistics: New York, McGraw-Hill, 481 p.

Tabac, H.H., Quave, S.A., Mashni, C.I., and Barth, E.F., 1981. Biodegradable studies with organic priority pollutant compounds: Journal Water Pollution Control Federation, v. 53, no. 10, p. 1503-1518.

Talley, J.H., 1980, Effects of earthquakes and earth tides on water levels in selected wells in the piedmont of Delaware: Delaware Geological Survey Open File Report No. 11, 11 p.

Tetrault, R.C., and Wuest, P.J., 1979, Pennsylvania grower's guide to mushroom pest control: University Park, Cooperative Extension Service, Pennsylvania State University.

Thomann, W.F., 1977, Igneous and metamorphic petrology of the Honey Brook upland in Elverson, Pottstown, and Phoenixville 7.5 minute quadrangles, southeastern Pennsylvania: unpublished M.A. thesis, Bryn Mawr College.

Thurman, E.M., 1985, Organic geochemistry of natural waters: Dordrect, Netherlands, Martinus Nijhoff/Dr. W. Junk Publishers, 497 p.

Turner-Peterson, 1980, Uranium in sedimentary rocks: Application of the facies concept to exploration: Denver, Rocky Mountain Section Society of Economic Palentologists and Mineralogists, 175 p.

U.S. Environmental Protection Agency, 1980, Water quality criteria documents; availability: Federal Register, November 28, 1980, p. 79318-79379.

U.S. Environmental Protection Agency, 1988a, Maximum contaminant levels (subpart B of part 141, National interim primary drinking-water regulations): U.S. Code of Federal regulations, Title 40, Parts 100 to 149, revised as of July 1, 1988, p. 530-533.

-----, 1988b, Secondary maximum contaminant levels (section 143.3 of part 143, National secondary drinking-water regulations): U.S. Code of Federal regulations, Title 40, Parts 100 to 149, revised as of July 1, 1988, p. 608.

Van Houten, F.B., 1964, Cyclic lacustrine sedimentation, Upper Triassic Lockatong Formation, Central New Jersey and adjacent Pennsylvania: Kansas Geological Survey Bulletin 169, p.497-531.

Vogel, K.L., Miller, W.E., and McManus, B.C., [IN REVIEW], Altitude and configuration of the potentiometric surface in the Lower Paleozoic and Precambrian crystalline rocks of the Red Clay Creek basin, Chester County, Pennsylvania, July 1989 through March 1990: U.S. Geological Survey Water Resources Investigations Report _____, 1 plate, scale 1:24,000.

Wagner, M.E., and Crawford, M.L., 1975, Polymetamorphism of the Precambrian Baltimore Gneiss in southeastern Pennsylvania: American Journal Science, v. 275, p. 653-682.

Wagner, M.E., and Srogi, Leeann, 1987, Early Paleozoic metamorphism at two crustal levels and a tectonic model for the Pennsylvania-Delaware piedmont: Geological Society America Bulletin, v. 99, p. 113-126.

Warshawer, I.R., 1982, The origin of graphite in amphibolite and granulite grade gneiss of the Honey Brook upland, southeastern Pennsylvania: unpublished B.A. thesis, Bryn Mawr College.

White, K.E., and Sloto, R.A., [IN REVIEW], Base-flow-characteristics of selected Pennsylvania streams: U.S. Geological Survey Water Resources Investigations Report.

Windholz, Martha, Budavari, Susan, Stroumtsos, L.Y., and Fertig, M.N., eds., 1976, The Merck Index: Ninth edition, Rahway, New Jersey, Merck and Co., Inc.

Wood, C.R., 1980, Groundwater resources of the Gettysburg and Hammer Creek Formations, southeastern Pennsylvania: Pennsylvania Geological Survey, 4th ser., Water Resources Report 49, 87 p.

Wood, C.R., 1984, Ground-water levels in the carbonate rocks of central Chester County, Pennsylvania, May 18 to June 15, 1984: U.S. Geological Survey Open-File Report 84-715, 1 plate, scale 1:24,000.

------, 1985, Ground-water levels in the lower Paleozoic carbonate rocks of western Chester Valley, Chester County, Pennsylvania, November, 1984: U.S. Geological Survey Water Resources Investigations Report 85-4224, 1 plate, scale 1:24,000.

REFERENCE NO. 28

EFFECT OF URBANIZATION ON THE WATER RESOURCES OF EASTERN CHESTER COUNTY, PENNSYLVANIA

By Ronald A. Sloto

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 87-4098

Prepared in cooperation with the

CHESTER COUNTY WATER RESOURCES AUTHORITY

Harrisburg, Pennsylvania

1987

Triassic Rocks

Triassic sedimentary and igneous rocks of the Newark Supergroup occur in northern Chester County along the Schuylkill River (fig. 5). The principal formations are the Hammer Creek, Lockatong, and Stockton Formations (plate 1). The Hammer Creek Formation includes a major interbedded quartz pebble conglomerate, for which separate hydrologic data are available. Diabase occurs as intruded dikes and sills. Hydrologic characteristics for the Triassic formations are given in table 3.

In the Triassic sedimentary rocks, most ground water occurs and moves through a network of interconnecting secondary openings, such as bedding planes, joints, and fractures. Some water may move through pores in the rock where the cement has been removed and the permeability has increased. At depth, water is often confined under pressure greater than atmospheric. This confinement is caused by vertical changes in permeability that result from the cementing material in some zones being less susceptible to removal by solution, gradations in the textures of the sediments, and varying degrees of fracturing (Greenman, 1955, p. 28). If the hydrostatic pressure is sufficient, the well will flow at the surface. Water levels in deep wells respond to changes in pressure; most deep wells penetrate several major water-bearing zones and are thus multiaquifer wells. Each zone may have a different hydraulic head. The hydraulic head in a deep well is the composite head of the several water-bearing zones it penetrates. Where differences in hydraulic head exist between water-bearing zones, water in the well under nonpumping conditions flows in the direction of decreasing head.

Cambrian-Ordovician Carbonate Rocks

Chester Valley, which cuts through the center of the county, is underlain by Cambrian and Ordovician limestones and dolomites (fig. 5). The principal formations are the Cambrian Ledger and Elbrook Formations and the Cambrian and Ordovican Conestoga Formation (plate 1). The Cambrian Vintage and Kinzers Formations also occur locally, but they are of limited areal extent. Hydrologic characteristics of the carbonate rocks are given in table 3.

In carbonate rock, ground water occurs in and moves through a network of interconnecting joints, fractures, and bedding planes, some of which may be enlarged by solution. Permeability of carbonate rock is predominately the result of solution. Where solution has been active, permeability may be high; elsewhere, the same unit may be nearly impermeable. Water in carbonate rock is generally under water-table conditions, but confined groundwater conditions may exist locally. Because acidic precipitation dissolves carbonate rock, water from wells is generally hard and high in dissolved solids.

Carbonate rock is generally more susceptible to ground-water contamination than most other rock terranes because of the formation of solution channels. Solution causes enlargement of openings along the more direct flow paths creating channels for the movement of contaminants. When a contaminant enters a solution channel, it may move a great distance in a short time toward a point of discharge. Ground-water and surface-water divides commonly do not coincide in carbonate-rock terranes, so that contaminates in solution channels may move rapidly beneath surface-water divides.

Carbonate rocks are susceptible to the formation of sinkholes. A sinkhole is a depression in the land surface, often round or funnel-shaped, caused by the collapse of a subterranean cavity. The following discussion of sinkhole formation is taken largely from Newton (1976) and Newton and Hyde (1971).

Sinkholes can be divided into two categories: induced and natural. Induced sinkholes are those that can be related to human activity, whereas natural ones cannot. This discussion will be restricted to induced sinkholes. Some induced sinkholes can develop within minutes or hours after the effects of human activity are exerted on existing geologic and hydrologic conditions. Induced sinkholes are particularly dangerous because they usually form instantaneously, and because they often occur in populated areas. Figure 6 shows several sinkholes that formed following a 1.12-inch rainfall on April 29, 1979. The sinkholes caused the failure of State Route 29, about 1 mile north of U.S. Route 202.

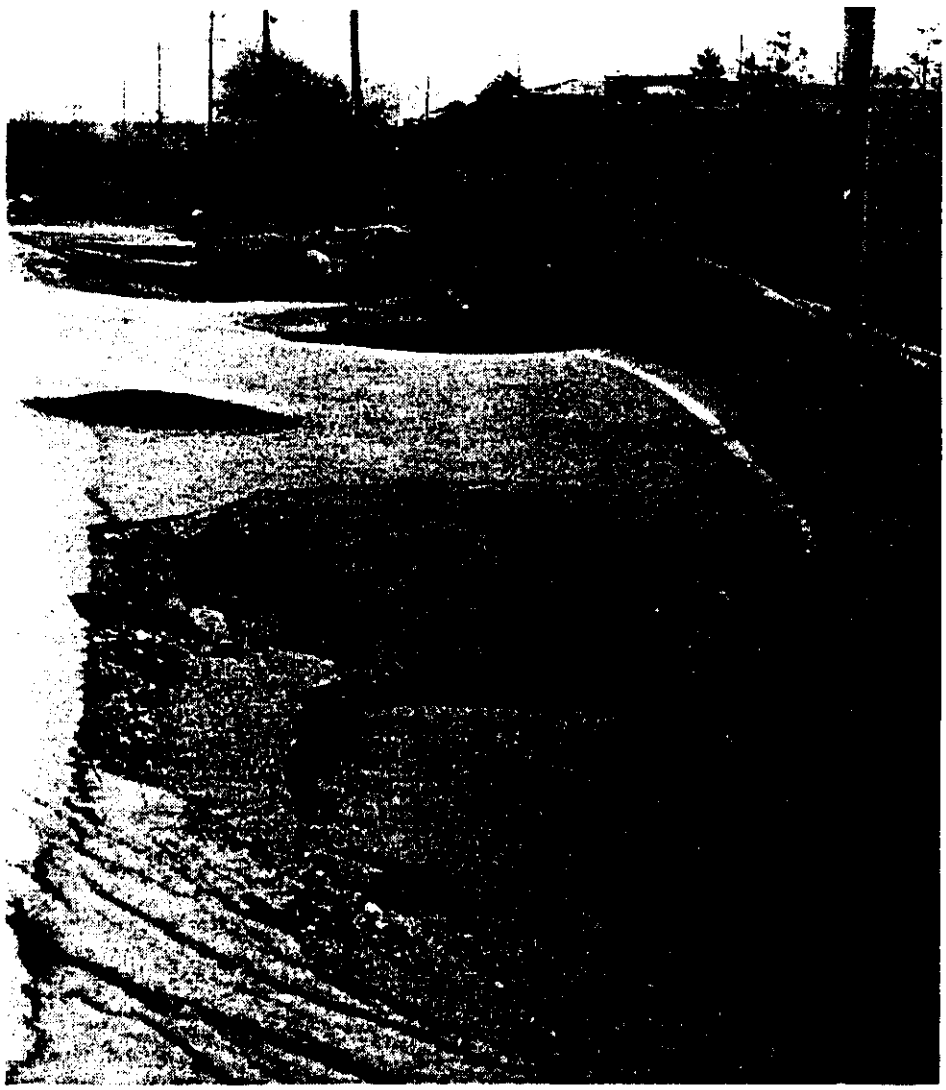

Figure 6.--Collapse beneath State Route 29, 1 mile north of U.S. Route 202.

Sinkholes develop above cavities in carbonate rock. Clay and soil materials migrate downward into openings in the underlying rock. The enlargement and collapse of such a cavity is illustrated in figure 7. The downward movement of material is often initiated by surface water that infiltrates unconsolidated deposits interconnected with openings in bedrock. The water moves with sufficient velocity to cause erosion and stoping of the unconsolidated material, resulting in the formation of a cavity. The conditions may be aggravated by a lowered water table caused by pumping. Downward migration of unconsolidated material and stoping continues until the roof of the cavity collapses, causing a sinkhole to form. Induced sinkholes in urbanized areas are often caused by the concentration of runoff from roofs, parking lots, and other impervious areas. All of the sinkholes observed by the author in eastern Chester County during 1979-86, such as the one shown in figure 8, formed during or immediately after a heavy rainfall.

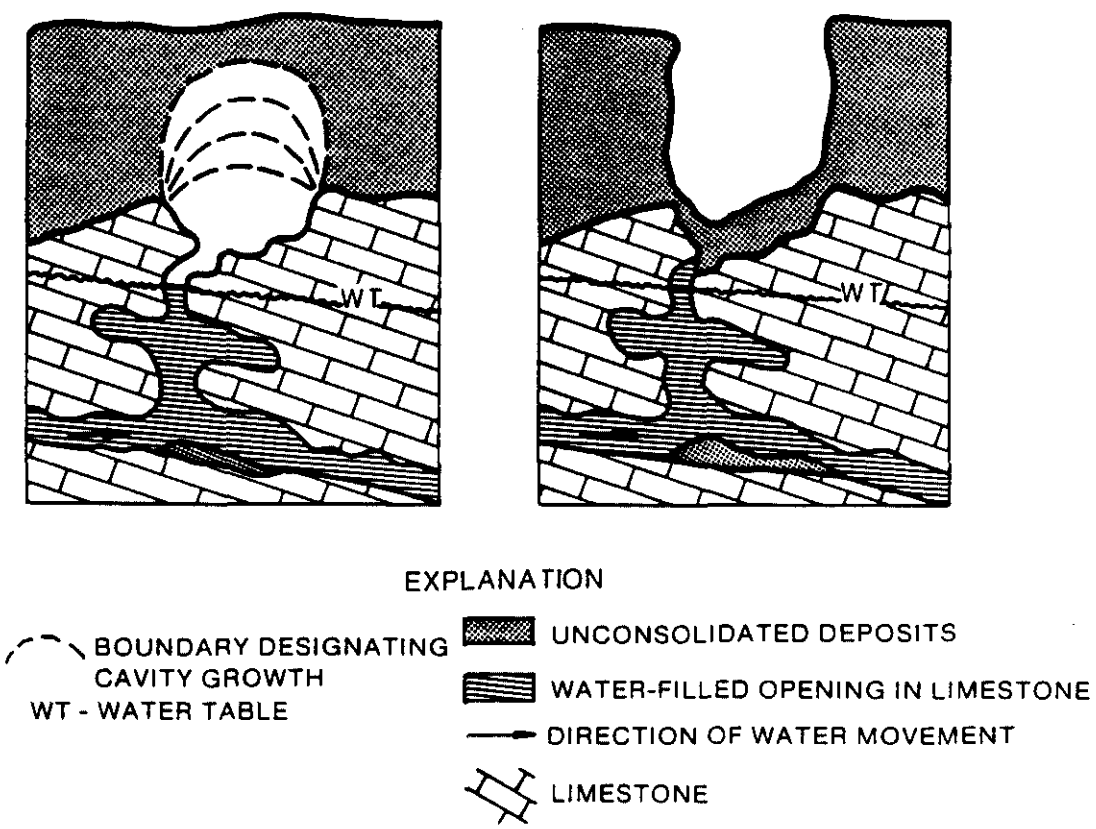

Figure 7.--Formation of sinkhole. (From Newton, 1976)

Figure 8.--Sinkhole along Flat Road, 0.1 mile west of State Route 29.

Precambrian and Lower Paleozoic Crystalline Rocks

The area underlain by crystalline rock is divided by Chester Valley (fig. 5). North of Chester Valley, the crystalline rocks are chiefly Precambrian graphitic gneiss, quartz monzonite and quartz monzonite gneiss, granodiorite and granodiorite gneiss, Franklin Marble, and Precambian and Cambrian quartzites (plate 1).

The quartzites comprise the North Valley Hills north of Chester Valley. They are the Chickies, Antietam, and Harpers Formations. The Antietam and Harpers Formations are undifferentiated. South of Chester Valley, the crystalline rocks are predominately the Precambrian and Lower Paleozoic Wissahickon Formation and serpentinite, and Precambrian felsic and mafic gneisses. The Wissahickon Formation is divided into two facies--an albite chlorite schist to the north and an oligoclase mica schist to the south.

In the crystalline rocks, ground water is present in and moves through intergranular openings in the weathered zone and through a network of interconnecting fractures and joints in the underlying bedrock. The permeability of fractured crystalline rock depends on the number of fractures, the size of the fracture openings, and the degree of interconnection of the fractures. Compression tends to close the openings with depth. Therefore, they are generally best developed near the surface. They occur less frequently and are not as wide with depth.

The crystalline rock is generally deeply weathered. The thickness of the unconsolidated weathered rock ranges from zero to a few hundred feet. Because most wells in Chester County have well casing set in the upper few feet of solid rock, casing length usually indicates the thickness of the unconsolidated zone. Based on median casing lengths, the average thickness of the unconsolidated weathered rock is 40 to 60 feet. The weathered materials overlying bedrock contain a considerable quantity of water in storage.

RELATION OF URBANIZATION TO WATER USE

Public Water Supplies

Public water companies and municipal authorities serve the more densely populated areas. In addition, some residential subdivisions in rural areas are served by small public water companies or by subsystems of the Great Valley Division of the Philadelphia Suburban Water Company. The public water companies that serve these residential subdivisions depend upon ground water for their source of supply.

Public water utilities that serve eastern Chester County and their source of water supply are listed in table 4; their service areas are shown in figure 9. In addition, a small part of the study area around Lionville is served by the Uwchlan Township Municipal Authority.

ORIGINAL (Red)

REFERENCE NO. 29

BULLETIN W 25

Hydrology of the Metamorphic and Igneous Rocks of Central Chester County, Pennsylvania

by Charles W. Poth
U. S. Geological Survey

Prepared by the United States Geological Survey, Water Resources Division, in cooperation with the Pennsylvania Geological Survey

PENNSYLVANIA GEOLOGICAL SURVEY
FOURTH SERIES
HARRISBURG
First Printing, 1968
Second Printing, 1973

	Harpers Schist	280—1,000+	Gray sandy micaceous schist; has thin quartzite beds.
	Chickies Quartzite and Hellam Conglomerate Member	500	Vitreous to granular quartzite, massive and thin bedded, some quartz schist and mica schist; conglomerate-bearing beds at base.

TABLE 1.—*Generalized geologic section (modified after Bascom and Stose)—Continued*

System	Series	Formation	Thickness (feet)	Character
Age uncertain—Precambrian to Lower Paleozoic		Gabbro	?	Chiefly calcic plagioclase and hypersthene or augite; may contain quartz. In small masses hornblende replaces pyroxenes.
Age uncertain—Precambrian to Lower Paleozoic		Pegmatite	?	Ranges in composition from that of granite to gabbro. Present as small sill-like bodies.
Age uncertain—Precambrian to Lower Paleozoic		Serpentine	?	Altered peridotite and pyroxenite. Present in small isolated exposures.
Age uncertain—Precambrian to Lower Paleozoic	Glenarm	Peters Creek Schist	2,000+	Green fine-grained laminated chlorite mica schist.
		Wissahickon Formation	5,000—8,000+	Chlorite phyllite and muscovite schist, injected by gabbro.
		Cockeysville Marble	200+	Medium to coarse grained white saccharoidal marble, banded with phlogopite.
		Setters Formation	1,000+	Quartz schist, quartzite, and mica gneiss.
Precambrian		Baltimore Gneiss and Franklin Limestone	?	Contorted, banded gneiss, in part graphitic, injected by gabbro, and serpentine. Franklin Limestone is a banded, white, coarsely crystalline marble containing graphite.

The amount of recharge an aquifer receives depends upon the amount and distribution of precipitation. Most recharge occurs during the winter and spring months.

Despite the fact that approximately 13 percent more precipitation falls between April and September than between October and March, little recharge occurs during the summer and fall months, because higher temperatures plus the growth of plants result in the evapotranspiration or consumption of nearly all precipitation. By the middle of May, generally, water levels begin to decline and may continue to do so past the period of high temperatures and the growing season. Cool and unusually wet summers and falls may allow recharge to occur a few weeks earlier than usual and may hold water levels slightly above their normal annual lows, but generally little recharge occurs during this period and that which does occur produces only a small and temporary reversal of the downward trend of the water level.

The rate at which the water level falls and the size of the annual fluctuation depend chiefly on the permeability of the rocks, the height of the water above points of discharge, and the distance the water must travel to the discharge point.

Plate 3 shows the water-level fluctuations in well 956-555-1 in Chester County.

Occurrence

In unconsolidated rocks such as sands and gravels the water occurs in and moves through the interstices between the grains (called primary openings). In consolidated clastic rocks such as sandstones and shales, and in crystalline rocks such as limestones, gneisses, schists, and gabbros that underlie the area covered by this report, the water is confined mainly to fractures (secondary openings).

Pumping Effects

In a well supplied from primary openings, water generally enters the borehole throughout the entire saturated thickness of the aquifer. In a well supplied by secondary openings, water generally enters the borehole in discrete zones separated from each other by nonproductive zones.

The amount of water a well is capable of yielding depends on the size, number, and degree of interconnection of the water-filled openings intercepted by the well. It depends also on how these features change at different distances from the well. As the well is pumped, the water level is drawn down in the well and in the formation surrounding the well. The zone in which the water level is drawn down is called the cone of depression. As pumping continues, the cone deepens and grows in areal extent as water from an ever greater area is diverted from its natural flow path to replace the water pumped from the well. If the aquifer is

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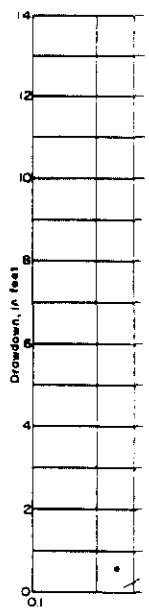

Figure 3. Gr

-3-

Ledger Dolomite, will suffer a more severe curtailment of yield than will a well in a formation such as Wissahickon, which commonly yields from several zones.

Ideally, Table 3 should show also the capacities of the zones to yield water and how the capacities differ at different depths. Such data were too scarce to put into a table, but they are discussed in connection with the appropriate formation.

EFFECT OF WEATHERING ON HYDROLOGY

In most places, a soft and poorly consolidated zone of weathered rock lies immediately below land surface. This zone is generally incapable of supporting itself and will collapse into the borehole unless kept from doing so by the use of casing. Casing is generally set just a few feet below the base of the zone—into more solid rock. Only rarely, as when caving zones are encountered at considerable depths in a well or when undesirable water must be sealed off, are greater amounts of casing used. Thus, the depth of weathering of the rocks in an area can generally be determined by the amount of casing used in the wells.

The thickness of the weathered mantle is considered important, because the mantle contains the major part of the water stored in the rocks of the area. The fractures that serve as conduits have a low capacity for storage.

The range and median depth of casing in wells are listed in Table 2. In most formations, the median depth is between 20 and 40 feet. Somewhat more casing is needed in wells in carbonate rocks than in other rocks of the area, because clay resulting from the weathering of the rocks may fill the fractures and solution cavities in many places. These cavities must be cased off. In such places, the casing is extended downward from the surface through both the overlying residuum and any fresh rock overlying the clay-filled solution opening.

EFFECT OF TOPOGRAPHY ON HYDROLOGY

The importance of topography to the hydrology of an area has long been known. (See LeGrand, 1949; Mundorff, 1948; and Dingman and Meyer, 1954.) To evaluate its effect in the area covered by this report a simple four-fold classification was used to divide the topography into (1) uplands, (2) slopes, (3) draws or small stream valleys and linear depressions on the slopes, and (4) the valleys of the major through-flowing streams. The last category is less useful than the others because it is dominated by the Chester Valley, which is underlain chiefly by carbonate rocks (so that it is difficult to distinguish the effect of topographic position from that due to rock type), and because there are fewer data in the valley category than in the others.

The northern facies is typically a phyllite (McKinstry, 1961, p. 562) and is composed chiefly of quartz, feldspar, muscovite, and chlorite. Minute euhedral albite crystals are reported to be intercalated with muscovite schist beds (Bascom and Stose, 1932, p. 4). The bedding is rarely visible, but where seen it is nearly parallel to the cleavage.

The southern facies is more coarsely crystalline than the northern, and according to Bascom and Stose (1932, p. 4-5) is separable into two gneissic members—although they did not map it in this way. The upper member is a muscovite gneiss and, is distinguished from the lower by "being excessively micaceous . . . and more schistose than gneissic . . . (It) is characteristically crinkled or fluted, with a schistosity cutting across the fluting" (Bascom and Stose, 1932, p. 5). It is composed chiefly of quartz, feldspar, and muscovite. The lower member is developed south of the report area and is a "biotite gneiss, abundantly injected by granitic and gabbroic pegmatites and by massive gabbro . . ." (Bascom and Stose, 1932, p. 4). Feldspar is more abundant in this member than in the upper member. In the past some of this member has been mistakenly mapped as Baltimore Gneiss. Because of the intense folding and lack of recognizable recurrent beds, the thickness of the Wissahickon is not known.

Water-bearing properties.—The capacity of the chlorite phase of the Wissahickon to yield water to wells is obscured by conflicting evidence. Based on reported yields, it is one of the poorer aquifers of the area. Of 41 wells on which yields were reported, about 7 yielded less than 1 gpm and only 2 wells yielded more than 50 gpm. The median yield was about 8 gpm. However, based on specific capacities determined from 18 pumping tests, it is one of the better aquifers. Specific capacities ranged from 0.04 to 38 gpm per ft. (Only a well in the Cockeysville Marble had a higher specific capacity than the best well in this unit.) The median was 2.4 gpm per ft.

The conflict in the data is probably partly due to the improper estimation of the yields of the high capacity wells, as many of these wells were drilled by churn drill and tested by bailing. Also, it may be partly due to the failure to include a sufficient number of the poorer wells in the sampling of wells for specific capacity tests, because many of these wells were abandoned immediately after drilling, when they proved completely inadequate.

In the muscovite gneiss phase of the Wissahickon, only 1 of the 77 wells reported yielded a gallon per minute or less, and 14 yielded 5 gpm or less. Only 4 wells were reported to yield more than 35 gpm, but 2 of these exceeded 300 gpm. The median yield was 10.5 gpm.

Specific capacities of the gneiss phase were determined from tests on 20 wells and ranged from 0.06 to 8.4 gpm per ft. The median was 0.4 gpm per ft.

Of 63 reported well depths in the chlorite phase 1 was less than 50 feet deep and 4 were over 300 feet deep. The median depth was 125 feet. In the muscovite gneiss phase 2 of the 115 well depths were less than 50 feet and 5 were more than 300 feet. The median was about 112 feet.

Data on the depth of casing were obtained for 46 wells in the chlorite phase. Eight wells had less than 20 feet of casing and 4 had more than 100 feet. The median depth of casing was 25 feet. Of the 10 wells yielding 20 gpm or more, 4 had 20 feet or less of casing and 7 contained 40 feet or less. The amount of casing was not reported in 2 of the 10 wells.

Of 67 casings in the muscovite gneiss phase 9 were less than 20 feet and only 1 casing was more than 100 feet deep. The median depth was 40 feet.

Data on depth to yielding zones was obtained for 20 wells in the chlorite phase. Eleven of the wells yielded water from a single zone, 5 yielded from 2 zones, 3 yielded from 3 zones, and 1 yielded from 4 zones. Only 2 yielding zones were deeper than 125 feet although 12 of the wells were between 125 and 400 feet deep.

This distribution of water-bearing zones is markedly different in the muscovite gneiss phase. Of 40 wells, 11 obtained water from a single zone, 18 from 2 zones, 6 from 3 zones, 2 from 4 zones, 1 from 5 zones, and 2 from 7 zones. Water-bearing zones were not restricted to within 125 feet of land surface, but were at depths as great as 285 feet. One well obtained 20 gpm from a zone 252 feet deep. Contrary to expectations, no systematic decrease in the density of yielding zones was noted as the well depth increased to as much as 400 feet.

Evaluation of the aquifer.—Both reported-yield and specific-capacity data indicate a wide range in the yielding capacity of wells in this aquifer. However, for reasons noted at the beginning of the discussion on this formation, reported yields are not satisfactory for estimating the more commonly expected yields. Specific capacities were used, therefore, to estimate the potential yields of the wells, and these estimated yields were used in the following evaluation. Wells in the chlorite phase should be drilled about 150 feet deep on slopes or in draws to realize an average yield of 75 gpm or more. The wells drilled on slopes appear to yield slightly better than those in draws.

In the muscovite phase, the wells should be at least 300 feet deep for maximum production, and they may be expected to yield 75 gpm or more. Wells drilled in draws appear to be somewhat better than those on slopes.

Water quality.—Three samples of water from each phase of the Wissahickon were analyzed in the laboratory. The dissolved-solids content of the samples ranged 115 to 250 ppm and was about the same in each phase. Iron ranged from 0.03 to 0.31 ppm. The potassium content of the chlorite phase was quite low (0.2 to 0.7 ppm) and makes water from this phase readily distinguishable from water from the muscovite phase (3.0 to 3.2 ppm).

ville and another leaves the area northeast of West Chester. The diabase is a medium- to fine-grained rock composed chiefly of plagioclase and pyroxene in equal amounts. It is Triassic in age.

Water-bearing properties and water quality.—The diabase is small in areal extent and, so, unimportant as an aquifer; also, it is dense and hard to drill, and only domestic supplies are obtainable. The single well record obtained from diabase in this area was that of a well 255 feet deep that yielded a half gallon per minute from a depth of 70 feet. The water had a pH of 7.3, a hardness of 5 gpg, and a conductance of 175 micromhos.

Reports from adjacent areas indicate that this is a somewhat poorer yield than normal, and that yields of about 5 gpm are more typical of the diabase.

CONCLUSIONS

The ground water occurs in and moves through fractures in the rocks. Most of these water-bearing zones are less than 200 feet below the surface, but some in the Baltimore Gneiss are deeper than 300 feet. Wells commonly intercept two or more zones.

Wells in draws and valleys yield more than those on slopes and uplands, and are generally shallower.

Depth of weathering, as indicated by casing lengths, is not affected by topographic position. The importance of the weathered zone as a reservoir appears to be restricted by the abundance of clayey material.

The influence of metamorphism is shown by a decrease in well yield and an increase in depth of weathering as the metamorphic rank of the rocks increases from slate to gneiss.

The water is of the calcium magnesium bicarbonate type. It is slightly acidic—having a median pH of 6.6—and is soft, having a median hardness of 3 gpg. The median dissolved-solids content is 146 ppm.

Large yields were obtained from several of the formations. These maximum yields were 270 gpm from the Baltimore Gneiss, 330 gpm from the Cockeysville Marble, 350 gpm from the Wissahickon Formation, 312 gpm from the Peters Creek Schist, 665 gpm from the Vintage Dolomite, 150 gpm from the Ledger Dolomite and Elbrook Limestone, 175 gpm from the Conestoga Limestone, 125 gpm from the gabbro, and 80 gpm from the serpentine. Although these yields are not typical of the yields that may be commonly expected, they are more indicative of the potential of these rocks than the median yields of the domestic wells that provided the bulk of the data available.

Data were not sufficiently abundant for adequate appraisal of the Setters Formation, Chickies Quartzite, Harpers Phyllite, Antietam Quartzite, Kinzers Formation, pegmatite, and diabase.

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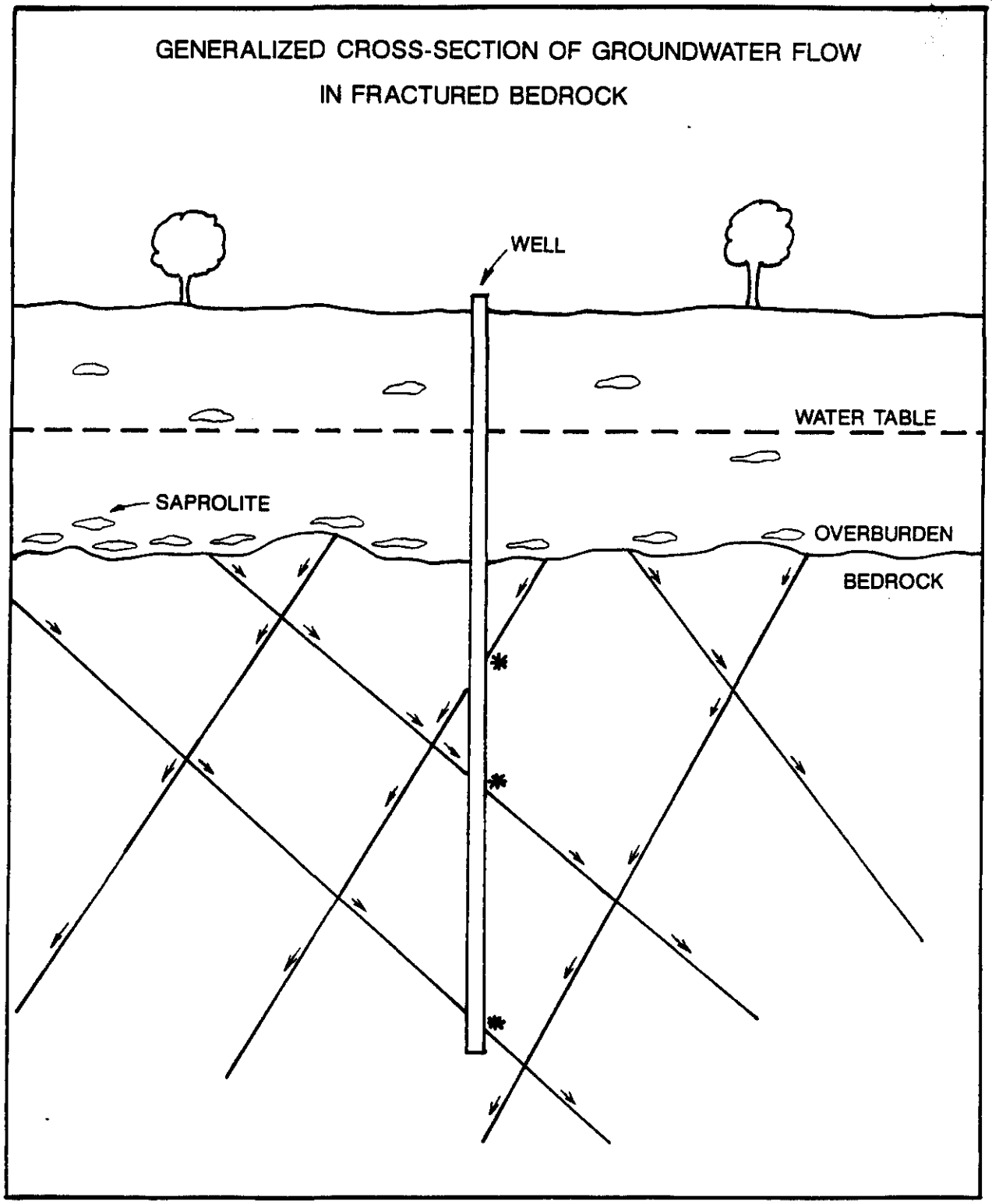
REFERENCE NO. 30

GENERALIZED CROSS-SECTION OF GROUNDWATER FLOW IN FRACTURED BEDROCK



* INTERSECTION OF WELL BOREHOLE AND WATER-BEARING FRACTURE

→ DIRECTION OF GROUNDWATER FLOW

MODIFIED BY HALLIBURTON NUS FROM REFERENCE NO. 20 (P. 13, FIG. 5)

HALLIBURTON NUS
Environmental Corporation

MAY 1995

ORIGINAL (Red)

REFERENCE NO. 31

NUS CORPORATION AND SUBSIDIARIES — **TELECON NOTE**

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DISTRIBUTION:

USGS Interpretation of The Wissahickon Aquifer

BETWEEN:	OF:	PHONE:
Karen Vogel	USGS: Malvern, Pa	(215) 647-9008

AND: (b) (4) [redacted]

DISCUSSION:

I called the USGS to discuss the Wissahickon Aquifer. The USGS considers the fractured crystalline rock and the weathered overburden to form a common, unconfined aquifer. As evidence, they use the fact that water levels from many area wells completed over a wide range of depths form a predictable and consistent pattern, as would be expected in a water-table aquifer. Ms. Vogel also stated that the water levels in the Wissahickon fluctuate seasonally, which also leads them to conclude that the aquifer is unconfined. Storativity values for the aquifer are in the range of 0.07 to 0.10; these are indicative of unconfined conditions.

ACTION ITEMS:

Ms. Vogel suggested I call John Talley of the Delaware Geological Survey (302/831-2833), who has also done research on the Wissahickon.

NUS 067 REVISED 0685

ORIGINAL
(Red)

REFERENCE NO. 32

SECOND EDITION

APPLIED HYDROGEOLOGY

C. W. FETTER

University of Wisconsin—Oshkosh

Merrill Publishing Company
A Bell & Howell Information Company
Columbus Toronto London Melbourne

1988

1

age, the aquifer remains saturated. The storativity (S) of a confined aquifer is the product of the specific storage (S_s) and the aquifer thickness (b):

$$S = bS_s \tag{4-19}$$

All of the water released is accounted for by the compressibility of the mineral skeleton and the pore water. The water comes from the entire thickness of the aquifer. The value of the storativity of confined aquifers is on the order of 0.005 or less.

In an unconfined unit, the level of saturation rises or falls with changes in the amount of water in storage. As the water level falls, water drains from the pore spaces. This storage or release is due to the **specific yield** (S_y) of the unit. Water is also stored or expelled depending on the specific storage of the unit. For an unconfined unit, the storativity is found by the formula

$$S = S_y + hS_s \tag{4-20}$$

where h is the thickness of the saturated zone.

The value of S_y is several orders of magnitude greater than hS_s for an unconfined aquifer, and the storativity is usually taken to be equal to the specific yield. For a fine-grained unit, the specific yield may be very small, approaching the same order of magnitude as hS_s. Storativity of unconfined aquifers ranges from 0.02 to 0.30.

The volume of water drained from an aquifer, V_w, may be found from the equation

$$V_w = SA\Delta h \tag{4-21}$$

where A is the horizontal area and Δh is the decline in head.

EXAMPLE PROBLEM An unconfined aquifer with a storativity of 0.13 has an area of 123 square miles. The water table drops 5.23 feet during a drought. How much water was lost from storage?

$$\begin{aligned} V_w &= SA\Delta h \\ &= 0.13 \times 123\ \text{mi}^2 \times 2.7878 \times 10^7\ \text{ft}^2/\text{mi}^2 \times 5.23\ \text{ft} \\ &= 2.33 \times 10^9\ \text{ft}^3 \end{aligned}$$

If the same aquifer had been confined with a storativity of 0.0005, what change in the amount of water in storage would have resulted?

$$\begin{aligned} V_w &= 0.0005 \times 123\ \text{mi}^2 \times 2.7878 \times 10^7\ \text{ft}^2/\text{mi}^2 \times 5.23\ \text{ft} \\ &= 8.97 \times 10^6\ \text{ft}^3 \end{aligned}$$

REFERENCE NO. 33

EPA REGION III
SUPERFUND DOCUMENT MANAGEMENT SYSTEM

DOC ID # 401695
PAGE #

IMAGERY COVER SHEET
UNSCANNABLE ITEM

Contact the CERCLA Records Center to view this document.

SITE NAME Bishop Tube

OPERABLE UNIT 00

SECTION/BOX/FOLDER 1E Box 1 1.006

REPORT OR DOCUMENT TITLE Reference # 18-57 (Volume III of III).

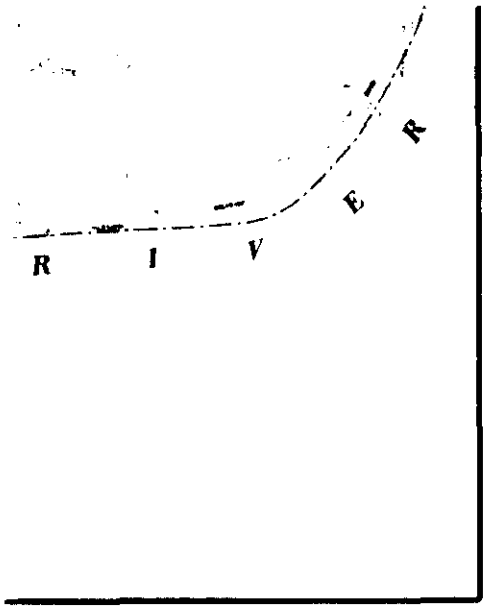
DATE OF DOCUMENT 01-01-01

DESCRIPTION OF IMAGERY Site Map.

NUMBER AND TYPE OF IMAGERY ITEM(S) 1 oversized Map

ORIGINAL (Red)

REFERENCE NO. 34



REVISED

DATE	INIT'L.
8-21-90	R.J.D.
10-16-92	SBP

MAP OF
SURROUNDING WATER CO's
WITHIN
DELA., MONTG. & CHESTER CO.

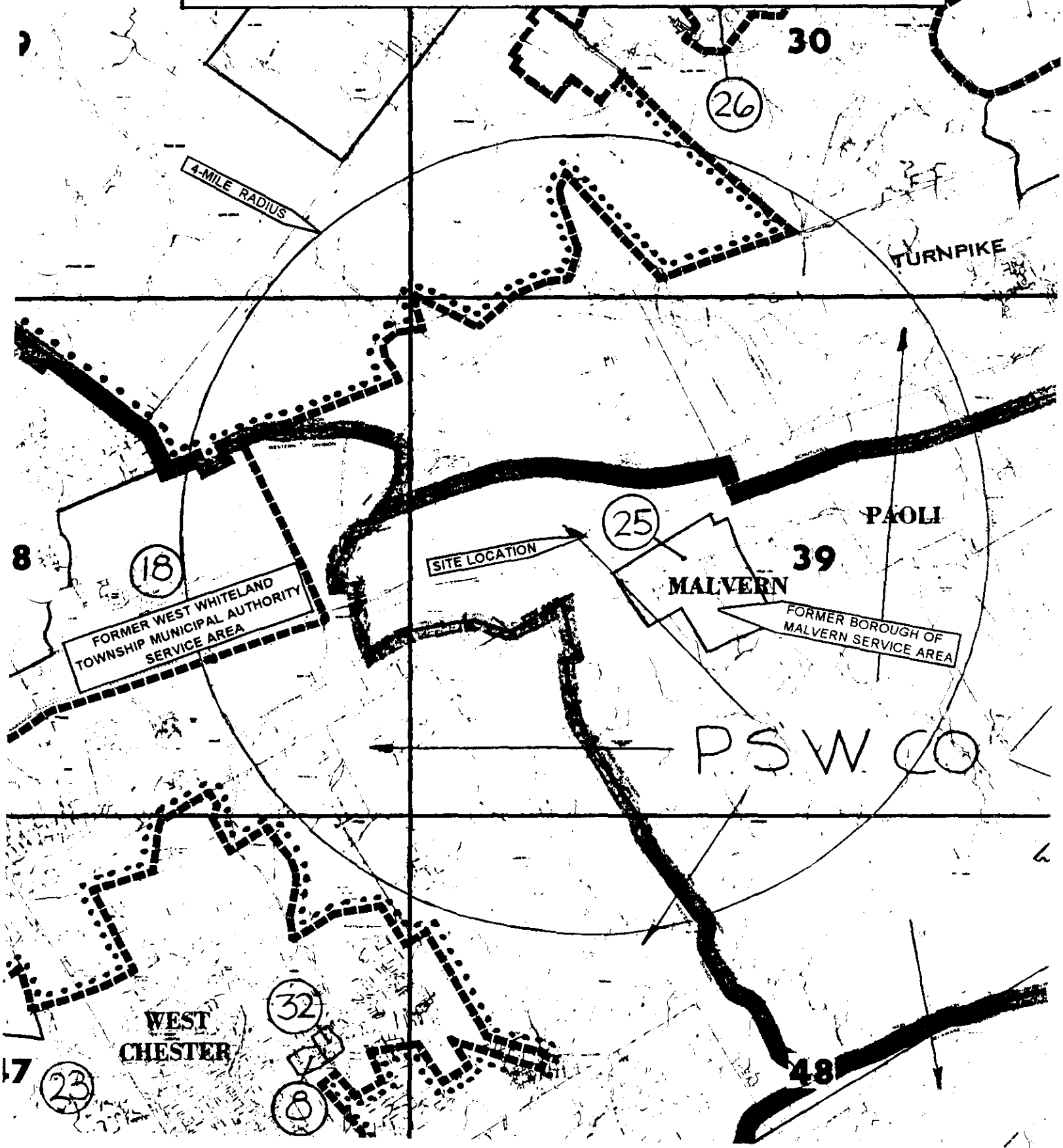
SCALE: N.T.S. CALCULATED: 1" = 6300'
DATE: 4-30-87

A-3262

ACC. NO. 40080

This map was generated in October 1992 by Philadelphia Suburban Water Company (PSWC) and shows the service territories of PSWC and various water supply companies in Chester, Delaware, and Montgomery Counties, Pennsylvania. No key or legend for this map were available from PSWC. PSWC maps showing the location of water mains are not available to the public [ref. no. 35 (p. 1)]. The only way to tell if an individual household is served by PSWC is to compare tax parcel maps with the PSWC customer billing list [ref. no. 35 (p. 2)]. The information added to this map by HNUS was obtained from reference nos. 35 (p. 1) and 39 (pp. 3 and 4)].

The heavy dashed line represents the PSWC service territory as of October 1992 (prior to the aquisition of the West Whiteland Township and the Malvern Borough Water Authority.) The heavy dotted line has been added by HNUS to represent the PSWC territory as of June 1995.



REFERENCE NO. 35

Meeting
~~TELEPHONE~~ CONVERSATION REPORTING FORM

ISSUE DATE	5-15-95
FILE NUMBER	
RECORDED BY	Jill Hartnell, Hydrogeologist
TELEPHONE NUMBER	610 971-0900
CALL ☐ TO ☐ FROM NA	NAME Preston Luteweiler, PE
TELEPHONE NUMBER	610 525-1400 / 1132
COMPANY	Manager, Research & Environmental Affairs
DATE OF ~~CALL~~ Meeting	5-15-95
ADDRESS	Philadelphia Suburban Water Company (PSWC)
TIME	2:00 ☐ A.M. ☒ P.M.
CONFERENCE CALL NA ☐ NO ☐ YES (If YES, list conferees, conferees company, etc. in notes.)	
JOB NUMBER	
CLIENT/PROJECT	Arco II
SUBJECT	Update on PSWC

CONVERSATION NOTES:

PSWC currently serves 800,000 people with water obtained from groundwater wells and surface water intakes (see attached sheets for specific ~~well names~~ water sources

With the exception of the Beversrede, LaReserve and Pocopson portions of the distribution area, the PSWC system is integrated. Water from the wells enters the water main system near to where the wells are located. Therefore, homes, etc. located near any particular well are more likely to obtain part of their water supply from that well.

Preston will send HNUS a copy of PSWC service territory map (note water main maps are not available for purchase).

PSWC recently purchased Malvern, Uwchlan & West Whiteland systems. All of the Malvern wells were abandoned. Uwchland & West Whitland wells are being used by PSWC.

PSWC will shortly purchase Media Water Co. and plan to use their

over

ACTION/RESPONSE		
RESPONSIBLE PERSON	ACTION NEEDED	DUE DATE

COPIES TO:

1

RECORDER'S SIGNATURE
(b) (4) [redacted]

Order No. 11028 (12-90)

two surface water intakes. The 4 Media wells will not be used.
PSWC plans to purchase Deerfield Knolls system (off Route 3) within the year and Castle Rock system (off Route 3) next year.

PSWC purchases water from North Wales Water Authority, Chester Water Authority, Tinicum, Ridley, Bucks County Water & Sewer Authority and West Chester Municipal Authority

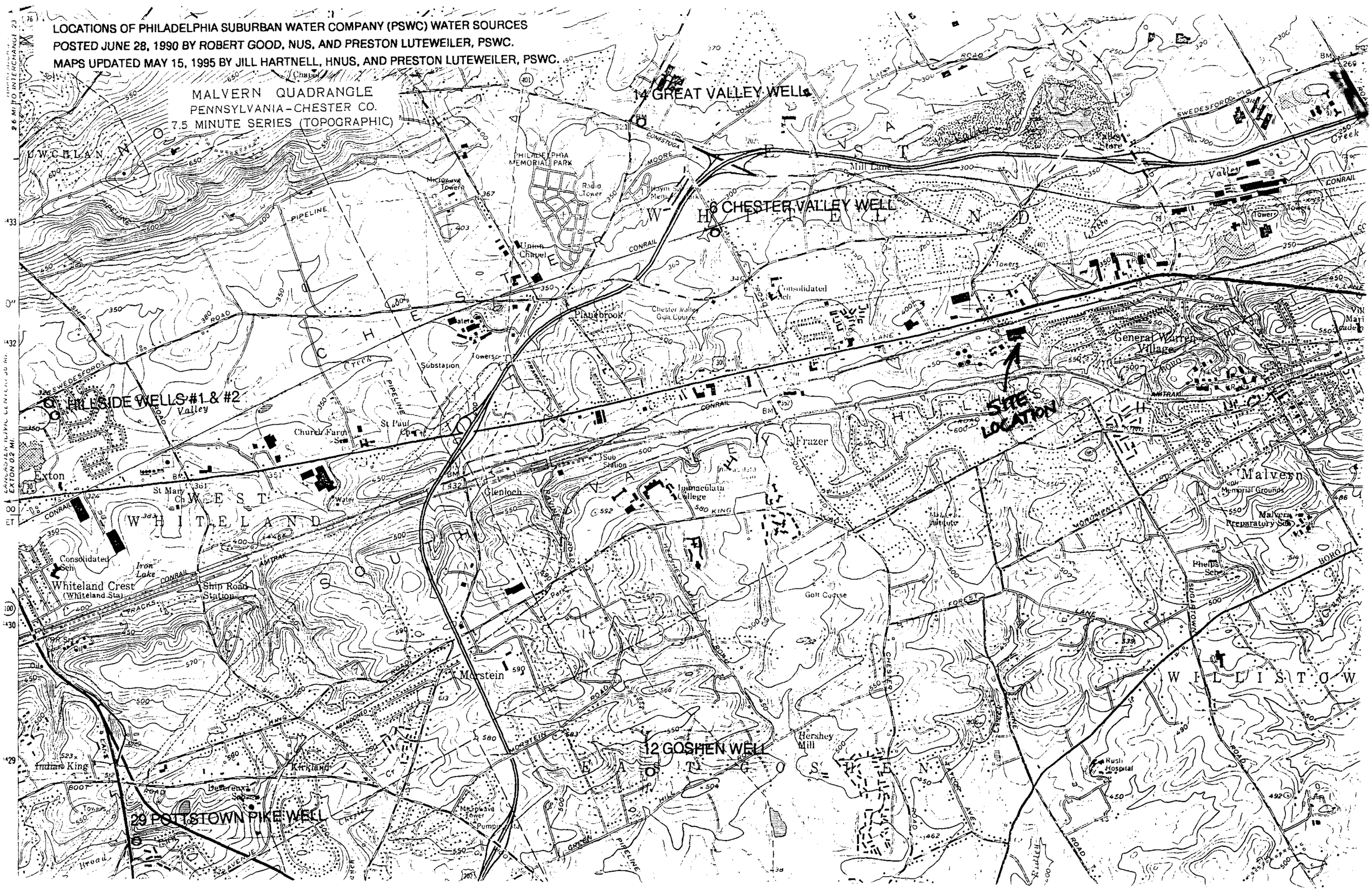
note: The only way to tell who is not served by PSWC (without their service territory) is to compare county tax parcel maps with the PSWC customer billing list

Preston requested copies of the update topographic maps that locate PSWC water sources and the attached summary sheets prepared by HNUS.

Preston supplied HNUS with 1994 sendout data (ie., allocation data) and the names of the Churchland & West Whitelands wells.

REFERENCE NO. 36

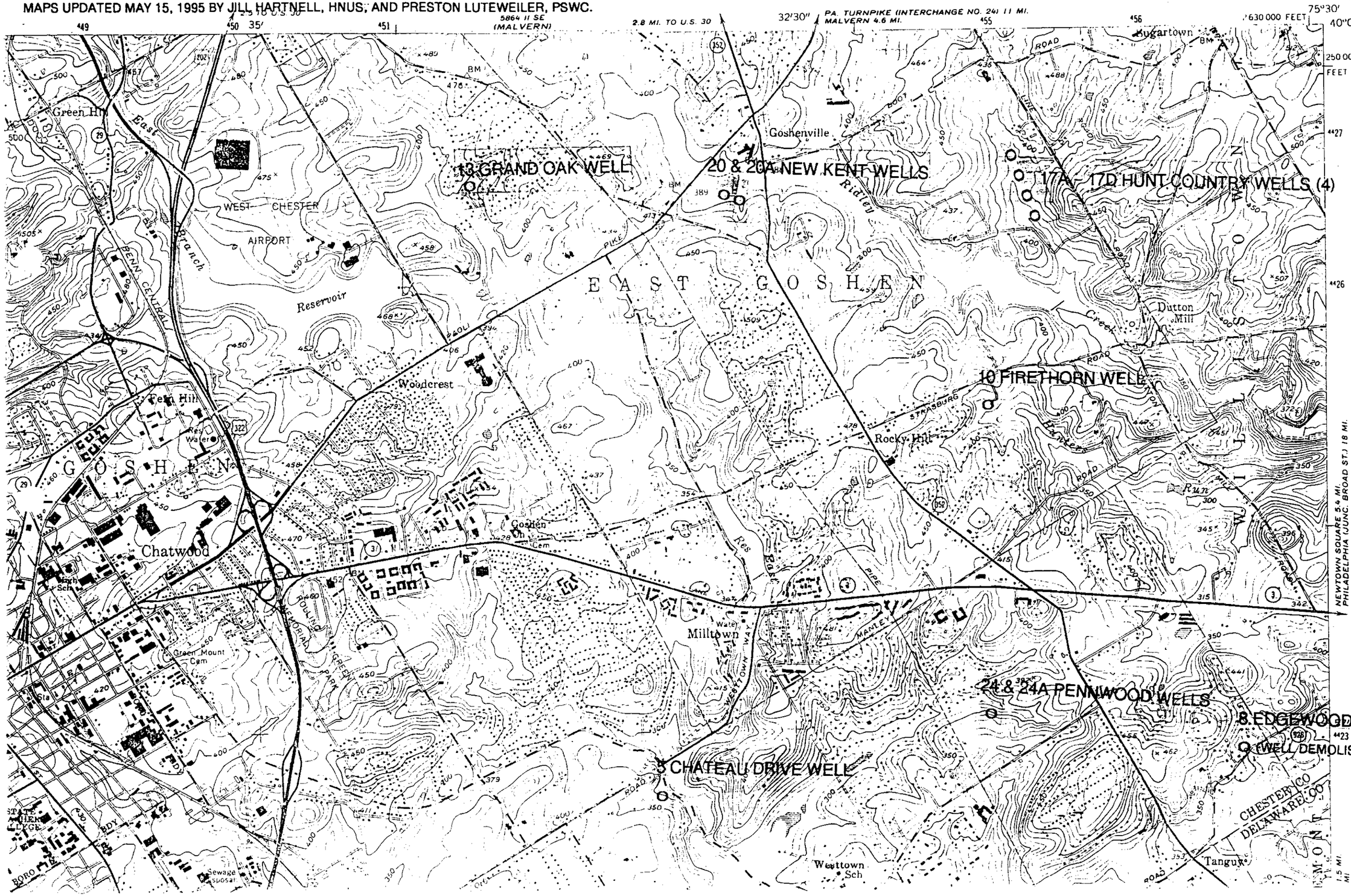
LOCATIONS OF PHILADELPHIA SUBURBAN WATER COMPANY (PSWC) WATER SOURCES
POSTED JUNE 28, 1990 BY ROBERT GOOD, NUS, AND PRESTON LUTEWEILER, PSWC.
MAPS UPDATED MAY 15, 1995 BY JILL HARTNELL, HNUS, AND PRESTON LUTEWEILER, PSWC.



LOCATIONS OF PHILADELPHIA SUBURBAN WATER COMPANY (PSWC) WATER SOURCES
POSTED JUNE 28, 1990 BY ROBERT GOOD, NUS, AND PRESTON LUTEWEILER, PSWC.
MAPS UPDATED MAY 15, 1995 BY JILL HARTNELL, HNUS, AND PRESTON LUTEWEILER, PSWC.

WEST CHESTER QUADRANGLE
PENNSYLVANIA
7.5 MINUTE SERIES (TOPOGRAPHIC)

ORIGINAL (Red)



ORIGINAL (Red)

REFERENCE NO. 37

NUS CORPORATION
SUPERFUND DIVISION

PROJECT NOTE

TO: FOOTE MINERAL - FRAZER AND CRATER RESOURCES FILES

DATE: JUNE 28, 1990

FROM: (b) (4) [redacted], NUS FIT 3

COPIES:

SUBJECT: WATER SUPPLY, PHILADELPHIA SUBURBAN WATER COMPANY

REFERENCE: 9006-28, FOOTE MINERAL - FRAZER & 9006-27, CRATER RESOURCES

I met with Mr Preston Entwisle of Philadelphia Suburban Water Company (PSWC) Thursday, June 28, 1990 from 9:00 am to 11:00 am at their offices. He showed me the location of all of PSWC's groundwater sources on USGS 7.5 Minute Series Topographic Maps, on maps included in the Chester County Water System Inventory 1984 by the Chester County Planning Commission, and on the Montgomery County Pennsylvania 1986 Existing Water Facilities Map by the Montgomery County Planning Commission. He also pointed out the locations of Thin Schuylkill River, Perkiomen Creek and Pickering Creek surface water sources on USGS 7.5 Minute Series Topographic Maps. He gave us a fact sheet of Groundwater Sources including well name, depth, diameter, 1989 Average Daily Withdrawal and Rated Capacity. He gave us a fact sheet of Surface Water Sources including average daily withdrawal, safe yield during dry years of record, and facilities which limit the total daily output. Groundwater and surface water source locations will be spotted on a set of USGS 7.5 Minute Series Topographic Maps for the water supply files. Mr Entwisle also provided some additional information concerning the status or history of some wells (test well, abandoned, etc) which will be included on the maps.

(b) (4) [redacted]

NUS 443A 58 1182

6/28/90

DEPENDABLE DAILY OUTPUT OF THE WATER SYSTEM-SOURCES

PWS I.D. #

SURFACE WATER SOURCES (Name of River, Creek, Stream, Run, Lake, Pond or Reservoir)	Is source metered		Average Daily Withdrawal[7]		Safe Yield or Minimum Production During Dry Years of Record (GPD)[8]	Facilities which limit the Total Daily Output (eg., Raw Water Pumps, Treatment Works, Transmission Mains, Distribution Systems, etc...)		USE		Reason for Period of Non-Use (code)[8]
	Yes	No	GPD	(Days)		TYPE	CAPACITY (GPD)	PERMANENT	EMERGENCY	
Crum Creek	x		21,277,685	(365)	16,000,000	Treatment Works	25,000,000	x		
Pickering Creek	x		6,506,301	(365)	5,500,000	Allocation	15,000,000	x		
Perkiomen Creek	x		21,542,192	(365)	24,000,000	Allocation & Pumps	24,000,000	x		
Neshaminy Creek	x		9,740,082	(365)	12,000,000	Treatment Plant	12,000,000	x		
Schuylkill River	x		5,768,493	(365)	20,000,000	Allocation	20,000,000	x		
				( )						
				( )						
				( )						
TOTAL			64,834,753	(365)	77,500,000		96,000,000	x		

GROUNDWATER SOURCES (WELLS)			Is source metered		Average Daily Withdrawal[7]		Safe Yield or Minimum Production During Dry Years of Record (GPD)[8]	Facilities which limit the Total Daily Output (eg., Raw Water Pumps, Treatment Works, Transmission Mains, Distribution Systems, etc...)		USE		Reason for Period of Non-Use (code)[8]
NAME or NUMBER	DEPTH (Feet)	DIAM. (Inches)	Yes	No	GPD	(Days)		TYPE	CAPACITY (GPD)	PERMANENT	EMERGENCY	
						( )						
						( )						
						( )	SEE SHEET "B"					
						( )						
						( )						
						( )						
						( )						
						( )						
						( )						
						( )						
						( )						
						( )						
						( )						
						( )						
TOTAL						( )						

DEPENDABLE DAILY OUTPUT OF THE WATER SYSTEM-SOURCES

PWS I.D. #

GROUNDWATER SOURCES (SPRINGS)	Is source metered		Average Daily Withdrawal[7]		Safe Yield or Minimum Production During Dry Years of Record (GPD)[8]	Facilities which limit the Total Daily Output (eg., Raw Water Pumps, Treatment Works, Transmission Mains, Distribution Systems, etc...)		USE		Reason for Period of Non-Use (code)[6]
	Yes	No	GPD	(Days)		TYPE	CAPACITY (GPD)	PERMANENT	EMERGENCY	
Upper Merion Reservoir	x		6,736,151	(365)	7,200,000	Pumps	20,000,000	x		
				( )						
				( )						
				( )						
				( )						
TOTAL			6,736,151	(365)	7,200,000		20,000,000	x		

INTERCONNECTIONS WITH OTHER WATER SUPPLIERS

NAME OF OTHER SUPPLIER	AVERAGE DAILY WATER TRANSFERRED				MAXIMUM WATER TRANSFER CAPABILITY (GPD)		USE		Reason for Period of Non-Use (code)[6]
	PURCHASE FROM		SALE TO		FROM	TO	PERMANENT	EMERGENCY	
	GPD	(Days)	GPD	(Days)					
		( )		( )					
SEE SHEET "C"		( )		( )					
		( )		( )					
TOTAL		( )		( )					

Average Daily Withdrawal of all surface and ground water sources, including purchased water if any, should be equal to the "Total Average Daily Water Use" indicated on page 2. (See instruction sheet).

If the Safe Yield is based on actual pumping tests of the well or spring indicate this by putting a "T" in parenthesis after the number (T).

RAW WATER STORAGE

NAME OF RAW WATER INTAKE DAMS, IMPOUNDING DAMS, RESERVOIRS OR STORAGE TANKS	LOCATION (Body of water if applicable)	STORAGE CAPACITY (Gallons)
Springton Reservoir	Crum Creek, Delaware County	3,500,000,000
Crum Creek Reservoir	" " " "	92,000,000
Green Lane Reservoir	Perkiomen Creek, Montgomery County	4,400,000,000
Pickering Creek Reservoir	Pickering Creek, Chester County	375,000,000
Ironworks Creek Reservoir	Ironworks Creek, Bucks County	650,000,000
Upper Merion Reservoir	McCoy Quarry, Montgomery County	400,000,000
TOTAL		9,417,000,000

SHEET "B"
GROUNDWATER SOURCES

NAME	Depth	Dia.	1989 Avg. Daily withdrawal (MGD)	Rated Capacity (MGD)
1. Aidenn Lair	502'	10"	0.25	0.36
2. Babb	476'	14"	0.91	1.00
3. Cabot	275'	8"	1.33	3.00
4. Cedar Grove	430'	10"	----	0.29
5. Chateau Drive	280'	8"	0.13	0.19
6. Chester Valley	197'	12"	0.89	1.44
7. Dilworth-town Oaks	400'	6"	0.05	0.06
8. Edgewood Chase	300'	8"	0.07	0.13
9. Enfield	350'	10"	0.13	0.30
10. Fire-thorn	222'	8"	0.09	0.09
11. Flour-town	300'	12"	1.21	1.44
12. Goshen Downs	260'	6"	0.04	0.09
13. Grand Oak	134'	8"	0.23	0.21
14. Great Valley	340'	8"	0.18	0.29
15. Hall Road	460'	12"	1.76	2.00

Sheet "B"
Groundwater Sources
Page 2

NAME	Depth	Dia.	1989 Avg. Daily Withdrawal (MGD)	Rated Capacity (MGD)
16. Highland Glen	360'	6"	0.11	0.14
17. Hunt Country	179'-400'	6"	0.35	0.32
18. Karrs Lane	590'	14"	1.66	2.00
19. Mt. Bradford	149'	8"	0.03	0.06
20. New Kent	340'	8"	0.13	0.20
21. North Hills	300'	12"	0.62	0.70
22. Oakbourne	126'	8"	0.04	0.07
23. Oreland	436'	12"	1.11	1.44
24. Pennwood	423'	8"	0.08	0.09
25. Plymouth #1	600'	8"	0.12	0.20
26. Plymouth #2	463'	10"	0.17	0.50
27. Pocopson	240'	6"	0.02	0.10
28. Pomona Park	190'	8"	0.04	0.06
29. Pottstown Pike	237'	6"	0.23	0.24

Sheet "B"
Groundwater Sources
Page 3

NAME	Depth	Dia.	1989 Avg. Daily Withdrawal (MGD)	Rated Capacity (MGD)
30. Radley Mews	495'	8"	0.12	0.29
31. Radley Run	398'	8"	0.13	0.19
32. Thomas Road	504'	12"	0.22	1.00
33. Tredy-ffrin	316'	12"	0.94	2.00
34. Upper Merion	502'	12"	0.51	1.44
35. Westtown Park	100'	8"	0.01	0.03
			13.91 MGD	21.96 MGD

A. All sources are permanent, metered facilities, and are limited to the rated capacities given.

B. Cedar Grove Well #4 is temporarily out of service due to quality problems.

36. La Reserve - Private development - Public water supply

37. Beversrede - 3 small wells

SHEET "C"

ORIGINAL (Red)

REFERENCE NO. 38

May 9, 1995

Mr. Richard C. Tortoriello, Ph.D., P.E.
Head, Operations Branch
Delaware River Basin Commission
P. O. Box 7360
West Trenton, N.J. 08628-0360

Re: 1994 Annual Surface Water Reports

Dear Mr. Tortoriello:

Attached are the completed Surface Water Use Reports for 1994.

Please call me at (610) 645-1092 if you have any questions about the reports.

Sincerely,

Thomas M. Kiely, P.E.
Chief Engineer

Enc.

PART A

DELAWARE RIVER BASIN COMMISSION
PO BOX 7360
WEST TRENTON, NEW JERSEY 08628-0360
609/883-9500; FAX: 609/883-9522

ANNUAL SURFACE WATER USE REPORT - CALENDAR YEAR 1994

1. NAME & ADDRESS OF USER — Philadelphia Suburban Water Company, 762 Lancaster Avenue, Bryn Mawr, PA 19010

2. SOURCE OF WATER SUPPLY — Crum Creek Intake, Springfield Township, Delaware Co.

3. PUMPING CAPACITY Specify units: million gallons per day (mgd) *or* gallons per minute (g/min.)

a. Intake Capacity 25.5 MGD

b. Pumping Capacity 45 MGD

4. TOTAL SURFACE WATER WITHDRAWALS IN MILLION GALLONS

JANUARY	618.520	JULY	670.261
FEBRUARY	536.820	AUGUST	610.365
MARCH	605.310	SEPTEMBER	594.286
APRIL	582.050	OCTOBER	606.498
MAY	620.690	NOVEMBER	586.898
JUNE	661.631	DECEMBER	606.607
		TOTAL FOR YEAR (MILLION GALLONS)	7,299.916

5. MEASUREMENT BASED ON (CIRCLE ONE)

(a.) Metering b. Hours of Operation c. Estimation

6. ESTIMATED VOLUME OF 1994 CONSUMPTIVE USE ATTRIBUTABLE TO SURFACE WATER WITHDRAWALS (REFER TO #4) 948.989 IN MILLION GALLONS.

State of Pennsylvania

County of Montgomery

Subscribed and sworn to before me

this 9th day of May, 1995

Notary

Thomas M. Kiely
Signature of Certifying Official

Thomas M. Kiely
Print Name

Chief Engineer
Title

(610) 645-1092
Phone

PART A

DELAWARE RIVER BASIN COMMISSION
PO BOX 7360
WEST TRENTON, NEW JERSEY 08628-0360
609/883-9500; FAX: 609/883-9522

ANNUAL SURFACE WATER USE REPORT - CALENDAR YEAR 1994

1. NAME & ADDRESS OF USER — Philadelphia Suburban Water Company
762 Lancaster Avenue
Bryn Mawr, PA 19010

2. SOURCE OF WATER SUPPLY — Neshaminy Creek Intake
Middletown Township, Bucks County

3. PUMPING CAPACITY Specify units: million gallons per day (mgd) *or* gallons per minute (g/min.)

a. Intake Capacity 13 MGD

b. Pumping Capacity 25 MGD

4. TOTAL SURFACE WATER WITHDRAWALS IN MILLION GALLONS

JANUARY	307.780	JULY	296.010
FEBRUARY	276.309	AUGUST	263.529
MARCH	296.010	SEPTEMBER	255.688
APRIL	279.400	OCTOBER	259.978
MAY	311.520	NOVEMBER	249.190
JUNE	334.280	DECEMBER	268.297
		TOTAL FOR YEAR (MILLION GALLONS)	3,397.991

5. MEASUREMENT BASED ON (CIRCLE ONE)

(a.) Metering b. Hours of Operation c. Estimation

6. ESTIMATED VOLUME OF 1994 CONSUMPTIVE USE ATTRIBUTABLE TO SURFACE WATER WITHDRAWALS (REFER TO #4) 441.739 IN MILLION GALLONS.

State of Pennsylvania

Thomas M. Kiely
Signature of Certifying Official

County of Montgomery

Thomas M. Kiely
Print Name

Subscribed and sworn to before me

this 9th day of May, 19 95

Chief Engineer
Title

Notary

(610) 645-1092
Phone

PART A

DELAWARE RIVER BASIN COMMISSION
PO BOX 7360
WEST TRENTON, NEW JERSEY 08628-0360
609/883-9500; FAX: 609/883-9522

ANNUAL SURFACE WATER USE REPORT - CALENDAR YEAR 1994

1. NAME & ADDRESS OF USER — Philadelphia Suburban Water Company
762 Lancaster Avenue
Bryn Mawr, PA 19010

2. SOURCE OF WATER SUPPLY — Perkiomen Creek Intake
Lower Providence Township, Montgomery Co.

3. PUMPING CAPACITY Specify units: million gallons per day (mgd) *or* gallons per minute (g/min.)

a. Intake Capacity 26 MGD

b. Pumping Capacity 39 MGD

4. TOTAL SURFACE WATER WITHDRAWALS IN MILLION GALLONS

JANUARY	543.870	JULY	406.929
FEBRUARY	584.592	AUGUST	630.086
MARCH	626.523	SEPTEMBER	594.999
APRIL	617.308	OCTOBER	624.097
MAY	610.111	NOVEMBER	562.124
JUNE	653.302	DECEMBER	550.742
		TOTAL FOR YEAR (MILLION GALLONS)	7,004.683

5. MEASUREMENT BASED ON (CIRCLE ONE)

(a) Metering b. Hours of Operation c. Estimation

6. ESTIMATED VOLUME OF 1994 CONSUMPTIVE USE ATTRIBUTABLE TO SURFACE WATER WITHDRAWALS (REFER TO #4) 910.609 IN MILLION GALLONS.

State of Pennsylvania

Thomas M. Kiely
Signature of Certifying Official

County of Montgomery

Thomas M. Kiely
Print Name

Subscribed and sworn to before me

this 9th day of May, 19 95

Chief Engineer
Title

Notary

(610) 645-1092
Phone

PART A

DELAWARE RIVER BASIN COMMISSION
PO BOX 7360
WEST TRENTON, NEW JERSEY 08628-0360
609/883-9500; FAX: 609/883-9522

ANNUAL SURFACE WATER USE REPORT - CALENDAR YEAR 1994

1. NAME & ADDRESS OF USER — Philadelphia Suburban Water Company, 762 Lancaster Avenue, Bryn Mawr, PA 19010

2. SOURCE OF WATER SUPPLY — Schuylkill River Intake, Schuylkill Township, Chester County

3. PUMPING CAPACITY Specify units: million gallons per day (mgd) *or* gallons per minute (g/min.)

a. Intake Capacity: 30 MGD

b. Pumping Capacity: 30 MGD

4. *TOTAL SURFACE WATER WITHDRAWALS IN MILLION GALLONS*

JANUARY	427.203	JULY	469.424
FEBRUARY	345.692	AUGUST	488.307
MARCH	460.007	SEPTEMBER	459.896
APRIL	420.462	OCTOBER	380.732
MAY	495.725	NOVEMBER	356.977
JUNE	483.903	DECEMBER	434.537
		TOTAL FOR YEAR (MILLION GALLONS)	5,222.865

5. MEASUREMENT BASED ON (CIRCLE ONE)

(a.) Metering b. Hours of Operation c. Estimation

6. *ESTIMATED VOLUME OF 1994 CONSUMPTIVE USE ATTRIBUTABLE TO SURFACE WATER WITHDRAWALS (REFER TO #4)* 678.972 IN MILLION GALLONS.

State of Pennsylvania

County of Montgomery

Subscribed and sworn to before me

this 9th day of May, 19 95

Notary

Thomas M. Kiely
Signature of Certifying Official

Thomas M. Kiely
Print Name

Chief Engineer
Title

(610) 645-1092
Phone

PART A

DELAWARE RIVER BASIN COMMISSION
PO BOX 7360
WEST TRENTON, NEW JERSEY 08628-0360
609/883-9500; FAX: 609/883-9522

ANNUAL SURFACE WATER USE REPORT - CALENDAR YEAR 1994

1. NAME & ADDRESS OF USER — Philadelphia Suburban Water Company
762 Lancaster Avenue
Bryn Mawr, PA 19010

2. SOURCE OF WATER SUPPLY — Pickering Creek Intake
Schuylkill Township, Chester County

3. PUMPING CAPACITY Specify units: million gallons per day (mgd) *or* gallons per minute (g/min.)

a. Intake Capacity 15 MGD

b. Pumping Capacity 58 MGD

4. TOTAL SURFACE WATER WITHDRAWALS IN MILLION GALLONS

JANUARY	234.100	JULY	124.100
FEBRUARY	174.100	AUGUST	85.200
MARCH	73.500	SEPTEMBER	102.300
APRIL	116.800	OCTOBER	111.200
MAY	111.600	NOVEMBER	109.600
JUNE	95.400	DECEMBER	95.500
		TOTAL FOR YEAR (MILLION GALLONS)	1,433.400

5. MEASUREMENT BASED ON (CIRCLE ONE)

a.) Metering b. Hours of Operation c. Estimation

6. *ESTIMATED VOLUME OF 1994 CONSUMPTIVE USE ATTRIBUTABLE TO SURFACE WATER WITHDRAWALS (REFER TO #4)* 186.342 IN MILLION GALLONS.

State of Pennsylvania

Thomas M. Kiely
Signature of Certifying Official

County of Montgomery

Thomas M. Kiely
Print Name

Subscribed and sworn to before me

this 9th day of May, 19 95

Chief Engineer
Title

Notary

(610) 645-1092
Phone

PART A

DELAWARE RIVER BASIN COMMISSION
PO BOX 7360
WEST TRENTON, NEW JERSEY 08628-0360
609/883-9500; FAX: 609/883-9522

ANNUAL SURFACE WATER USE REPORT - CALENDAR YEAR 1994

1. NAME & ADDRESS OF USER — Philadelphia Suburban Water Company
762 Lancaster Avenue
Bryn Mawr, PA 19010

2. SOURCE OF WATER SUPPLY — Pennypack Creek Intake
Lower Moreland Township, Montgomery Co.

3. PUMPING CAPACITY Specify units: million gallons per day (mgd) *or* gallons per minute (g/min.)

a. Intake Capacity — 5 MGD

b. Pumping Capacity — 0 MGD

4. TOTAL SURFACE WATER WITHDRAWALS IN MILLION GALLONS

JANUARY	-0-	JULY	-0-
FEBRUARY	-0-	AUGUST	-0-
MARCH	-0-	SEPTEMBER	-0-
APRIL	-0-	OCTOBER	-0-
MAY	-0-	NOVEMBER	-0-
JUNE	-0-	DECEMBER	-0-
		TOTAL FOR YEAR (MILLION GALLONS)	-0-

5. MEASUREMENT BASED ON (CIRCLE ONE)

(a.) Metering b. Hours of Operation c. Estimation

6. ESTIMATED VOLUME OF 1994 CONSUMPTIVE USE ATTRIBUTABLE TO SURFACE WATER WITHDRAWALS (REFER TO #4) -0- IN MILLION GALLONS.

State of Pennsylvania

Thomas M. Kiely
Signature of Certifying Official

County of Montgomery

Thomas M. Kiely
Print Name

Subscribed and sworn to before me

this 9th day of May, 19 95

Chief Engineer
Title

Notary

(610) 645-1092
Phone

7

PART B
TO BE COMPLETED BY WATER PURVEYORS ONLY

7. TOTAL 1994 WATER WITHDRAWALS IN MILION GALLONS FROM ALL SOURCES

MONTH	SURFACE WATER	WELLS	PURCHASED WATER	UPPER MERION	TOTAL
JANUARY	2,131.473	409.615	222.298	183.648	2,947.034
FEBRUARY	1,917.513	372.454	191.960	171.612	2,653.539
MARCH	2,061.350	412.654	203.879	162.772	2,840.655
APRIL	2,016.020	424.075	187.178	161.101	2,788.374
MAY	2,149.646	453.335	204.326	167.762	2,975.069
JUNE	2,228.516	461.715	210.470	250.816	3,151.517
JULY	1,966.724	471.741	215.695	246.135	2,900.295
AUGUST	2,077.467	424.258	196.486	160.855	2,859.066
SEPTEMBER	2,007.169	407.789	184.267	200.866	2,800.091
OCTOBER	1,982.505	417.912	194.968	151.200	2,746.585
NOVEMBER	1,864.789	383.162	172.755	181.362	2,602.068
DECEMBER	1,955.683	398.203	172.465	157.523	2,683.874
TOTAL(S)	24,358.855	5,036.913	2,356.747	2,195.652	33,948.167

NUMBER OF WELLS 41

LOCAL WELL NAME(S) See Attachments

NUMBER OF PURCHASED-WELL INTERCONNECTIONS 5

8. DATA ON DISTRIBUTION

a. POPULATION SERVED 830,000 (est.) (#)

b. NUMBER OF SERVICE CONNECTIONS 249,535 (#)

c. PERCENTAGE OF CONNECTIONS METERED 100 (%)

i. Residential	50.58%
ii. Industrial	6.36%
iii. Commercial	23.81%
iv. Public, Fire, Other Utilities	1.90%
v. Unaccounted-for water and line loss	17.35%
TOTAL (Should equal 100%)	100.00%

ORIGINAL SYSTEM WELL SENDOUT - 1994

WELL NAME	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	TOTAL GALLONS
AIDEN LAIR	6,662,518	4,985,217	7,325,948	7,649,471	6,833,628	5,627,331	4,127,613	5,054,053	4,850,622	4,369,144	3,682,949	3,992,381	65,160,775
BABB	28,065,790	27,132,760	30,208,688	28,895,735	29,584,993	29,408,905	30,653,325	31,400,175	30,146,395	30,690,535	25,927,450	30,825,088	352,939,839
CABOT	47,391,450	44,417,095	49,549,895	48,568,570	49,381,790	46,600,985	50,363,980	49,128,005	46,826,595	47,297,695	45,539,865	47,485,750	572,551,675
CHESTER VAL.	30,213,215	26,393,025	30,012,223	29,572,733	30,425,275	28,587,748	29,816,490	29,646,903	28,443,540	28,384,980	27,441,090	25,533,858	344,471,080
ENFIELD	0	0	0	531,773	5,970,508	5,628,011	5,484,993	5,254,196	5,165,754	588,092	0	0	28,623,327
FLOURTOWN	35,423,495	34,296,808	39,801,520	36,871,295	39,538,933	38,247,973	39,371,468	36,832,733	36,364,825	37,490,505	37,688,340	38,923,005	450,850,900
GREAT VALLEY	0	0	0	0	0	0	0	0	0	0	0	0	0
HALL ROAD	48,228,315	43,557,370	48,890,155	47,145,450	48,137,350	46,230,475	47,981,110	47,765,290	33,155,825	47,402,805	45,295,510	45,991,210	549,780,865
KARRS LANE	0	0	0	0	0	23,236,575	22,164,848	0	0	0	0	0	45,401,423
NORTH HILLS	18,315,700	18,042,846	21,343,975	21,023,715	20,691,796	17,080,160	19,058,880	21,956,310	23,291,605	20,876,646	19,078,246	20,344,910	241,104,789
ORELAND	29,305,475	27,404,846	12,841,764	30,043,100	35,015,820	33,000,013	31,093,725	18,091,214	22,792,033	25,061,608	20,311,553	28,986,320	313,947,471
PLYMOUTH 1	4,152,055	3,877,749	4,574,757	4,395,419	4,261,599	3,640,574	3,276,206	3,211,979	3,112,919	2,899,471	2,542,548	2,769,465	42,714,741
PLYMOUTH 2	0	0	0	280,710	3,505,393	3,120,000	3,590,000	399,723	0	0	0	0	10,895,826
THOMAS ROAD	0	0	0	0	0	0	0	0	0	0	0	0	0
TREDYFFRIN	26,481,413	23,416,555	29,001,933	30,529,505	31,489,940	27,221,403	24,912,205	26,818,985	28,172,238	31,380,930	29,044,245	28,229,908	336,699,260
UPPER MERION	13,625,535	13,005,973	13,815,474	13,392,108	13,837,643	15,636,045	16,574,039	15,921,444	15,819,335	15,403,428	14,202,244	12,460,616	173,693,884
MALVERN	5,925,135	6,321,209	8,181,096	6,688,757	5,225,678	5,355,000	6,100,000	5,850,358	8,126,731	6,983,954	4,363,946	0	69,121,864
TOTALS:	293,790,096	272,851,453	295,547,428	305,588,341	323,900,246	328,621,198	334,568,882	297,331,368	286,268,417	298,829,793	275,117,986	285,542,511	3,597,957,719

Note: Total figures may not agree with th daily pumping report due to hexidecimal round-off.

GREAT VALLEY SYSTEM WELL SENDOUT - 1994

WELL NAME	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	TOTAL GALLONS
BEVERSREDE	862,164	681,583	813,620	855,492	857,035	797,021	1,010,431	1,008,580	1,007,005	893,530	753,000	914,133	10,453,594
CHATEAU DRIVE	3,983,629	3,847,251	4,330,691	3,862,175	4,201,679	3,860,230	4,037,322	3,936,033	3,828,159	3,789,376	3,545,889	3,293,507	46,515,941
EDGEWOOD	0	0	0	0	0	0	0	0	0	0	0	0	0
FIRETHORN	0	0	1,301,963	2,391,344	2,640,798	2,307,397	2,401,613	2,516,450	2,005,447	194,284	0	0	15,759,296
GOSHEN DOWNS	0	0	0	0	0	328,291	624,596	47,032	0	0	0	0	999,919
GRAND OAK	6,203,637	5,612,429	6,213,560	6,016,309	7,660,205	7,422,924	7,554,515	7,213,649	6,612,351	6,165,830	5,899,568	5,599,373	78,174,350
HIGHLAND GLEN	3,042,019	2,466,749	3,648,167	3,526,167	3,461,302	3,101,194	2,810,567	3,225,903	3,900,127	3,560,913	2,957,657	2,851,107	38,551,872
HOLLOW RUN	4,746,846	3,571,047	3,010,492	3,511,840	4,465,843	4,917,426	5,390,440	5,287,572	4,838,916	4,861,224	2,898,097	4,339,851	51,839,594
HUNT COUNTRY	9,865,642	9,224,629	10,357,302	10,084,876	10,167,645	10,000,806	10,286,652	10,268,859	9,521,353	9,901,246	9,452,619	9,689,401	118,821,030
MT. BRADFORD	0	0	0	0	0	0	0	0	0	0	0	0	0
NEW KENT	0	0	967,427	1,967,419	2,015,730	1,983,135	2,062,767	2,033,893	1,680,752	1,926,812	1,942,640	1,919,410	18,499,985
OAKBOURNE	2,078,505	1,967,641	2,164,841	2,163,461	2,204,723	2,175,975	2,059,313	1,989,157	1,828,302	1,925,867	1,886,556	1,989,938	24,434,279
PENNWOOD	0	0	0	0	0	0	58,482	47,422	53,898	16,238	0	0	176,040
POCOPSON	598,365	506,150	569,805	173,651	745,899	709,172	622,004	450,710	582,551	573,456	567,574	610,040	6,709,377
POMONA PARK	1,141,829	1,021,211	1,088,781	1,080,305	1,070,688	1,034,927	1,158,462	1,163,514	1,086,745	1,063,574	1,063,345	1,098,414	13,071,795
RADLEY MEWS	4,560,007	4,250,083	4,685,406	4,436,068	4,695,649	4,337,348	4,660,228	4,576,296	4,404,283	4,343,113	4,157,830	4,250,329	53,356,620
RADLEY RUN	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTALS:	37,082,643	33,148,773	39,152,055	40,069,107	44,187,196	42,975,846	44,737,392	43,765,070	41,349,869	39,215,463	35,124,775	36,555,503	477,363,692

Note: Total figures may not agree with th daily pumping report due to hexidecimal round-off.

W. WHITELAND & UWCHLAN SYSTEM WELL SENDOUT - 1994

WELL NAME	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	TOTAL GALLONS
HILLSIDE 1	2,567,423	2,178,476	1,895,435	2,008,437	1,743,572	2,170,498	2,397,600	3,040,937	3,831,990	2,459,700	3,612,223	3,718,187	31,625,478
HILLSIDE 2	13,656,458	12,358,644	14,384,296	13,577,421	14,170,328	13,139,215	13,294,653	13,116,966	12,170,948	13,944,571	11,401,653	11,894,003	157,109,156
BELL TAVERN 1	264,700	7,280	4,828	28,892	366,426	1,343,261	2,567,148	4,053,352	161,934	891,763	3,825	3,160	9,696,569
BELL TAVERN 2	4,346,575	5,140,125	5,798,766	4,013,962	7,504,825	9,022,748	11,211,803	10,681,569	4,334,762	5,911,871	4,677,868	5,249,306	77,894,180
MLFORD	4,081,463	3,882,138	3,315,972	3,676,835	4,146,373	3,715,848	3,047,712	3,209,201	4,402,540	4,668,905	4,532,681	4,665,277	47,344,945
R. DEAN 1	12,255,236	11,319,528	12,831,498	12,587,315	12,800,801	12,063,941	12,061,415	12,188,928	11,844,081	12,023,991	11,763,563	12,342,889	146,083,186
R. DEAN 2	0	0	0	0	0	5,250,542	8,669,616	4,943,680	6,006,023	5,655,918	0	0	30,525,779
SAYBROOK 1	7,615,820	7,204,354	9,053,184	8,893,048	8,803,807	9,120,575	9,246,193	6,718,306	5,702,825	5,007,968	2,952,752	3,524,976	83,843,808
SAYBROOK 2	3,133,674	1,599,067	3,032,935	2,806,702	2,906,842	2,890,843	3,045,280	2,446,504	2,518,392	2,585,076	2,503,937	2,582,838	32,052,090
SHOEN RD. 1	19,158,306	16,310,163	15,839,343	18,775,703	19,838,910	18,959,018	16,220,241	13,757,550	17,738,444	16,465,244	19,966,148	20,761,996	213,791,066
SHOEN RD. 2	10,638,078	5,574,494	10,846,564	11,032,639	11,831,553	11,064,313	9,440,909	7,933,950	10,366,647	9,212,346	10,512,655	10,355,853	118,810,001
STONEHEDGE	1,024,368	879,400	952,143	1,016,533	1,134,675	1,377,174	1,231,734	1,070,677	1,092,158	1,039,798	991,909	1,005,220	12,816,789
TOTALS:	78,742,101	66,453,669	77,954,964	78,417,487	85,248,112	90,117,976	92,434,304	83,161,620	80,170,744	79,867,151	72,919,214	76,104,705	961,592,047
GRANDSTAFF	0	0	0	0	0	0	0	0	0	0	0	138,000	138,000

Note: Grandstaff Water Co. purchased Dec. 22, 1994. Total sendout does not include Grandstaff sendout figures.

ORIGINAL (Red)

REFERENCE NO. 39

COMMUNITY FACILITIES INVENTORY

CHESTER COUNTY, PENNSYLVANIA

VOLUME 2
WATER FACILITIES

VOLUME 1
SEWER FACILITIES

VOLUME 2
WATER FACILITIES

VOLUME 3
RECREATION & OPEN SPACE

VOLUME 4
UTILITIES

VOLUME 5
EDUCATIONAL FACILITIES

VOLUME 6
TRANSPORTATION FACILITIES

VOLUME 7
GOVERNMENT & EMERGENCY SERVICES

VOLUME 8
HUMAN SERVICE FACILITIES

Prepared by the CHESTER COUNTY PLANNING COMMISSION

COMMUNITY FACILITIES INVENTORY

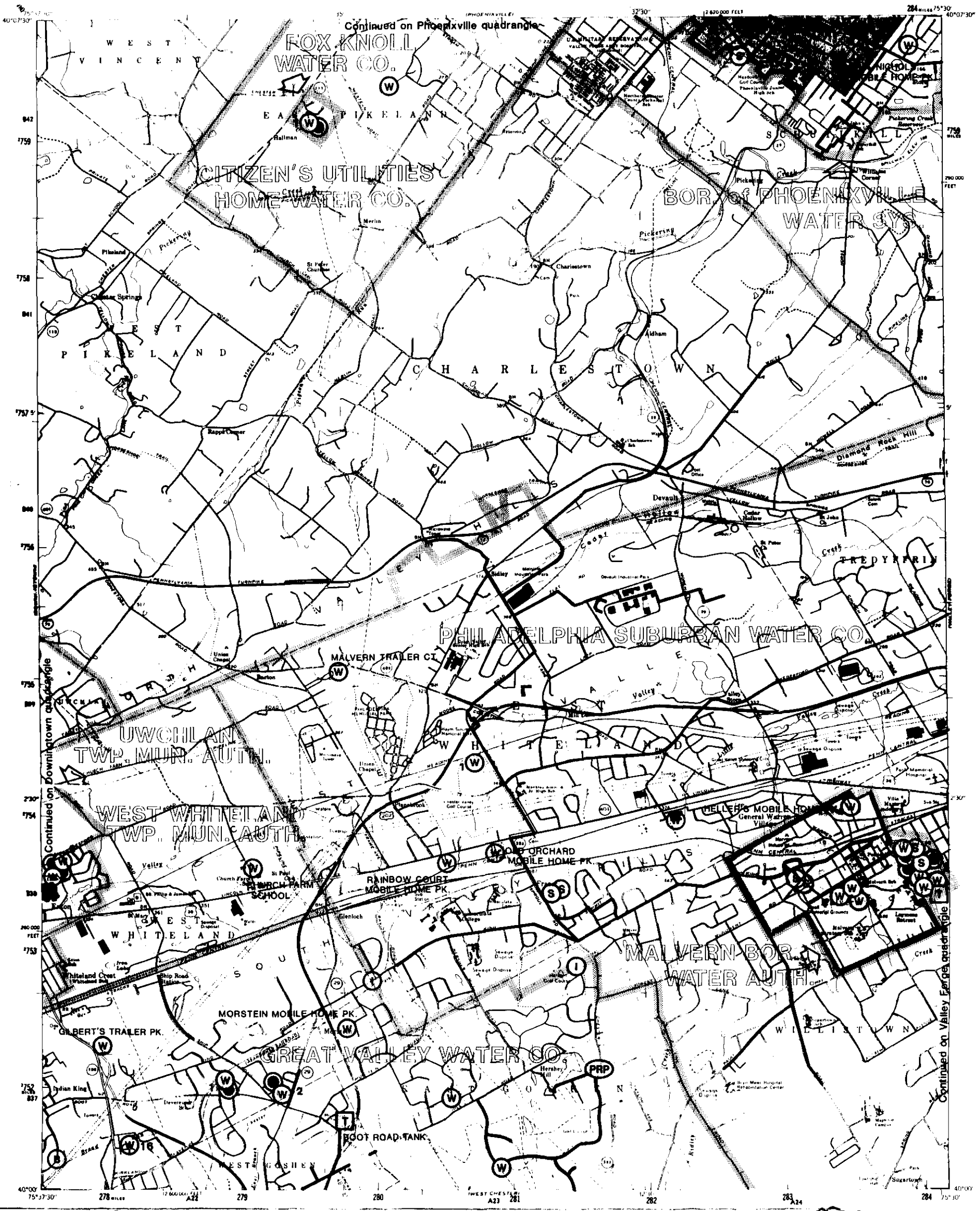
CHESTER COUNTY, PENNSYLVANIA

VOLUME 2
WATER FACILITIES

BOARD OF COUNTY COMMISSIONERS
COUNTY OF CHESTER, PENNSYLVANIA

ROBERT J. THOMPSON, Chairman
EARL M. BAKER
PATRICIA M. BALDWIN

Prepared by the
Chester County Planning Commission
December, 1985



SERVICE AREA / FRANCHISE BOUNDARY

WATER LINE (10" or more)

WATER LINE (8" or less)

BOROUGH COMPLETELY SERVED BY PUBLIC WATER
No lines smaller than 10" shown

PUMPING STATION
with franchise ID number

SURFACE RESERVOIR

WATER TREATMENT PLANT

INGRAM'S MILL

BOOSTER PUMP

SYSTEM INTERCONNECT

PRESSURE-REDUCING PUMP

CLOSED-TANK RESERVOIR
with franchise ID number

STANDPIPE

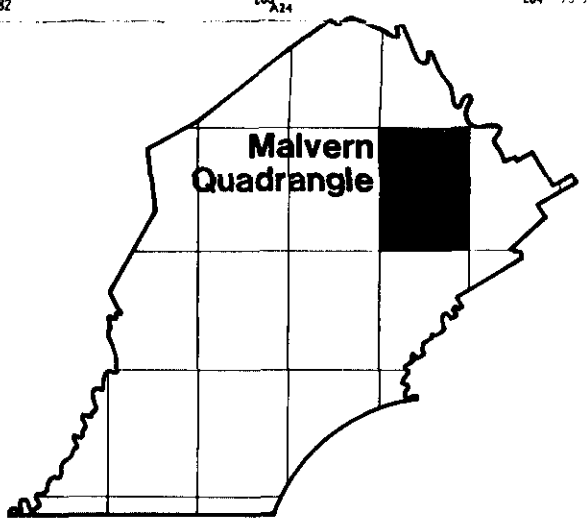
STORAGE TANK
with franchise ID number

WELL
with franchise ID number

WELL SERVING INDEPENDENT FACILITY
No franchise or municipal authority

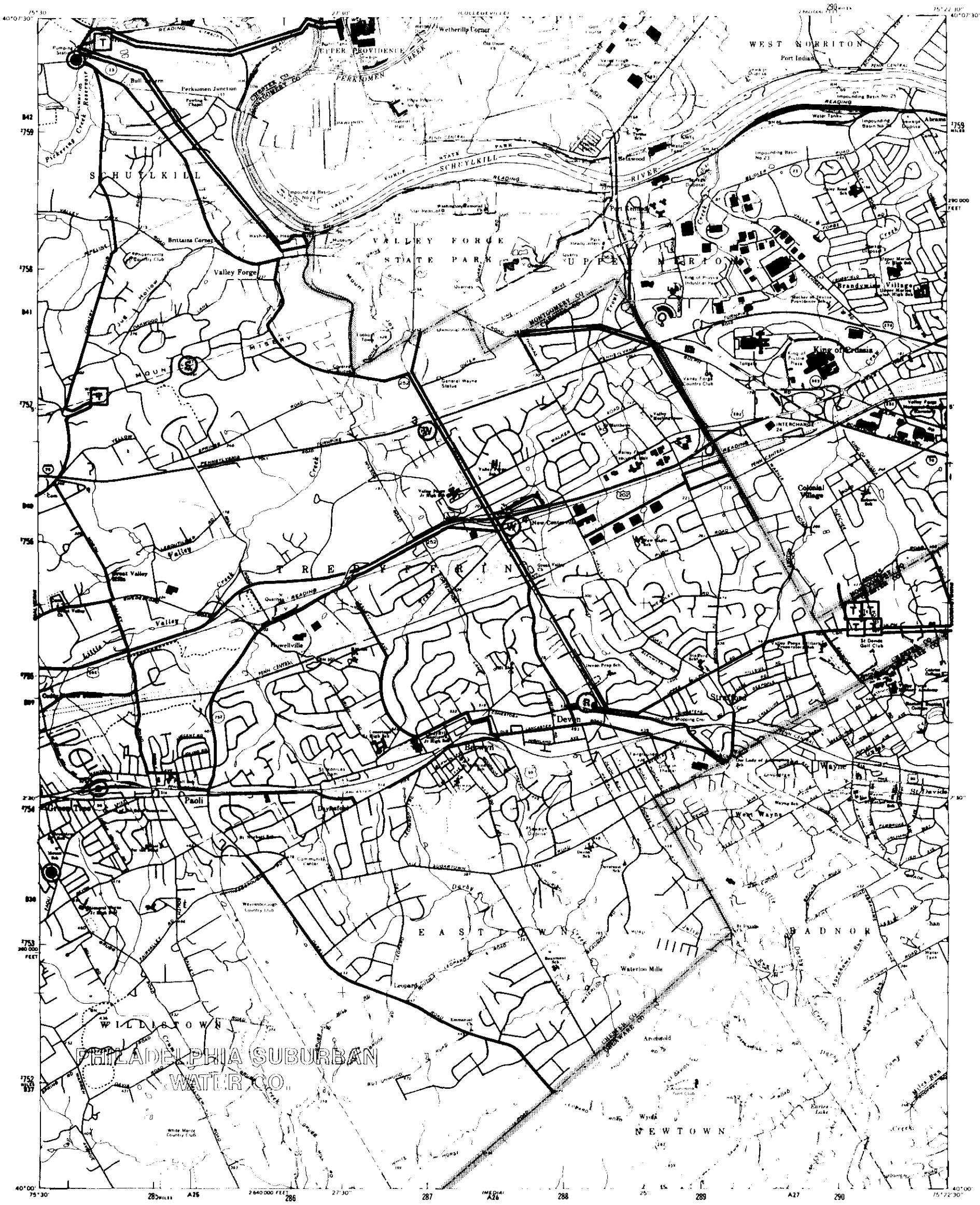
NEW KENT APTS.

2000 0 2000 4000 6000 FEET



CHESTER COUNTY WATER SYSTEMS INVENTORY 1984

MAP PREPARED BY THE CHESTER COUNTY PLANNING COMMISSION, 1984 DECEMBER.



SERVICE AREA / FRANCHISE BOUNDARY

WATER LINE (10" or more)

WATER LINE (8" or less)

BOROUGH COMPLETELY SERVED BY PUBLIC WATER
No lines smaller than 10" shown

PUMPING STATION
with franchise ID number

SURFACE RESERVOIR

INGRAM'S MILL — WATER TREATMENT PLANT

B — BOOSTER PUMP

I — SYSTEM INTERCONNECT

PRP — PRESSURE-REDUCING PUMP

R — CLOSED-TANK RESERVOIR
with franchise ID number

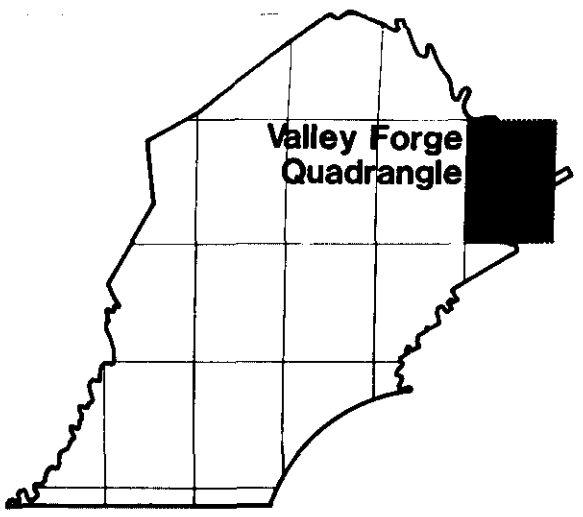
S — STANDPIPE

T — STORAGE TANK
with franchise ID number

W — WELL
with franchise ID number

NEW KENT APTS. — WELL SERVING INDEPENDENT FACILITY
No franchise or municipal authority

2000 0 2000 4000 6000 FEET



CHESTER COUNTY WATER SYSTEMS INVENTORY 1984

MAP PREPARED BY THE CHESTER COUNTY PLANNING COMMISSION, 1984

REFERENCE NO. 40

SELECTED GROUND-WATER DATA, CHESTER COUNTY, PENNSYLVANIA

by Ronald A. Sloto

U.S. GEOLOGICAL SURVEY

Open-File Report 87-217

Prepared in cooperation with the

CHESTER COUNTY WATER RESOURCES AUTHORITY

Harrisburg, Pennsylvania

1989

Table 1.--Aquifer codes

Era, system or series[1]	Code	Geologic unit
Upper Triassic	231DIBS	Diabase
	231BRCK	Brunswick Formation
	231HMCK	Hammer Creek Formation Conglomerate
	231LCKG	Lockatong Formation
	231SCKN	Stockton Formation
Middle Ordovician	300PRCK	Peters Creek Schist
Lower Ordovician to Lower Cambrian	367CNSG	Conestoga Formation
Middle Cambrian	371ELBK	Elbrook Formation
	377LDGR	Ledger Formation
Middle to Lower Cambrian	377KZRS	Kinzers Formation
Lower Cambrian	377VNTG	Vintage Formation
	377ANTM	Antietam Formation
Upper Precambrian	377HRPR	Harpers Formation
	377CCKS	Chickies Formation
	377HLLM	Chickies Formation, Hellam Conglomerate Member
	300STRS	Setters Formation

Table 1.--Aquifer codes--Continued

Era, system or series[1]	Code	Geologic unit
Lower Paleozoic	300WSCKA	Wissahickon Formation, albite chlorite schist
	300WSCKO	Wissahickon Formation, oligoclase mica schist
	300CCKV	Cockeysville Marble
Precambrian	400FLCGH	Felsic gneiss, hornblende-bearing
	400FLCGP	Felsic gneiss, pyroxene-bearing
	400MFCGH	Mafic gneiss, hornblende-bearing
	400MFCGP	Mafic gneiss, pyroxene-bearing
	400FRKL	Franklin Marble
	400GRGS	Granitic gneiss
Unknown age	000ANRS	Anorthosite
	000GBBR	Gabbro and gabbroic gneiss
	000GRDR	Granodiorite and granodiorite gneiss
	000GRGS	Granite gneiss
	000GRPC	Graphitic gneiss
	000MDBS	Metadiabase
	000MFCGH	Mafic gneiss, hornblende-bearing
	000MGBR	Metagabbro
	000QZMZ	Quartz monzonite and quartz monzonite gneiss
	000SRPN	Serpentinite

1/ From Berg and others (1983)

Table 2.--Records of wells

Site-ID: Well location. First six numbers are latitude in degrees, minutes, and seconds. Next seven numbers are longitude in degrees, minutes, and seconds. Last two numbers are sequence number.

Use of site: O, observation well; T, test well; U, unused; W, withdrawal; Z, destroyed.

Use of water: A, air conditioning; C, commercial; H, domestic; I, irrigation; J, industrial cooling; N, industrial; P, public supply; R, recreational; S, livestock; T, institutional; U, unused; Z, other.

Aquifer codes are given in table 1.

Altitude of land surface is estimated from topographic maps. Datum is National Geodetic Vertical Datum of 1929.

Water level is in feet below land surface. FLOWING, well flows but head is unknown; A, airline; M measured; P, pumping water level; R, reported.

Table 2.-- Records of wells -- Continued

Local number	Site identification number	Owner	Driller	Date drilled	Use of site	Use of water	Aquifer code
CH-- 141	401133C75334301	PENNHURST STATE SCHOOL	CONNOR & MAGEE	1913	I	U	231BRCK
142	401130C75333001	PENNHURST STATE SCHOOL	RIDPATH AND POTTER COMPANY	1928	U	U	231BRCK
143	401122C75333901	PENNHURST STATE SCHOOL	CONNOR & MAGEE	1914	I	U	231BRCK
144	401125C75340901	PENNHURST STATE SCHOOL	CONNOR & MAGEE	1914	W	T	231BRCK
145	401117C75340101	PENNHURST STATE SCHOOL	CONNOR & MAGEE	1914	U	U	231BRCK
146	401119C75341001	PENNHURST STATE SCHOOL	--	--	I	U	231BRCK
147	401122C75339101	PENNHURST STATE SCHOOL	P. L. BOLLINGER & SONS	--	W	T	231BRCK
148	401C54C75324801	SPRING CTY BLEACH & DYE	--	1905	I	U	231BRCK
149	401051C75324701	SPRING CTY BLEACH & DYE	KERMIT S. SNYDER	1969	I	U	231BRCK
150	401052C75325001	SPRING CTY BLEACH & DYE	KERMIT S. SNYDER	1954	I	U	231BRCK
151	400806C75310501	PHOENIX IRON & STEEL	KOHL BROS., INC.	1952	U	U	231SCKN
152	400805C75304801	PHOENIX IRON & STEEL	KOHL BROS., INC.	1952	O	U	231SCKN
153	400811C75304301	PHOENIX IRON & STEEL	KOHL BROS., INC.	1953	U	U	231SCKN
154	400750C75312901	PHOENIX IRON & STEEL	KOHL BROS., INC.	1953	U	U	231SCKN
155	400733075320401	THE WEST COMPANY	KOHL BROS., INC.	1946	W	N	231SCKN
156	400734C75320601	THE WEST COMPANY	KOHL BROS., INC.	1954	W	N	231SCKN
157	400749C75312701	WEILAND PACKING CO.	KOHL BROS., INC.	1938	U	U	231SCKN
158	400750C75313001	WEILAND PACKING CO.	KOHL BROS., INC.	1930	U	U	231SCKN
159	400748075311401	BRYNE, T F	--	1900	U	U	231SCKN
160	400748C75311601	BYRNE, T F	--	1900	U	U	231SCKN
161	400747C75302301	BOILER ENG SUPPLY CO	--	1910	U	U	231SCKN
162	400747075301501	BOILER ENG SUPPLY CO	--	1910	U	U	231SCKN
163	400749075301901	BOILER ENG SUPPLY CO	--	--	U	U	231SCKN
164	400827C75311501	BUDD CO	--	1906	W	N	231LCKG
165	400755C75314301	A P DESANNO & SON	--	1943	W	N	231SCKN
166	400755075313801	A P DESANNO & SON	--	--	W	N	231SCKN
167	395634075434401	EMBREEVILLE STATE HOSPITAL	--	--	U	U	300PRCK
168	395636C75434301	EMBREEVILLE STATE HOSPITAL	--	--	U	U	300PRCK
169	395650C75433501	EMBREEVILLE STATE HOSPITAL	--	--	U	U	300PRCK
170	395641C75435401	EMBREEVILLE STATE HOSPITAL	--	--	U	U	300PRCK
171	395608C75433401	EMBREEVILLE CENTER	P. L. BOLLINGER & SONS	1956	W	T	3COWSCKO
172	395603075434301	EMBREEVILLE STATE HOSPITAL	P. L. BOLLINGER & SONS	1956	W	T	300WSCKO
173	400413C75463301	SPRINGTON MANOR	--	--	W	N	400ANRS
174	400753C75310301	HUNGARIAN-AMERICAN CLUB	KOHL BROS., INC.	1951	W	A	231SCKN
175	400802075310401	VARIETY THEATRE	KOHL BROS., INC.	--	W	A	231SCKN
176	400804075311701	PHOENIX IRON & STEEL	KOHL BROS., INC.	1956	W	N	231SCKN
177	400807C75304301	PHOENIX IRON & STEEL	KOHL BROS., INC.	1952	W	N	231SCKN
178	400907C75333901	FLATCO, N	KOHL BROS., INC.	1957	W	N	231SCKN
179	395411C75393201	POCOPSON HOME	LEROY MYERS	1947	W	T	300WSCKO
180	395414C75393401	POCOPSON HOME	LEROY MYERS	1947	W	T	3COWSCKO
181	401129C75340901	PENNHURST STATE SCHOOL	P. L. BOLLINGER & SONS	1953	W	T	231BRCK
182	400555075331401	SOULEN, HENRY	--	1943	W	N	OCOGRDR
183	400247C75305001	WACK, RALPH	--	--	I	U	367CNSG
184	400527C75265501	VALLEY FORGE NATIONAL PARK	THOMAS B. HARPER	1906	I	U	377LDGR
185	400430C75412701	CONTINENTAL GRAPHITE	THOMAS B. HARPER	1907	U	U	000GRPC
186	400430C75413302	CONTINENTAL GRAPHITE	THOMAS B. HARPER	1907	U	U	000GRPC
187	400540C75370501	SMITH, D.L.	THOMAS B. HARPER	1909	W	N	0C0GRPC
188	400543C75371001	MCLEAN , J	ARTESIAN WELL DRLG. CO.	1916	W	N	000GRPC
189	400402075242701	LIVINGSTON	--	--	W	N	300WSCKA
190	400200075302201	GIVEN, S	--	--	W	N	300WSCKA
191	400159C75302201	GILL , I	--	--	W	N	3COWSCKA
192	400201C75305501	TOWNSLEY, W	CONNOR & MAGEE	1925	W	N	30CWSCKA
193	400202C75305501	MIGHLY , C	CONNOR & MAGEE	1912	W	N	30CWSCKA
194	400906C75491701	KURTZ, H	--	--	W	N	0000ZMZ
195	400923C75494601	OELPINGER CREAMERY	--	--	W	N	377CCKS
196	400925C75495401	IOOK, H	--	--	W	N	377CCKS
197	400542C75371501	BNERY , J	CONNOR & MAGEE	1912	W	N	000GRPC
198	400441075404701	HARRISON DAIRY	--	--	W	N	000GRPC
199	400445C75404701	IMPERIAL GRAPHITE CO	--	--	U	U	000GRPC
200	400746075312801	WEILAND PACKING CO	KOHL BROS., INC.	1948	U	U	231SCKN
201	400218075334901	KEYES, THOMAS	--	1958	W	C	367CNSG
202	400404C75284501	BRAKEN, JOHN	--	1929	W	N	371ELBK
203	400405C75285601	RINGE, THOMAS	THOMAS G. KEYES	1964	I	U	371ELBK
204	400404C75290001	WADE, GEORGE	THOMAS G. KEYES	1963	W	N	371ELBK
205	400804C75393401	JOHNSON, G	KOHL BROS., INC.	1957	W	N	0C00ZMZ
206	400555075413901	TEXAS EASTERN TRANSMISSION CORP.	--	1943	W	P	000GRPC
207	400247075335001	PHILADELPHIA SUBURBAN WATER CO	THOMAS G. KEYES	1955	W	P	377LDGR
208	400452C75255601	PHILADELPHIA SUBURBAN WATER CO	THOMAS G. KEYES	1964	I	U	371ELBK
209	400453075264501	PHILADELPHIA SUBURBAN WATER CO	--	1963	W	P	371ELBK
210	400453C75255601	PHILADELPHIA SUBURBAN WATER CO	THOMAS G. KEYES	1963	O	U	371ELBK

CHESTER VALLEY WELL

Depth of well (feet)	Depth cased (feet)	Casing diameter (inches)	Elevation of land surface (feet)	Water level (feet)	Date water level measured	Discharge (gallons per minute)	Specific capacity (gpm/ft)	Specific conductance (micro-siemens)	pH	Local number
327	--	8	250	52.0	1948	90	.50	--	--	CH- 141
529	172	8	240	190	1954	60	1.5	--	--	142
443	--	8	320	171	10-09-1948	40	--	--	--	143
421	10	8	320	115	01-23-1956	135	18.0	--	--	144
404	--	8	330	175	10- -1946	144	4.88	--	--	145
400	--	8	350	--	--	--	--	--	--	146
804	74	12	310	101	04- -1948	200	3.3	--	--	147
180	18	8	100	--	--	140	--	540	6.8	148
230	22	8	100	30.0 R	05-01-1956	150	3.8	620	6.7	149
260	--	8	100	30.0	05-01-1956	220	5.5	410	6.7	150
785	57	12	90	FLOWING	04-10-1956	220	1.5	600	7.7	151
750	35	12	90	2.00	04-10-1956	800	5.3	470	7.6	152
752	30	12	80	FLOWING	04-10-1956	500	4.5	460	7.7	153
902	64	12	100	12.0	10-25-1953	650	6.4	860	--	154
485	--	8	220	64	10-09-1986	70	--	240	7.1	155
300	--	8	220	--	--	70	--	225	7.5	156
180	--	6	130	90.0	04-10-1956	120	--	410	7.7	157
60	--	--	130	30.0	04-10-1956	30	--	--	--	158
100	--	6	140	--	--	--	--	245	6.1	159
120	--	6	140	--	--	--	--	--	--	160
--	--	6	120	--	09-12-1956	30	--	--	--	161
--	--	6	120	--	04-12-1956	30	--	--	--	162
--	--	6	120	--	04-12-1956	30	--	--	--	163
600	190	8	230	115	02-19-1942	50	1.3	520	7.7	164
400	--	8	190	70.0	09-25-1950	100	10.0	360	6.6	165
250	--	--	150	--	--	--	--	--	--	166
166	--	8	290	4.51	09-18-1956	24	.2	--	--	167
246	--	8	300	13.1	09-18-1956	5	.03	--	--	168
145	--	8	410	10.1	09-17-1956	15	.1	--	5.4	169
188	--	6	350	29.2	09-18-1956	20	2.5	--	--	170
147	87	10	215	7.41	09-19-1956	270	38.6	--	--	171
170	51	14	205	2.59	11-20-1956	330	4.46	310	--	172
93	67	6	595	31.0	10-10-1985	7	1.7	70	5.9	173
300	130	8	150	--	--	84	--	--	--	174
--	--	8	120	--	--	80	--	--	--	175
410	50	8	100	12.0	08-31-1956	350	2.5	--	--	176
387	24	12	103	5.00	12-18-1952	550	13.8	--	--	177
140	84	6	280	63.0	08-21-1957	6	.3	--	--	178
201	29	12	290	27.9	12-12-1961	50	1.3	--	7.0	179
250	20	12	310	32.6	12-12-1961	20	.3	--	7.0	180
700	56	16	280	132	05-24-1963	224	2.0	--	--	181
20	--	--	210	14.0	-1963	8	--	--	--	182
7	--	6	340	4.00	05-14-1951	--	--	--	--	183
240	31	6	250	--	--	6	--	--	--	184
245	31	8	500	--	--	--	--	--	--	185
340	31	8	500	--	--	--	--	--	--	186
30	16	6	--	--	--	--	--	--	--	187
185	30	6	--	--	--	--	--	--	--	188
290	120	6	350	--	--	--	--	--	--	189
115	--	--	--	18.0	06-21-1951	--	--	--	--	190
40	--	--	--	--	--	60	--	--	--	191
65	6	6	--	15.0	1934	10	--	--	--	192
75	26	6	--	--	--	25	--	--	--	193
70	60	6	610	50	12-06-1976	15	--	--	--	194
80	--	6	660	--	--	40	--	--	--	195
34	--	6	670	--	--	20	--	--	--	196
129	30	6	--	35.0	1934	3	.07	--	--	197
300	260	6	660	--	--	8	--	--	--	198
300	--	--	600	--	--	8	--	--	--	199
500	--	12	120	203	09-21-1950	200	--	--	--	200
208	30	6	400	--	--	150	--	690	--	201
--	--	--	150	3.10	11-01-1983	30	10.0	960	--	202
268	17	5	180	10.0	05-22-1964	4	--	--	--	203
170	22	5	150	2.12	10-20-1983	4	--	--	--	204
67	--	6	360	35	05-01-1964	10	1.00	82	--	205
45	--	--	520	--	--	75	--	180	--	206
197	90	14	310	22.0 R	07-11-1955	350	70.0	--	--	207
431	16	14	140	6.00	02-21-1964	5	--	--	--	208
316	154	12	215	112	07-25-1963	1200	24.0	--	--	209
400	15	16	150	28.0	11-06-1963	50	.20	--	--	210

Table 2.-- Records of wells -- Continued

Local number	Site identification number	Owner	Driller	Date drilled	Use of site	Use of water	Aquifer code
CM-1051	395238075571401	LAPPEY, NORMAN	--	--	W	H	300PRCK
1052	395240C75571301	LAPPEY, NORMAN	--	--	W	S	300PRCK
1053	395314075572201	MCLIMANS, ROSS	--	--	W	H	300PRCK
1054	395439C75573401	THOMPSON, ELAM	PETERSHEIN BROS.	1962	U	U	300PRCK
1055	395441C75573501	THOMPSON, ELAM	--	1962	U	U	300PRCK
1056	395306075573701	UMBLE, OMAR	--	1920	W	S	300PRCK
1057	395405075575101	BROSIUS, W	PETERSHEIN BROS.	1954	W	H	300WSCKA
1058	395456075573401	KENNEL, VERNON	PETERSHEIN BROS.	1952	W	H	367CNSG
1059	395740075574101	SMOKER, WILMER	--	--	W	H	000GRGS
1060	395729075571401	MILLER, NORMAN	--	--	W	H	377CCKS
1061	395740075574301	BOROUGH OF ATGLEN	--	--	W	P	000GRGS
1062	395740075573001	BOROUGH OF ATGLEN	PETERSHEIN BROS.	--	W	P	000GRGS
1063	395841075571501	ENGEL, MAYNARD	LEROY MYERS	1961	W	H	000GRGS
1064	395800C75575401	STOLTZFUS, RALPH	PETERSHEIN BROS.	1922	W	H	000GRGS
1065	395906075571301	GLICK	--	--	U	U	000GRGS
1066	395930075572501	JACKSON, HARRY	--	--	W	H	000GRGS
1067	395925C75572401	LAPP, LEROY	--	1955	W	H	377CCKS
1068	395237075583001	EGOLF, EARL	--	--	W	H	300PRCK
1069	395317C75580101	MENDENHALL, ROBERT	--	1915	W	H	300PRCK
1070	395538075582001	RITTER, LAWRENCE	PETERSHEIN BROS.	1928	W	H	300WSCKA
1071	395621075581401	BUCKWALTER, N	--	1809	W	H	300WSCKA
1072	395618075585801	EWING, R	--	--	W	H	367CNSG
1073	395607075580901	HARVEY , A	LEROY MYERS	1963	W	H	300WSCKA
1074	395703075585001	PELET	LEROY MYERS	1947	W	H	377MRPR
1075	395735075581501	KENNEL, IRA	--	--	W	H	000GRGS
1076	395804075580901	STOLTZFUS, JOSEPH	O. B. KAUFFMAN	1958	W	H	000GRGS
1077	395436C75592501	SCHOFF, LEONARD	LEROY MYERS	1962	W	H	300WSCKA
1078	395432C75592301	SCHOFF, LEONARD	LEROY MYERS	1962	U	U	300WSCKA
1079	395523C75591101	SCHOFF, LEONARD	--	--	W	H	300WSCKA
1080	395715C75590701	SMOKER, DAVID	--	--	W	H	000GRGS
1081	395733C75591701	BAYNARD, JOHN	LEROY MYERS	1960	W	H	000GRGS
1082	395829075593701	BAWELL, ELIAS	--	--	W	H	000GRGS
1083	400700C7533C001	VALLEY FORGE CHRISTIAN COLLEGE	--	--	W	T	231SCKN
1084	400700075330002	VALLEY FORGE CHRISTIAN COLLEGE	--	--	W	T	231SCKN
1085	400801075322701	HOLLINGSWORTH, J	C. S. GARBER & SONS, INC.	1957	W	H	231SCKN
1086	395823C75440801	BRADFORD GLEN W CO	--	1977	W	P	300WSCKA
1087	395827075441001	BRADFORD GLEN W CO	--	1977	W	P	300WSCKA
1088	395820C75441701	BRADFORD GLEN W CO	--	--	W	P	300WSCKA
1089	400909C755C3801	FRY, EDWARD	PETERSHEIN BROS.	1984	W	H	377CCKS
1090	400108075545801	FUNK, JIM	BROOKOVER WELL DRLG. CO.	1979	W	H	377CCKS
1091	400030075534201	LOGGINS, LAWRENCE	PETERSHEIN BROS.	1975	W	H	377CCKS
1092	400333C75490501	LABAN, JOE	--	--	W	H	377CCKS
1093	400225C75381401	PATTIONI, AMBERTO	ALFRED G. GURLEY	--	W	H	377CCKS
1094	400254C75531301	BRYAN, JOSEPH R	--	--	W	H	377CCKS
1095	395817C75531301	WOLF, LENTMA	MYERS BROS. DRLG. CONT.	1975	W	H	377CCKS
1096	400206075533701	GREGOR, ADAM	ROBERT E. MATTSON	1987	W	H	377CCKS
1097	400214075555101	BATDORF, VERNON	MYERS BROS. DRLG. CONT.	1978	W	H	377ANTM
1098	400246C75542301	SUPPLEE, ELAM	PETERSHEIN BROS.	1977	W	H	377CCKS
1099	400927075492701	AUSTIN, JEFF	--	--	W	H	000GIMZ
1100	395936075452001	BACK, ROB	LEROY MYERS	1972	W	H	367CNSG
1101	395854075451101	CAPOZZOLI, FRANK	--	1972	W	H	300WSCKA
1102	395903075451501	McGRAW	PETERSHEIN BROS.	1979	W	H	300WSCKA
1103	395846075451701	THOMPSON, RONALD	LEROY MYERS	--	W	H	300WSCKA
1104	395855075455401	MONTGOMERY	BARRY LEE MYERS	1977	W	H	300WSCKA
1105	395857C75454301	McWILLIAMS	--	1977	W	H	300WSCKA
1106	395807C75455701	McGLINCHEY	--	1966	W	H	300WSCKA
1107	395825C75283501	U. S. ARMY	--	1950	U	U	40CPLCGM
1108	400003075343501	TAIT, W P	--	1964	T	H	300WSCKO
1109	400005075341901	KEESEY	THOMAS G. KEYES	--	W	H	300WSCKO
1110	400114C75322301	SIMONS	CALVIN E. POWELL	--	W	H	300WSCKO
1111	400126075343301	CAVIS	--	1950	W	H	300WSCKO
1112	400224C75321201	BISHOP TUBE	--	--	U	U	300WSCKO
1113	395952C75341001	BEWLEY	THOMAS G. KEYES	--	W	H	300WSCKO
1114	395858C75344601	SPIVEY	--	--	W	H	300WSCKO
1115	395852C75345501	IMMEKUS	THOMAS G. KEYES	--	W	H	300WSCKO
1116	395914C75372102	JARRETT	BROOKOVER WELL DRLG. CO.	1980	W	H	300WSCKO
1117	400113C75325001	DORTON	BROOKOVER WELL DRLG. CO.	1981	W	H	300WSCKO
1118	395953075310201	LOEW	--	1936	W	H	40CPLCGP
1119	395824C75310901	TRENNER	BONNIE J. MYERS	1978	W	H	400MPCGP
1120	395844075374201	SMALL	THOMAS G. KEYES	--	W	H	300WSCKO

Depth of well (feet)	Depth cased (feet)	Casing diameter (inches)	Elevation of land surface (feet)	Water level (feet)	Date water level measured	Discharge (gallons per minute)	Specific capacity (gpm/ft)	Specific conductance (micro-siemens)	pH	Local number
32	--	6	455	13.0 M	08-23-1963	--	--	--	6.1	CH-1051
52	--	6	460	8.00	08-29-1963	--	--	90	5.1	1052
72	--	--	590	37.0 M	08-23-1963	--	--	50	5.8	1053
126	--	6	605	51.0 M	08-22-1963	--	--	--	--	1054
331	31	6	605	50.0 M	08-22-1963	3	.02	220	7.1	1055
300	--	6	640	42.0 M	08-21-1963	6	.05	500	6.2	1056
70	20	6	640	10.0	10-01-1954	25	--	260	4.3	1057
160	30	6	515	36.7	11-15-1984	10	.5	430	7.6	1058
35	--	6	610	16.0 M	07-25-1963	--	--	75	6.2	1059
--	--	6	720	38.0 M	07-25-1963	--	--	50	5.6	1060
65	50	6	570	12.0	10-01-1963	25	4.2	--	--	1061
359	40	6	615	35.0	07-01-1960	80	2.5	--	--	1062
135	--	--	660	--	--	2	--	200	6.4	1063
80	--	6	575	23.0 M	07-19-1963	5	8.92	375	6.2	1064
60	--	--	715	--	--	--	--	--	--	1065
18	--	--	730	15.0 M	06-19-1963	--	--	130	6.4	1066
120	--	6	760	25.0 M	06-20-1963	3	.05	75	6.2	1067
42	--	--	485	39.0 R	08-23-1963	10	--	80	5.3	1068
40	--	6	460	23.0 M	08-23-1963	6	6.27	170	5.6	1069
60	40	6	625	10.0	08-21-1963	30	--	90	5.7	1070
17	--	--	500	12.0 M	07-30-1963	--	--	110	5.8	1071
41	--	--	460	--	--	--	--	220	6.3	1072
100	65	6	600	25.0 M	09-03-1964	13	.78	65	5.9	1073
160	--	8	575	43.0 R	08-06-1963	23	1.72	--	--	1074
10	--	--	550	9.00 M	07-25-1963	--	--	200	5.8	1075
58	--	--	605	33.0	1958	--	--	250	5.9	1076
200	19	6	570	30.0	1962	<1	--	300	6.7	1077
170	18	6	510	6.00 M	06-14-1963	1	.04	210	7.6	1078
--	--	6	665	--	--	--	--	145	5.5	1079
30	--	--	495	28.0	07-23-1963	--	--	310	5.9	1080
56	--	6	580	50.0 M	07-25-1963	3	4.33	90	5.8	1081
23	--	--	550	22.0 M	07-23-1963	--	--	280	6.7	1082
260	--	--	--	--	--	--	--	250	--	1083
--	--	--	--	--	--	--	--	237	--	1084
135	34	8	120	--	--	--	--	--	--	1085
305	50	6	445	--	--	--	--	--	--	1086
--	41	6	470	--	--	--	--	--	--	1087
260	78	6	440	10	1977	--	--	--	--	1088
140	120	6	675	90.9 R	06-12-1987	40	1	165	5.3	1089
63	21	6	800	29 M	06-17-1987	20	.99	76	4.7	1090
153	39	6	880	45	12-11-1975	5	.25	39	4.8	1091
95	--	--	730	40 M	06-25-1987	12	--	62	5.0	1092
150	43	6	450	59.4 R	06-26-1987	5	.33	193	5.6	1093
155	--	--	920	70 R	06-26-1987	22	--	10	5.2	1094
150	63	6	640	--	--	10	--	163	4.7	1095
120	--	--	760	29.9 R	07-29-1987	10	--	15	5.0	1096
200	21	6	740	82 R	08-04-1987	6	--	121	4.9	1097
200	40	6	890	--	--	9	1.80	70	4.7	1098
--	--	--	610	24 R	08-06-1987	--	--	100	5.1	1099
--	--	--	330	40.5 M	06-23-1987	--	--	--	--	1100
--	--	6	560	38.0 M	06-23-1986	--	--	--	--	1101
363	--	6	560	39.5 R	06-23-1987	1	--	--	--	1102
--	--	6	560	39.3 M	06-23-1987	--	--	--	--	1103
--	--	6	570	29.8 M	06-23-1986	--	--	--	--	1104
--	--	6	560	59.7 M	06-23-1987	--	--	--	--	1105
--	--	6	630	3.2 M	06-23-1987	--	--	--	--	1106
255	--	--	340	--	--	19	--	228	--	1107
110	--	6	550	51.5 M	06-27-1986	--	--	--	--	1108
--	--	6	530	37.8 M	06-27-1986	--	--	--	--	1109
--	--	5	480	33.6 M	06-30-1986	--	--	--	--	1110
90	--	6	590	45.6 M	06-30-1986	--	--	--	--	1111
20	--	5	395	11.0 M	06-30-1986	--	--	--	--	1112
--	--	6	520	47.2 M	07-01-1986	--	--	--	--	1113
--	--	6	435	59.1 M	07-01-1986	--	--	--	--	1114
--	--	6	420	35.1 M	07-01-1986	--	--	--	--	1115
--	--	6	440	29.4 M	07-03-1986	--	--	--	--	1116
185	20	6	540	57 M	07-03-1986	10	.09	--	--	1117
--	--	6	450	6.4 M	07-07-1986	--	--	--	--	1118
--	--	6	330	14.9 M	07-08-1986	--	--	--	--	1119
--	--	6	410	36.1 M	07-09-1986	--	--	--	--	1120

Table 2.-- Records of wells -- Continued

Local number	Site identification number	Owner	Driller	Date drilled	Use of site	Use of water	Aquifer code
CH-1121	395815075371901	ELLIOTT, N	PETERSHEIN BROS.	1980	W	H	000SRPN
1122	400027075371001	DARLINGTON	BONNIE J. MYERS	1947	W	H	300WSCKA
1123	395854075343501	ALLAN	BROOKOVER WELL DRLG. CO.	--	W	H	400FLCGP
1124	395713075312201	DAVIS	THOMAS G. KEYES	1980	W	H	400FLCGH
1125	395704075303802	GIPPORD	--	--	W	H	400FLCGH
1126	395723075305501	KEENAN	--	--	W	H	400FLCGH
1127	395754075343101	BRUGLER	THOMAS G. KEYES	1981	W	H	400FLCGP
1128	395753075343701	ATATY	BROOKOVER WELL DRLG. CO.	1968	W	H	400FLCGP
1129	395717075330401	POTTHOFF	THOMAS G. KEYES	1981	W	H	400FLCGP
1130	395609075351801	WINNER	THOMAS G. KEYES	1981	W	H	400FLCGP
1131	395609075352001	WRIGHT	KENNETH L. MADRON	1981	W	H	400FLCGP
1132	395631075345301	CRANDALL	--	--	W	H	400FLCGP
1133	395817075342001	MARGARITA'S	--	--	W	H	400FLCGP
1134	395817075341901	MARGARITA'S	THOMAS G. KEYES	1985	W	H	400FLCGP
1135	395844075332601	JOHNSON	BROOKOVER WELL DRLG. CO.	1979	W	H	400FLCGP
1136	395554075353701	ZULTEWILZ	--	--	W	H	400FLCGP
1137	395555075354001	DEVLIN	WILLIAM CAMPBELL	1966	H	H	400FLCGP
1138	395535075353301	CARSON	WILLIAM CAMPBELL	--	H	D	300WSCKO
1139	395446075334901	YOUNG	--	1956	H	-	000SRPN
1140	395612075322201	THE CONCEPT SCHOOL	CALVIN E. POWELL	--	W	H	400FLCGH
1141	395613075322701	DOTY	WILLIAM CAMPBELL	1978	W	H	400FLCGH
1142	395616075330901	JONES	--	1913	W	H	300WSCKO
1143	400003075345301	SANOCHWAL	BROOKOVER WELL DRLG. CO.	1970	W	H	300WSCKO
1144	400005075345501	MILEWSKI	--	1960	W	H	300WSCKO
1145	395941075343501	HICKS	OBERLANDER DRILLING CO.	--	W	H	300WSCKO
1146	395826075345301	SMITH	--	1960	W	H	400FLCGP
1147	395731075353601	WYETH LABORATORIES	THOMAS G. KEYES	--	W	H	400FLCGP
1148	395724075353701	WYETH LABORATORIES	THOMAS G. KEYES	1983	W	H	400FLCGP
1149	395741075310801	BARTON DAVIS, INC	THOMAS G. KEYES	1968	W	H	400FLCGP
1150	395705075310801	BARBONE, P	CALVIN E. POWELL	1976	W	H	400FLCGH
1151	394805075305001	McCORMICK	--	1986	W	H	400MFCGP
1152	395854075341201	BIBLE BAPTIST CHURCH	BONNIE J. MYERS	--	W	H	400FLCGP
1153	395536075345901	WILLIAMS	--	--	W	H	400FLCGH
1154	395653075334201	MRINCEVICH	WILLIAM CAMPBELL	1986	W	H	400FLCGH
1155	395653075334401	THOMPSON	THOMAS G. KEYES	1985	W	H	400FLCGH
1156	395733075435701	BRADLEY, WALTER	--	--	W	H	300WSCKA
1157	395810075440801	MERIEGLE	--	--	W	H	300WSCKA
1158	395828075444601	WAY, CHARLES A	--	--	W	H	300WSCKA
1159	395831075422902	COLLIGAN	--	--	W	H	300WSCKA
1160	395715075324201	WESTTOWN SCHOOL	WILLIAM CAMPBELL	--	W	H	300WSCKO
1161	395516075342301	RUSZKAY	WILLIAM CAMPBELL	--	W	H	300WSCKO
1162	395517075324801	JARMON	WILLIAM CAMPBELL	--	W	H	400FLCGH
1163	395443075331201	PACKINNET	CALVIN E. POWELL	--	W	H	400FLCGH
1164	395414075333001	PENN OAKS COUNTRY CLUB	--	--	W	H	400FLCGH
1165	395434075340201	CHESKY	BONNIE J. MYERS	--	W	H	400FLCGH
1166	395403075334801	GETTY STATION	THOMAS G. KEYES	--	W	H	400FLCGH
1167	395426075325301	DEVER	CALVIN E. POWELL	--	W	H	400FLCGH
1168	395340075320301	GOLTZ, R	OBERLANDER DRILLING CO.	1985	W	H	400FLCGH
1169	395912075373701	DISANTI	WILLIAM CAMPBELL	--	W	H	300WSCKO
1170	395813075373101	JONES	THOMAS G. KEYES	1978	W	H	300WSCKO
1171	395928075311601	SABATINO	BROOKOVER WELL DRLG. CO.	--	W	H	400FLCGP
1172	395444075304901	IVYRIDGE	--	--	W	H	400FLCGP
1173	395835075310701	WEICHELT	THOMAS G. KEYES	1978	W	H	400MFCGP
1174	395824075313201	CHEW	THOMAS G. KEYES	--	W	H	400FLCGP
1175	395820075323201	SABATINI	THOMAS G. KEYES	--	W	H	400FLCGP
1176	395942075324401	FAMILY DENTAL GROUP	--	--	W	H	400FLCGP
1177	395833075321201	PALONE	THOMAS G. KEYES	1980	W	H	400FLCGP
1178	395833075321301	SECUNDA	--	--	W	H	400FLCGP
1179	395524075363801	THOMPSON	--	--	W	H	300WSCKO
1180	395531075345901	TIGUE	--	--	W	H	400FLCGP
1181	395456075361601	BARBER	--	--	W	H	300WSCKO
1182	395413075352801	WYLIE	--	1837	W	H	400FLCGH
1183	395427075352431	SPACKMAN	--	--	W	H	300WSCKO
1184	395503075344701	PACDONNELL	THOMAS G. KEYES	1984	W	C	300WSCKO
1185	395918075312501	PHILADELPHIA SUBURBAN WATER CO	THOMAS G. KEYES	--	T	U	400FLCGP
1186	395919075312901	PHILADELPHIA SUBURBAN WATER CO	THOMAS G. KEYES	--	T	U	400FLCGP
1187	395924075313101	PHILADELPHIA SUBURBAN WATER CO	THOMAS G. KEYES	--	T	U	400FLCGP
1188	395928075312901	PHILADELPHIA SUBURBAN WATER CO	THOMAS G. KEYES	--	T	U	400FLCGP
1189	395931075313301	PHILADELPHIA SUBURBAN WATER CO	THOMAS G. KEYES	--	T	U	400FLCGP
1190	395929075322401	PHILADELPHIA SUBURBAN WATER CO	THOMAS G. KEYES	--	T	U	430MFCGP

HUNT COUNTRY WELLS

Depth of well (feet)	Depth cased (feet)	Casing diameter (inches)	Elevation of land surface (feet)	Water level (feet)		Date water level measured	Discharge (gallons per minute)	Specific capacity (gpm/ft)	Specific conductance (micro-siemens)	pH	Local number
273	40	6	280	22.0	M	07-09-1986	10	--	--	--	CM-1121
137	15	6	365	44.4	M	07-09-1986	--	--	--	--	1122
--	--	6	440	28.6	M	07-09-1986	--	--	--	--	1123
200	--	6	450	61.9	M	07-10-1986	--	--	--	--	1124
--	20	6	350	23.2	M	07-10-1986	--	--	--	--	1125
--	--	--	460	39.1	M	07-10-1986	--	--	--	--	1126
100	78	6	450	32.3	M	07-14-1986	75	11.7	--	--	1127
58	35	6	430	7.8	M	07-14-1986	--	--	--	--	1128
120	--	6	420	25.5	M	07-14-1986	--	--	--	--	1129
180	--	6	455	35.8	M	07-15-1986	--	--	--	--	1130
--	--	6	450	29.2	M	07-15-1986	--	--	--	--	1131
--	--	6	420	23.8	M	07-15-1986	--	--	--	--	1132
--	--	6	420	19.4	M	07-16-1986	15	--	--	--	1133
120	--	6	415	17.2	M	07-16-1986	60	--	--	--	1134
44	33	6	410	24.5	M	07-16-1986	30	6.0	--	--	1135
--	--	6	390	17.5	M	07-17-1986	--	--	--	--	1136
--	--	--	400	28.6	M	07-17-1986	--	--	--	--	1137
--	--	--	325	26.4	M	07-17-1986	--	--	--	--	1138
60	--	--	295	25.9	M	07-17-1986	--	--	--	--	1139
--	--	--	270	27.1	M	07-17-1986	--	--	--	--	1140
--	--	--	265	19.6	M	07-17-1986	--	--	--	--	1141
--	--	--	290	23.0	M	07-17-1986	--	--	--	--	1142
75	--	6	475	28.5	M	07-18-1986	--	--	--	--	1143
--	--	6	470	27.6	M	07-18-1986	--	--	--	--	1144
284	--	6	445	21.8	M	07-18-1986	--	--	--	--	1145
64	59	6	465	16	R	07-18-1986	--	--	--	--	1146
--	--	--	410	4.5	M	07-18-1986	--	--	--	--	1147
50	50	6	405	6.6	M	07-18-1986	10	1.33	--	--	1148
120	48	6	380	19.4	M	07-21-1986	8	1.08	--	--	1149
155	--	--	450	27.5	M	07-21-1986	7	1.07	--	--	1150
--	--	--	370	24.7	M	07-21-1986	--	--	--	--	1151
--	--	--	410	12.9	M	07-22-1986	--	--	--	--	1152
--	--	--	360	26.2	M	07-22-1986	--	--	--	--	1153
--	--	--	435	30.7	M	07-22-1986	--	--	--	--	1154
120	--	--	445	38.1	M	07-22-1986	--	--	--	--	1155
--	--	6	430	30.6	M	07-06-1987	--	--	--	--	1156
--	--	6	570	55.7	M	07-06-1987	--	--	--	--	1157
--	--	6	450	11.4	M	07-06-1987	--	--	--	--	1158
--	--	6	550	57.4	M	07-07-1987	--	--	--	--	1159
--	--	--	350	19.9	M	07-22-1986	--	--	--	--	1160
--	--	6	340	17.4	M	07-22-1986	--	--	--	--	1161
--	--	6	310	26.6	M	07-23-1986	--	--	--	--	1162
425	--	4	420	56.0	M	07-23-1986	--	--	--	--	1163
--	--	6	390	0	M	07-23-1986	--	--	--	--	1164
--	--	--	405	47.4	M	07-23-1986	--	--	--	--	1165
--	--	--	415	21.6	M	07-23-1986	--	--	--	--	1166
--	--	6	435	25.1	M	07-25-1986	--	--	--	--	1167
106	--	6	260	23.5	M	07-25-1986	--	--	--	--	1168
--	--	0	450	36.7	M	07-28-1986	--	--	--	--	1169
--	--	6	305	13.5	M	07-28-1986	--	--	--	--	1170
--	--	6	415	30.5	M	07-28-1986	--	--	--	--	1171
--	--	6	400	36.9	M	07-28-1986	--	--	--	--	1172
140	--	6	405	34.8	M	07-29-1986	--	--	--	--	1173
--	--	6	410	15.2	M	07-29-1986	--	--	--	--	1174
200	--	4	440	21.2	M	07-29-1986	--	--	--	--	1175
--	--	6	420	14.4	M	07-29-1986	--	--	--	--	1176
--	--	6	470	39.2	M	07-29-1986	--	--	--	--	1177
--	--	36	465	33.0	M	07-29-1986	--	--	--	--	1178
150	--	4	330	52.3	M	07-31-1986	--	--	--	--	1179
--	--	6	300	45.8		07-31-1986	--	--	--	--	1180
--	--	--	280	19.7	M	07-31-1986	--	--	--	--	1181
--	--	36	385	30.6	M	07-31-1986	--	--	--	--	1182
--	--	--	350	10.2	M	07-31-1986	--	--	--	--	1183
225	--	--	380	42.1	M	07-31-1986	25	--	--	--	1184
--	--	--	375	3.7	M	08-01-1986	--	--	--	--	1185
--	--	--	380	4.8	M	08-01-1986	--	--	--	--	1186
--	--	--	390	5.3	M	08-01-1986	--	--	--	--	1187
--	--	--	390	6.0	M	08-01-1986	--	--	--	--	1188
--	--	--	390	--		--	--	--	--	--	1189
--	--	6	380	1.8	M	08-01-1986	--	--	--	--	1190

Table 2.-- Records of wells -- Continued

Local number	Site identification number	Owner	Driller	Date drilled	Use of site	Use of water	Aquifer code
CH-1401	400044C75483201	SMITH, JEROME	PETERSHEIM BROS.	1968	W	H	000GRDR
1402	400044075480801	GADLE	THOMAS G. KEYES	1970	W	H	000GRDR
1403	400045C75480301	HOWARD, JOHN	PETERSHEIM BROS.	1970	W	H	000GRDR
1404	400106C75473201	CANALE, J	BROOKOVER WELL DRLG. CO.	1967	W	H	000GRDR
1405	400224C75474901	BALDERSTON, WILLIAM	THOMAS G. KEYES	1973	W	H	000GRDR
1406	400059C75490601	CIGAS, ANDREW	PETERSHEIM BROS.	1969	W	H	000GRDR
1407	400657C75500201	HAINES, CHARLES	PETERSHEIM BROS.	1969	W	H	000GRDR
1408	400344C75501601	HONEYBROOK LIONS CLUB	PETERSHEIM BROS.	1966	W	Z	377CCKS
1409	400323C75493501	BATES, J	PETERSHEIM BROS.	1972	W	H	000GRDR
1410	400323075495201	BELLAR	--	1972	W	H	000GRDR
1411	400359C75501301	SCHUL, ALBERT	PETERSHEIM BROS.	1971	W	H	000ANRS
1412	400445C75485001	GRIFFIN, JAMES	PETERSHEIM BROS.	1971	W	H	000ANRS
1413	400402075485001	HOOPES, EVERETT	THOMAS G. KEYES	1969	W	P	000ANRS
1414	400333C75470201	YOUNG, JERRY	PETERSHEIM BROS.	1973	W	H	000GRDR
1415	400304C75440001	FOWLER, C	PETERSHEIM BROS.	1972	W	H	000GRDR
1416	400310C75434901	GROVE, CONRAD	PETERSHEIM BROS.	1968	W	H	000GRDR
1417	400112075442201	HARRINGTON, R	BROOKOVER WELL DRLG. CO.	1970	W	H	000GRDR
1418	400126C75463901	CARPENTER, W	BROOKOVER WELL DRLG. CO.	1970	W	H	000GRDR
1419	400143C75450001	CULLEN, RUTH	PETERSHEIM BROS.	1970	W	C	000GRDR
1420	400326075444701	DEMPSAY, C	BROOKOVER WELL DRLG. CO.	1969	W	H	000GRPC
1421	400333C75444201	SIMER, F	THOMAS G. KEYES	1969	W	C	000GRPC
1422	400250075435401	STEINER, W	THOMAS G. KEYES	1970	W	H	000GRDR
1423	400353C75453401	STEVENS	THOMAS G. KEYES	1973	W	H	000GRPC
1424	400050075444501	STRINGER, F	PETERSHEIM BROS.	1972	W	H	000GBBR
1425	400128075432401	DANKANICH, CHAS	PETERSHEIM BROS.	1970	W	H	000GRDR
1426	400210C75425201	WINSHIP, R	BROOKOVER WELL DRLG. CO.	1969	W	H	000GRDR
1427	400247C75425901	RITCHEY, E	THOMAS G. KEYES	1969	W	H	000GRDR
1428	400421075432301	WOODWARD, ROBERT	BROOKOVER WELL DRLG. CO.	1971	W	H	000GBBR
1429	400413C75453701	HESSNER, CHARLES	PETERSHEIM BROS.	1967	W	H	000GBBR
1430	400347C75471501	WALLACE, MURIEL	PETERSHEIM BROS.	1971	W	H	000GRPC
1431	400348075471701	DAVIDSON, LESTER	PETERSHEIM BROS.	1973	W	H	000GRPC
1432	400448C75481001	SARNECKI, FRANK	THOMAS G. KEYES	1971	W	H	000ANRS
1433	400459C75480801	PINNICK, DAVID	PETERSHEIM BROS.	1973	W	H	000ANRS
1434	400634C75440001	MASON, C	--	1969	W	H	000QZMZ
1435	400706075431501	McAFFEE, T	PETERSHEIM BROS.	1972	W	H	000QZMZ
1436	400718C75435801	PULBERRY, G	THOMAS G. KEYES	1972	W	H	000QZMZ
1437	400721075441601	LILLEY, W	BROOKOVER WELL DRLG. CO.	1967	W	H	000QZMZ
1438	400027075543001	PARCHINSKI, E	PETERSHEIM BROS.	1970	W	H	377MRPR
1439	395959075542701	PARSONS, HERMAN	PETERSHEIM BROS.	1968	W	H	377CCKS
1440	395924C75540001	CIBALDA	BARRY LEE MYERS	1973	W	H	000GBBR
1441	400215C75503101	TAGGART, WILLIAM	LEROY MYERS	1968	W	H	000GBBR
1442	400148075474501	MORGAN, ALLEN	PETERSHEIM BROS.	1969	W	H	000GRDR
1443	400116C75454101	WHITEMAN, JERRY	BROOKOVER WELL DRLG. CO.	1970	W	H	000GRDR
1444	400315075450501	JEFFERIS, DENNIS	PETERSHEIM BROS.	1969	W	H	000GRPC
1445	400301075450101	YEAGER, ELWOOD	MAURICE E. BROWN	1973	W	H	000GRDR
1446	400234075434101	WALKER, C	PETERSHEIM BROS.	1973	W	H	000GRDR
1447	395154C75385001	PHILADELPHIA SUBURBAN WATER CO	THOMAS G. KEYES	1964	W	P	400FLCGH
1448	395554C75345501	PHILADELPHIA SUBURBAN WATER CO	THOMAS G. KEYES	1964	W	P	400FLCGP
1449	395956C75374701	PHILADELPHIA SUBURBAN WATER CO	THOMAS G. KEYES	1966	W	P	300WSCKA
1450	395624C75371201	PHILADELPHIA SUBURBAN WATER CO	THOMAS G. KEYES	1966	W	P	400FLCGP
1451	400036075353101	PHILADELPHIA SUBURBAN WATER CO	THOMAS G. KEYES	1961	W	P	300WSCKA
1452	400040C75353401	PHILADELPHIA SUBURBAN WATER CO	THOMAS G. KEYES	1962	W	P	300WSCKA
1453	395840075313501	PHILADELPHIA SUBURBAN WATER CO	THOMAS G. KEYES	1965	W	P	400MFCGP
1454	395928C75340001	PHILADELPHIA SUBURBAN WATER CO	THOMAS G. KEYES	1965	W	P	400FLCGP
1455	395724075302401	PHILADELPHIA SUBURBAN WATER CO	THOMAS G. KEYES	1972	W	P	400FLCGH
1456	395732C75312702	PHILADELPHIA SUBURBAN WATER CO	THOMAS G. KEYES	1964	W	U	400FLCGH
1457	395641C75362101	PHILADELPHIA SUBURBAN WATER CO	THOMAS G. KEYES	1965	W	P	400FLCGP
1458	395434C75370201	PHILADELPHIA SUBURBAN WATER CO	THOMAS G. KEYES	1964	W	P	300WSCKD
1459	395341075330401	PHILADELPHIA SUBURBAN WATER CO	THOMAS G. KEYES	1968	W	P	400FLCGH
1460	395358075323701	PHILADELPHIA SUBURBAN WATER CO	THOMAS G. KEYES	1968	W	P	400FLCGH
1461	395209075341701	PHILADELPHIA SUBURBAN WATER CO	THOMAS G. KEYES	1966	W	P	400MFCGH
1462	395209075341801	PHILADELPHIA SUBURBAN WATER CO	THOMAS G. KEYES	1964	W	P	400MFCGH
1463	395201C75341601	PHILADELPHIA SUBURBAN WATER CO	THOMAS G. KEYES	1964	U	U	400FLCGH
1464	400353075465601	KNOWETON, MARJORIE	--	1972	W	H	377CCKS
1465	400423075463901	SPRINGTON MANOR	PETERSHEIM BROS.	1966	W	H	000ANRS
1466	400507075485301	FLEGAN, E	PETERSHEIM BROS.	1973	W	H	000ANRS
1467	400335075472801	CARR, FLOYD	PETERSHEIM BROS.	1969	W	H	000ANRS
1468	400549C75472701	MILLER, FRED	PETERSHEIM BROS.	1969	W	H	000ANRS
1469	400520075470201	MOORE, EDWARD	PETERSHEIM BROS.	1972	W	H	000ANRS
1470	400622C75444801	CARPENTER, C	PETERSHEIM BROS.	1966	W	H	000QZMZ

GRAND OAK WELL

Depth of well (feet)	Depth cased (feet)	Casing diameter (inches)	Elevation of land surface (feet)	Water level (feet)	Date water level measured	Discharge (gallons per minute)	Specific capacity (gpm/ft)	Specific conductance (micro-siemens)	pH	Local number
150	31	6	560	--	--	5	--	--	6.1	CH-1401
135	33	6	560	38.0 R	09-22-1970	4	.04	--	--	1402
139	--	6	580	40.0 R	09-09-1970	--	--	--	--	1403
45	25	6	560	25.5 R	05-17-1967	30	3.00	--	--	1404
174	52	6	520	12.0 R	08-24-1973	6	.04	--	--	1405
125	30	6	480	--	--	4	--	170	6.4	1406
95	57	6	580	15.0 R	10-09-1969	6	--	80	6.4	1407
165	76	6	800	55.0 R	05-03-1966	10	--	--	--	1408
295	40	6	580	10.1 M	04-12-1974	3	--	--	--	1409
75	40	6	620	17.2 M	04-12-1974	50	--	70	5.9	1410
198	83	6	660	49.9 M	04-12-1974	5	--	60	6.2	1411
78	42	6	600	3.03 M	04-12-1974	100	--	120	6.2	1412
160	38	8	640	39.0 R	11-17-1969	225	1.89	--	--	1413
100	40	6	560	--	--	30	--	--	--	1414
100	40	6	440	6.00 M	04-01-1974	30	--	200	6.4	1415
80	40	6	480	32.0 R	07-01-1968	35	--	180	6.1	1416
45	25	6	410	7.00 M	04-01-1974	20	.95	260	6.1	1417
44	20	6	500	20.0 M	04-16-1974	15	7.50	--	--	1418
230	20	6	580	50.0 R	02-27-1970	2	--	320	6.5	1419
300	19	6	380	30.0 R	12-05-1969	5	1.25	280	6.3	1420
161	36	5	330	21.0 M	04-01-1974	8	.06	--	--	1421
90	41	6	370	13.0 M	04-16-1974	20	.36	80	6.0	1422
98	35	6	520	27.6 M	04-16-1974	10	.14	--	--	1423
108	40	6	340	22.0 M	04-17-1974	15	--	120	6.3	1424
168	60	6	550	--	--	6	--	--	--	1425
103	12	6	300	43.0 R	05-06-1969	6	.16	100	6.2	1426
143	35	6	330	40.0 R	01-07-1969	30	.31	--	--	1427
88	21	6	480	23.0 R	06-08-1971	20	.49	250	6.4	1428
130	41	6	500	8.39 M	04-13-1974	37	--	170	6.6	1429
198	40	6	580	34.3 M	04-17-1974	6	--	90	5.6	1430
108	61	6	600	38.6 M	04-17-1974	25	--	70	6.1	1431
70	40	6	640	14.0 R	09-19-1971	30	.55	--	--	1432
90	68	6	620	18.2 M	04-17-1974	30	--	--	6.5	1433
107	87	6	620	17.5 M	04-18-1974	60	.79	100	6.5	1434
85	40	6	670	--	--	40	.74	110	6.1	1435
77	42	6	680	30.0 M	04-01-1974	45	--	--	--	1436
55	40	6	660	24.0 R	04-10-1967	30	1.43	110	6.3	1437
168	36	6	820	40.0 R	07-09-1970	5	--	--	--	1438
148	112	6	790	60.0 R	02-26-1968	30	--	--	--	1439
73	42	6	650	21.0 R	07-08-1973	80	--	--	--	1440
50	22	6	700	20.0 R	02-05-1968	15	.75	--	--	1441
72	35	6	520	--	--	28	--	380	5.9	1442
63	20	6	620	16.0 R	12-16-1970	15	.48	--	--	1443
88	49	6	420	29.9 M	04-22-1974	16	--	250	6.6	1444
64	33	6	500	21.6 M	04-22-1974	35	11.67	60	6.2	1445
85	37	6	570	--	--	35	--	--	--	1446
190	35	8	385	3.00 R	06-01-1964	175	1.61	--	--	1447
120	34	5	350	--	--	12	--	--	--	1448
360	20	14	370	2.50 R	06-02-1966	191	2.3	--	--	1449
149	43	8	350	14.0 R	10-01-1966	75	.73	--	--	1450
314	21	14	515	4.78 M	04-24-1974	85	.6	--	--	1451
300	62	8	530	14.0	11-19-1962	230	2.6	--	6.1	1452
222	40	8	380	8.00	02-01-1965	150	.89	--	--	1453
~~134~~	~~43~~	~~8~~	~~395~~	~~4.00 R~~	~~09-01-1965~~	~~300~~	~~4.65~~	~~--~~	~~--~~	~~1454~~
~~365~~	~~57~~	~~8~~	~~350~~	~~3.00 R~~	~~12-01-1972~~	~~300~~	~~1.60~~	~~--~~	~~--~~	~~1455~~
370	71	8	340	2.00 R	06-01-1964	270	1.44	--	--	1456
190	37	8	330	12.0 R	03-01-1965	108	1.50	--	--	1457
400	44	8	195	--	--	350	--	--	--	1458
300	30	8	260	--	--	75	--	240	7.3	1459
422	46	8	250	5.00 R	10-01-1968	280	3.59	--	--	1460
120	44	6	240	17.0 R	06-02-1964	60	.94	--	--	1461
125	42	5	240	18.0 R	06-02-1964	100	1.4	--	--	1462
100	39	5	210	12.0 R	06-02-1964	15	.19	--	--	1463
108	68	6	680	--	--	35	--	--	--	1464
77	67	6	515	33.6 M	10-10-1985	100	1.30	--	--	1465
78	44	6	660	--	--	100	--	--	--	1466
200	40	6	700	40.0 R	10-01-1969	3	--	--	--	1467
92	30	6	680	45.0 R	09-29-1969	15	--	--	--	1468
115	57	6	620	28.7 M	04-22-1974	25	--	100	5.6	1469
67	36	6	600	20.0 R	09-30-1966	20	--	--	--	1470

Table 2.-- Records of wells -- Continued

Local number	Site identification number	Owner	Driller	Date drilled	Use of site	Use of water	Aquifer code
CM-2171	395645C75410501	W BRADFORD WATER CO	BROOKOVER WELL DRLG. CO.	--	W	P	300CCKV
2172	395645C75410502	W BRADFORD WATER CO	BROOKOVER WELL DRLG. CO.	1969	W	P	300WSCKO
2173	395802C75410701	W BRADFORD WATER CO	BROOKOVER WELL DRLG. CO.	1969	W	P	300WSCKO
2174	395802C75410702	W BRADFORD WATER CO	BROOKOVER WELL DRLG. CO.	1968	U	U	300WSCKO
2175	395802C75410703	W BRADFORD WATER CO	BROOKOVER WELL DRLG. CO.	1968	W	P	300WSCKO
2176	395802C75410704	W BRADFORD WATER CO	BROOKOVER WELL DRLG. CO.	1968	W	P	300WSCKO
2177	395802C75410705	W BRADFORD WATER CO	BROOKOVER WELL DRLG. CO.	1968	W	P	300WSCKO
2178	395906C75435001	W BRADFORD WATER CO	BROOKOVER WELL DRLG. CO.	1973	W	P	300WSCKA
2179	395906C75435002	W BRADFORD WATER CO	BROOKOVER WELL DRLG. CO.	1973	W	P	300WSCKA
2180	395906C75435003	W BRADFORD WATER CO	BROOKOVER WELL DRLG. CO.	1973	W	P	300WSCKA
2181	395906C75435004	W BRADFORD WATER CO	BROOKOVER WELL DRLG. CO.	1973	U	U	300WSCKA
2182	395906C75374501	CAVANAUGH, JAMES	BROOKOVER WELL DRLG. CO.	1969	W	H	300WSCKO
2183	395325C75372001	SMOKER, N.	PETERSHEIM BROS.	1970	W	H	300WSCKA
2184	394635C75585501	BOROUGH OF OXFORD	--	--	U	U	300WSCKO
2185	394635C75585502	BOROUGH OF OXFORD	--	--	U	U	300WSCKO
2186	394755C75583901	BOROUGH OF OXFORD	--	1961	W	P	300WSCKO
2187	394730C75582701	BOROUGH OF OXFORD	--	--	W	P	300WSCKO
2188	394641C75574201	BOROUGH OF OXFORD	RULON AND COOK, INC.	1967	U	U	300WSCKO
2189	394646C75592501	BOROUGH OF OXFORD	RULON AND COOK, INC.	1967	W	P	300WSCKO
2190	400126C75373201	WEST WHITELAND FIRE COMPANY	THOMAS G. KEYES	1973	W	H	367CWSG
2191	400129C75390101	WARREN BUICK CO.	BROOKOVER WELL DRLG. CO.	1967	W	C	377LDGR
2192	400130C75385201	PORTER, PAINTER, AND PORTER	THOMAS G. KEYES	1973	W	C	377LDGR
2193	400224C75380301	ARCO GAS STATION	THOMAS G. KEYES	1971	W	C	377CCKS
2194	400147C75344701	ARCO GAS STATION	THOMAS G. KEYES	1971	W	C	377LDGR
2195	400126C75350701	TURBO RESEARCH INC.	THOMAS G. KEYES	1971	W	H	300WSCKA
2196	395823C75415301	BRANDYWINE GREENS WATER COMPANY	THOMAS G. KEYES	1974	W	P	300WSCKA
2197	400512C75291001	UNIVERSITY OF PENNSYLVANIA	--	--	W	H	377CCKS
2198	400326C75290101	UNIVERSITY OF PENNSYLVANIA	--	--	W	H	371ELBK
2199	400313C75341301	PHILADELPHIA SUBURBAN	THOMAS G. KEYES	1967	W	P	377LDGR
2200	395720C75351001	GROCERY STORE PRODUCTS	PETERSHEIM BROS.	1967	W	I	400FLCGP
2201	395653C75351801	GROCERY STORE PRODUCTS	PETERSHEIM BROS.	1971	W	I	400FLCGP
2202	395654C75351601	GROCERY STORE PRODUCTS	PETERSHEIM BROS.	1971	W	I	400FLCGP
2203	395710C75350801	GROCERY STORE PRODUCTS	PETERSHEIM BROS.	1972	W	H	400FLCGP
2204	395737C75354801	GROCERY STORE PRODUCTS	--	--	W	H	400FLCGP
2205	400914C75482101	WILLIAMS, W	--	--	W	H	000QZMZ
2206	395813C75355101	FOLAND, JAMES	THOMAS G. KEYES	1971	W	H	300WSCKO
2207	395554C75391801	ERNST, CHARLES	THOMAS G. KEYES	1969	W	H	400FLCGP
2208	400227C75452501	JANIEC, ANTHONY	BROOKOVER WELL DRLG. CO.	1973	W	H	030GRDR
2209	401106C75383401	CURRY, J	DOUGLAS K. REIGNER	1966	W	H	231HNCK
2210	395328C75442701	GLASCO, EARL	R. WALTER SLAUCH & SONS	1967	W	H	300WSCKO
2211	395328C75442501	MILLER, LEVI	R. WALTER SLAUCH & SONS	1968	W	H	300WSCKO
2212	395251C75435001	HOOVER, GERALD	R. WALTER SLAUCH & SONS	1971	W	H	300WSCKO
2213	395336C75432401	MERRING, WALTER	PETERSHEIM BROS.	1968	W	H	300WSCKO
2214	395200C75421501	JACKSON, MILTON	THOMAS G. KEYES	1968	W	H	400FLCGM
2215	395155C75453601	UPLAND DAY SCHOOL	PETERSHEIM BROS.	1966	W	T	300STRS
2216	395155C75453602	UPLAND DAY SCHOOL	PETERSHEIM BROS.	1966	W	T	300STRS
2217	400508C75541501	LINCOLN UNIVERSITY	PETERSHEIM BROS.	1975	W	P	400FRXL
2218	394518C75573901	HUNTINGTON, DAVE	MAURICE E. BROWN	1973	W	H	300WSCKO
2219	394634C75585001	MOLSTON, ALVA	R. WALTER SLAUCH & SONS	1970	W	H	300WSCKO
2220	394320C75574701	WEAVER, H	R. WALTER SLAUCH & SONS	1970	W	H	000SRPN
2221	400152C75252401	PENNYPACKER, PETER	THOMAS G. KEYES	1971	W	H	000GRBR
2222	401009C75341001	STAUFFER, A	DOUGLAS K. REIGNER	1967	W	H	231BRCK
2223	394358C75543201	BRATNER, F	MAURICE E. BROWN	1968	W	H	000SRPN
2224	394406C75564101	OXFORD GUN CLUB	MAURICE E. BROWN	1968	W	H	000SRPN
2225	394417C75552501	SIPLE, S	MAURICE E. BROWN	1970	W	H	300WSCKO
2226	400624C75520301	WRIGHT, J	PETERSHEIM BROS.	1973	W	H	000GRDR
2227	400400C75564001	MASCHER, WILLIAM	THOMAS G. KEYES	1972	W	H	377CCKS
2228	394843C75422001	TURIS, RICHARD	WILLIAM H. LAMBERSON	1967	W	H	300WSCKO
2229	394740C75492301	AYERS, W	R. WALTER SLAUCH & SONS	1966	W	H	300WSCKO
2230	395119C75493401	CHATAM MILLS INC	R. WALTER SLAUCH & SONS	1967	Z	U	400FLCGM
2231	395115C75493001	HODGES, R	R. WALTER SLAUCH & SONS	1966	W	H	400FLCGM
2232	394722C76004001	SHOEMAKER, A	MAURICE E. BROWN	1972	W	H	300WSCKO
2233	394859C75554801	HALL , C	MAURICE E. BROWN	1973	W	H	300WSCKO
2234	394947C76010201	DUSEY, R	MAURICE E. BROWN	1968	W	H	300PRCK
2235	394820C75554001	LINCOLN UNIVERSITY	MAURICE E. BROWN	1966	U	U	300WSCKO
2236	395557C75420501	CROWLEY, FRED	THOMAS G. KEYES	1970	W	H	300WSCKO
2237	401253C75430501	HEINS, I	MICHAEL KUSIYK	1969	W	H	231BRCK
2238	401337C75415901	HANSEN, H	MICHAEL KUSIYK	1967	W	H	231BRCK
2239	401347C75425001	SMITH, D	DOUGLAS K. REIGNER	1969	W	H	231HNCK
2240	401218C75420801	ZIMMER, P	PETERSHEIM BROS.	1973	W	H	231HNCK

GREAT VALLEY WELL

Depth of well (feet)	Depth cased (feet)	Casing diameter (inches)	Elevation of land surface (feet)	Water level (feet)	Date water level measured	Discharge (gallons per minute)	Specific capacity (gpm/ft)	Specific conductance (micro-siemens)	pH	Local number
105	--	--	320	--	--	225	--	--	--	CH-2171
90	20	6	320	10.0 R	05-09-1969	12	.2	--	--	2172
207	14	6	300	3.00 R	02-23-1966	20	.4	--	--	2173
155	21	6	300	3.00 R	01-28-1968	3	.02	--	--	2174
75	10	6	300	.00 R	02-06-1968	6	.1	--	--	2175
93	12	6	300	8.00 R	04-18-1966	14	.3	--	--	2176
93	15	6	300	12.0 R	04-19-1968	6	.16	--	--	2177
105	21	6	480	6.00 R	04-18-1973	22	.3	--	--	2178
126	21	6	480	9.5 R	04-19-1973	18	.3	--	--	2179
315	23	11	480	12.0 R	08-31-1973	21	.1	--	--	2180
166	17	6	480	5.00 R	04-17-1973	5	.2	--	--	2181
63	20	6	480	5.00 R	04-28-1969	8	.2	--	--	2182
360	30	6	670	--	--	300	--	--	--	2183
197	63	6	500	--	--	--	--	--	--	2184
253	91	8	500	--	--	--	--	--	--	2185
400	56	8	540	3.00 R	05-01-1941	90	.58	--	--	2186
425	45	8	525	4.00 R	08-01-1953	175	1.23	--	--	2187
383	55	6	525	--	02-01-1967	--	--	--	--	2188
430	50	8	470	10.0 R	02-01-1967	72	.32	--	--	2189
489	20	6	360	19.0 M	12-01-1974	1	<.01	1100	6.9	2190
135	21	6	335	40.0 P	12-01-1974	35	.73	500	7.4	2191
98	62	6	320	31.0 R	02-26-1973	50	.76	--	--	2192
120	75	6	370	33.0 R	10-22-1971	7	.29	--	--	2193
97	51	6	335	10.0 R	12-28-1971	30	.3	--	--	2194
105	27	6	570	40.0 R	06-22-1971	12	.2	--	--	2195
400	25	12	320	22.0 R	12-12-1974	180	1.2	--	--	2196
--	--	--	560	--	--	--	--	--	--	2197
--	--	--	230	43.0	10-20-1983	--	--	--	--	2198
390	90	6	310	2.94 P	01-03-1973	500	5.63	--	--	2199
198	44	6	410	10.0 R	04-01-1967	75	--	--	--	2200
250	57	6	400	--	--	20	--	--	--	2201
242	65	6	410	--	--	40	--	--	--	2202
175	61	6	380	--	--	60	--	--	--	2203
100	--	--	420	--	--	90	--	--	--	2204
--	--	--	550	--	--	--	--	120	6.2	2205
56	30	6	260	10.0 R	05-27-1971	20	.44	--	--	2206
63	35	5	320	25.0 R	10-24-1969	25	.69	--	--	2207
65	21	7	590	2.00 R	04-14-1973	12	.25	--	--	2208
136	64	7	260	--	--	8	--	--	--	2209
76	51	6	390	1.00 R	12-29-1967	25	.6	--	--	2210
70	39	6	390	4.00 R	02-05-1968	20	1.0	--	--	2211
92	30	6	360	13.0 R	08-23-1971	15	.3	--	--	2212
108	57	6	460	--	--	35	.10	--	--	2213
140	34	5	450	33.0 R	08-29-1968	10	--	--	--	2214
300	65	6	420	45.0 R	12-17-1966	2	--	--	--	2215
300	72	6	420	45.0 R	12-20-1966	10	--	--	--	2216
295	20	12	670	5.00 M	02-10-1975	75	--	330	7.4	2217
124	96	6	490	30.0 R	06-27-1973	8	.2	--	--	2218
95	69	6	540	15.0 R	06-27-1970	15	.3	--	--	2219
67	45	6	470	10.0 R	08-27-1970	20	1.0	--	--	2220
250	60	6	390	10.0 R	05-18-1971	1	--	--	--	2221
89	28	7	230	--	--	20	--	--	--	2222
53	20	6	360	13.0 R	08-13-1968	45	15.0	--	--	2223
145	40	6	400	40.0 R	09-30-1968	4	.04	--	--	2224
85	50	6	380	20.0 R	11-02-1970	20	.8	--	--	2225
295	41	6	660	--	--	2	--	--	--	2226
125	90	6	700	30.0 R	08-01-1972	10	.10	--	--	2227
85	27	7	230	5.00 R	04-13-1967	75	--	--	--	2228
93	49	6	340	31.0 R	08-09-1966	8	.2	--	--	2229
88	27	6	410	4.00 R	12-01-1967	15	.2	--	--	2230
73	50	6	420	10.0 R	09-12-1966	20	.67	--	--	2231
80	64	6	440	20.0 R	04-14-1972	12	.3	--	--	2232
166	109	6	535	55.0 R	05-29-1973	5	.3	--	--	2233
55	20	--	300	9.00 R	08-16-1968	10	.6	--	--	2234
111	86	6	520	31.0 R	08-15-1966	12	.2	--	--	2235
125	48	6	350	46.0 R	06-10-1970	12	.1	--	--	2236
225	52	6	700	--	--	8	--	--	--	2237
98	50	6	340	--	--	14	--	--	--	2238
95	31	--	290	--	--	8	--	--	--	2239
265	79	6	700	--	--	12	--	70	--	2240

Table 2.-- Records of wells -- Continued

Local number	Site identification number	Owner	Driller	Date drilled	Use of site	Use of water	Aquifer code
CM-2381	401140C75333001	TYSON, M S	--	--	W	H	231BRCK
2382	401143C75345401	WEAVER, J K	--	1956	W	H	231BRCK
2383	401137C75344001	WENSEL, R G	C. S. GARBER & SONS, INC.	1976	W	H	231BRCK
2384	401130C75344001	WILSON, R E	--	1972	W	H	231BRCK
2385	401128C75343701	COLLINS, C E	--	1951	W	H	231BRCK
2386	401138C75354801	GORMAN, W	DOUGLAS K. REIGNER	1976	W	H	231BRCK
2387	401055C75331001	MOLES	--	--	W	H	231BRCK
2388	401146C75340001	PEYERS	--	1956	W	H	231BRCK
2389	400347C75331401	TEL MAI REST HOME	PETERSHEIM BROS.	1966	W	T	377HRPR
2390	401038C75353801	SUNNY SLOPE DAIRY	KOHL BROS., INC.	1944	U	U	231BRCK
2391	401039C75353301	SUNNY SLOPE DAIRY	KOHL BROS., INC.	1947	U	U	231BRCK
2392	401040C75352601	SUNNY SLOPE DAIRY	KOHL BROS., INC.	1951	W	I	231BRCK
2393	395936C75451401	HOME FARM EQUIPMENT	--	1921	W	P	300WSCKA
2394	395404C75390001	POCOPSON WATER CO	THOMAS G. KEYES	1977	W	P	300WSCKC
2395	395405C75383401	POCOPSON WATER CO	THOMAS G. KEYES	1977	U	U	300WSCKC
2396	401032C75430731	VERDET, J	C. S. GARBER & SONS, INC.	1977	W	H	231DIBS
2397	395819C75415501	BRANDYWINE GREENE WATER CO	THOMAS G. KEYES	1977	W	P	3CCWSCKA
2398	395906C75432601	WOOD	--	--	W	H	3COWSCKA
2399	395840C75442901	REINERT	--	--	W	H	3COWSCKA
2400	395034C75431901	SENECA KENNETT POOOS	R. WALTER SLAUCH & SONS	1977	W	I	300CCKV
2401	395623C75454901	PACE, VINCENT	--	--	W	H	300PRCK
2402	400313C75315301	CERELICE, EUGENE	--	--	W	H	377LDGR
2403	395936C75542501	DURHAM , L	--	--	W	H	377CCKS
2404	395639C75442601	CUMMINGS, JANET	C. S. GARBER & SONS, INC.	--	W	H	300PRCK
2405	400428C75405731	WOLPINGTON, RICHARD	--	--	W	H	000GRPC
2406	400109C75543231	HOFFMAN, J	ROBERT E. MATTSON	1972	W	H	377CCKS
2407	400704C75343601	CITIZENS UTILITIES HOME W CO	THOMAS G. KEYES	1978	W	P	CCOGRPC
2408	395521C75573001	UMBLE,JR., HENRY	MYERS BROS. DRLG. CONT.	1974	W	H	3CCWSCKA
2409	394400C76014901	MYLIN, J W	MAURICE E. BROWN	1977	W	H	300WSCKA
2410	400301C75545101	BALDWIN CLEMENT	E. J. MYER & SONS	1978	W	H	377CCKS
2411	400329C75315501	CINEO	--	--	W	H	377LDGR
2412	400129C75345901	TABAS ENTERPRISES	--	--	W	I	367CNSG
2413	395435C75430601	MUNSON, GEORGE	--	--	W	H	000SRPN
2414	395037C75433201	SAM'S INN	--	--	W	C	300CCKV
2415	395731C75485201	TAYLOR, JOHN	--	--	W	H	300PRCK
2416	395940C75493701	IRWIN, ROBERT	--	--	W	H	000GRPR
2417	400117C75541501	SNYDER, E	--	--	W	H	3[illegible]CKS
2418	400340C75501201	HOOPER , ROBERT	--	--	W	H	377CCKS
2419	400712C75550001	MARTIN, J E	--	--	W	H	377HCCM
2420	395814C75584901	COATES, BARRY	MYERS BROS. DRLG. CONT.	1979	W	H	000GR[illegible]S
2421	395322C75561701	MILLER, DALE	--	1972	W	H	300PRCK
2422	400130C75362301	COCKERMAN, GILBERT	--	--	W	H	367CNSG
2423	400219C75533701	CICK, W	--	--	W	H	377CCKS
2424	395744C75473901	LUNIA BROS	--	--	W	H	3COWSCKA
2425	400335C75374401	DIETZ, ROBERT	--	--	W	H	000GROR
2426	401015C75321601	EWING, R	--	--	W	H	231BRCK
2427	400918C75361901	MCKEAN	--	--	W	H	231SCKN
2428	400427C75411501	BUDD CO	--	--	W	N	000GRPC
2429	400227C75431201	HIGHLAND ORCHARDS	--	--	W	P	377CCKS
2430	395812C75403401	DIMATTEO, PAUL	--	--	W	C	300WSCKD
2431	395727C75541231	SNADER, PAUL	--	1955	W	H	367CNSG
2432	400221C75321201	BISHOP TUBE CO	F. L. BOLLINGER & SONS	1950	W	N	3COWSCKD
2433	400420C75563801	IU CONVERSION SYSTEMS	PETERSHEIM BROS.	1980	W	I	377CCKS
2434	401221C75353601	GELETEG	--	--	W	H	231BRCK
2435	401210C75351501	GORBETS AUTO	--	--	U	U	231BRCK
2436	400313C75365501	DIEST, ROBERT	--	--	W	H	377CCKS
2437	394740C75436201	ST ANTHONY'S CHURCH	--	--	W	H	300WSCKD
2438	400331C75342401	CALLOWAY, VERNON	--	--	W	H	377LDGR
2439	394626C75584901	PRENITT, ORVILLE	--	--	W	H	300WSCKD
2440	394607C75385601	HUDSON, THOMPSON	--	--	W	H	300WSCKD
2441	400625C75391501	CUFFIELD, R	--	--	W	H	000GBBR
2442	400601C75503501	CEPASQUALE, LOUIS	--	--	W	H	000ANRS
2443	400654C75282401	CZOROWSKI, WALTER	--	--	W	H	231SCKN
2444	400243C75292501	WHYTE, GEORGE	--	--	W	H	3COWSCKA
2445	400254C75295801	PALUMBO, P	--	--	W	H	300WSCKA
2446	395733C75442801	SNODGRASS	--	--	W	H	300PRCK
2447	400533C75412901	ATLANTIC RICHFIELD	--	--	W	C	000GRPC
2448	400258C75311001	84 LUMBER	--	--	W	U	367CNSG
2449	400658C75325401	VALLEY FORGE CHRISTIAN COLLEGE	--	--	W	U	231SCKN
2450	395439C75375301	LENAPE FORGE	--	--	W	N	300WSCKD

Depth of well (feet)	Depth cased (feet)	Casing diameter (inches)	Elevation of land surface (feet)	Water level (feet)		Date water level measured	Discharge (gallons per minute)	Specific capacity (gpm/ft)	Specific conductance (micro-siemens)	pH	Local number
203	--	6	130	11.0	M	08-24-1976	11	--	--	--	CH-2381
125	--	--	150	40.0	R	1956	30	--	--	--	2382
250	84	6	130	55.0	M	08-23-1976	80	.43	--	--	2383
120	30	6	180	47.0	M	08-24-1976	--	--	--	--	2384
104	55	6	190	--		--	--	--	--	--	2385
94	43	6	220	52.0	M	08-24-1976	15	--	--	--	2386
--	--	--	240	19.0	M	08-24-1976	--	--	--	--	2387
80	--	--	205	--		--	--	--	--	--	2388
109	47	6	670	20		05-26-1966	75	.84	--	--	2389
156	53	6	290	23.0		10-19-1944	112	--	--	--	2390
137	64	6	300	36.0		09-11-1947	20	.83	--	--	2391
232	60	6	300	32.0		04-23-1951	165	--	540	7.6	2392
275	58	8	325	18.0		1921	35	--	--	7.4	2393
240	20	10	255	18.1	M	04-18-1977	70	1.72	120	--	2394
270	20	6	240	8.25	M	04-18-1977	24	--	--	--	2395
400	22	6	570	260	R	11-01-1977	4	.03	--	--	2396
360	54	6	290	24		1977	40	--	--	--	2397
--	--	6	440	32.3	M	07-07-1987	--	--	--	--	2398
--	--	6	500	42.3	M	07-07-1987	--	--	--	--	2399
80	36	8	280	15.0		10-01-1977	175	--	--	--	2400
575	--	--	345	--		--	--	--	200	7.8	2401
--	--	--	230	--		--	--	--	1200	6.6	2402
50	--	--	700	--		--	--	--	115	5.1	2403
360	--	--	480	--		--	--	--	125	6.2	2404
--	--	--	530	--		--	--	--	190	6.5	2405
67	35	6	550	--		--	15	--	150	5.1	2406
345	286	6	320	57	R	08-22-1978	150	12	--	--	2407
100	--	6	665	19.8	M	07-16-1980	--	--	465	--	2408
73	47	6	470	29.6	M	07-17-1980	6	--	202	--	2409
145	20	6	910	52.9	M	07-24-1980	10	--	285	--	2410
--	--	--	245	28.6		10-14-1983	--	--	950	7.8	2411
--	--	6	350	6.73	M	06-15-1984	--	--	420	8.9	2412
--	--	--	475	--		--	--	--	1300	7.1	2413
--	--	--	380	--		--	--	--	560	7.5	2414
--	--	--	510	--		--	--	--	60	5.5	2415
--	--	--	350	--		--	--	--	395	5.8	2416
--	--	--	815	--		--	--	--	--	7.1	2417
--	--	--	770	--		--	--	--	--	4.5	2418
--	--	--	910	--		--	--	--	900	7.8	2419
350	39	6	655	97.7	M	08-28-1980	1	--	238	--	2420
--	--	6	575	40.2	M	09-09-1980	--	--	--	--	2421
130	--	--	410	40.0	R	1983	--	--	990	6.4	2422
--	--	--	840	--		--	--	--	50	5.0	2423
--	--	--	325	--		--	--	--	102	6.4	2424
--	--	--	390	--		--	--	--	190	5.4	2425
--	--	--	120	--		--	--	--	220	5.6	2426
--	--	--	210	--		--	--	--	260	5.3	2427
--	--	--	520	--		--	--	--	238	5.5	2428
--	--	--	550	--		--	--	--	220	3.8	2429
--	--	--	205	--		--	--	--	220	7.6	2430
--	--	6	470	--		11-15-1986	--	--	675	6.8	2431
300	41	8	610	33.6	P	11-09-1983	50	1.0	325	7.1	2432
200	63	6	860	51.8	M	06-08-1981	25	--	90	6.7	2433
--	--	--	155	--		--	--	--	220	5.6	2434
--	--	--	130	--		--	--	--	300	5.7	2435
--	--	--	690	--		--	--	--	85	4.5	2436
--	--	--	360	--		--	--	--	285	5.9	2437
--	--	--	350	30.9		09-23-1983	--	--	420	7.4	2438
--	--	--	525	--		--	--	--	105	5.9	2439
--	--	--	520	--		--	--	--	180	5.6	2440
--	--	--	515	--		--	--	--	125	6.6	2441
--	--	--	555	--		--	--	--	224	6.2	2442
--	--	--	110	--		--	--	--	465	6.6	2443
--	--	--	540	--		--	--	--	460	5.8	2444
--	--	--	320	--		--	--	--	725	7.2	2445
--	--	6	460	54.9	M	07-07-1987	--	--	--	--	2446
--	--	--	565	--		--	--	--	155	6.8	2447
--	--	--	270	--		--	--	--	1000	8.7	2448
--	--	--	245	--		--	--	--	465	7.7	2449
--	--	--	190	--		--	--	--	320	--	2450

NEW KENT WELLS

GOSHEN WELL

Table 2.-- Records of wells -- Continued

Local number	Site identification number	Owner	Driller	Date drilled	Use of site	Use of water	Aquifer code
CH-2661	394614C75453601	PASQUALE , L	--	--	W	H	300CCKV
2662	400435C75293401	MASSEY, A	THOMAS G. KEYES	1980	W	H	377LDGR
2663	394624C75444001	WILKINSON, LEON	--	1979	O	U	300CCKV
2664	400255C75261701	WAMORA INC	THOMAS G. KEYES	1979	U	U	300WSCKA
2665	395924C75324801	PHILADELPHIA SUBURBAN WATER CO	--	--	W	P	400PLCGP
2666	395924C75325001	PHILADELPHIA SUBURBAN WATER CO	THOMAS G. KEYES	--	W	P	400PLCGP
2667	400037C75341101	PHILADELPHIA SUBURBAN WATER CO	THOMAS G. KEYES	1979	W	P	300WSCKO
2668	395707C75330501	PHILADELPHIA SUBURBAN WATER CO	--	--	W	P	400PLCGH
2669	400142C75391101	UWCHLAN TWP MUN AUTH	RULON AND COOK, INC.	1979	W	P	377LDGR
2670	400145C75391201	UWCHLAN TWP MUN AUTH	RULON AND COOK, INC.	1978	W	P	377LDGR
2671	400426C75304001	JOHNSON, FRED	--	--	W	H	377LDGR
2672	400313C75340301	CHEMCLENE	--	--	U	U	371ELBK
2673	394630C75525101	PULLINS, CURTIS	--	--	W	H	300WSCKO
2674	400147C75363101	STS. PHILLIP & JOHN CHURCH	--	--	W	T	347CNSG
2675	395007C75474101	ABERNATHEY	--	--	W	C	300CCKV
2676	400402C75304701	SLEVIN, EDWARD	--	--	W	H	371ELBK
2677	400356C75295201	BACK	--	--	W	H	371ELBK
2678	394609C75560101	KEYSTONE WOOD TREATING	BROOKOVER WELL DRLG. CO.	--	U	U	300WSCKO
2679	395159C75304201	COATES SAMUEL	--	--	W	H	300WSCKO
2680	400736C75331501	MOUDAK	--	--	W	H	231SCKN
2681	400712C75332801	HARTER, HARRY	--	--	W	H	231SCKN
2682	400005C75464101	CROUTHAMEL, JAMES	KENNETH L. MADRON	1982	W	I	377ANTM
2683	395951C75455601	INGLESIDE ASSOCIATES	--	--	W	C	377LDGR
2684	395948C75455701	INGLESIDE ASSOCIATES	--	--	I	C	377LDGR
2685	395955C75455001	INGLESIDE ASSOCIATES	--	--	W	C	377VNTG
2686	400022C75451501	HUMPTON, SARA	--	--	W	H	377VNTG
2687	400026C75445201	HERPELFINGER, RUTH	--	--	W	H	377VNTG
2688	400016C75444501	RUTHERFORD, ROBERT	--	--	W	H	377VNTG
2689	395928C75463401	CROSS CUT HAIR CARE	KENNETH L. MADRON	1984	W	C	377LDGR
2690	395947C75444501	FRANKOW, JULIUS	THOMAS G. KEYES	1980	W	H	371ELBK
2691	395858C75475201	PISCOGLIO, SANTE	PETERSHEIM BROS.	1983	W	I	300WSCKA
2692	395922C75471601	POWER-SPRAY CAR WASH	C. S. GARBER & SONS, INC.	1976	W	C	377LDGR
2693	395946C75463501	MATTHEWS, DOROTHY	C. S. GARBER & SONS, INC.	1974	W	H	377KZRS
2694	395937C75465901	EVANS, FRANK	THOMAS G. KEYES	1970	W	H	377LDGR
2695	395932C75464001	ZIEGLER HAROLD	BARRY LEE MYERS	1977	W	H	377LDGR
2696	400016C75452701	RANCK, ANNA	C. S. GARBER & SONS, INC.	1976	W	H	377VNTG
2697	395938C75441101	EASH DONALD	PETERSHEIM BROS.	1983	W	H	300WSCKA
2698	395944C75442101	BURFORD, ROBERT	BARRY LEE MYERS	1979	W	H	367CNSG
2699	395932C75443701	REGENER, JOHN	LEROY MYERS	1939	U	U	371ELBK
2700	395941C75451001	COLLINS, CORDELIA	C. S. GARBER & SONS, INC.	1981	W	H	377LDGR
2701	395959C75445001	KUGLER, CHARLES	--	1942	W	H	377LDGR
2702	400017C75433001	SPAULDING, JAMES	--	1942	W	H	377LDGR
2703	400033C75442801	SPANCO INC	THOMAS G. KEYES	1979	W	N	377KZRS
2704	400041C75440901	CHOC, JOSEPH	PETERSHEIM BROS.	1981	W	H	377VNTG
2705	400042C75432201	DONAHUE, JACK	BARRY LEE MYERS	1980	W	C	377LDGR
2706	400108C75423601	BAUER	--	--	W	C	377CCKS
2707	395956C75425601	GIRFALCO, AGNES	L. F. YOCUM	1940	U	U	367CNSG
2708	400020C75412601	REYNOLDS METALS CO	THOMAS G. KEYES	1975	W	J	377LDGR
2709	400116C75412501	KOHLMAS, D	PETERSHEIM BROS.	1984	W	H	377VNTG
2710	400022C75413001	PEPPERIDGE FARM INC	THOMAS G. KEYES	1975	W	J	377LDGR
2711	400017C75413901	PEPPERIDGE FARM INC	THOMAS G. KEYES	1979	W	N	377LDGR
2712	400013C75413001	PEPPERIDGE FARM INC	THOMAS G. KEYES	1976	W	N	367CNSG
2713	400015C75410901	PEPPERIDGE FARM INC	--	1982	W	N	367CNSG
2714	400102C75423601	BRANDYWINE WATER CO	--	1978	W	P	377LDGR
2715	400022C754C2201	T'S PUB INC.	BARRY LEE MYERS	1981	W	C	367CNSG
2716	400022C754C2701	T'S PUB INC.	BROOKOVER WELL DRLG. CO.	1966	U	U	367CNSG
2717	400001C75414601	DOPACO INC	--	1930	W	N	367CNSG
2718	400002C75414601	DOPACO INC	--	1930	W	N	367CNSG
2719	400020C754C1101	PISTONE, RONALD	BARRY LEE MYERS	1980	W	C	300WSCKA
2720	400058C75410901	SHEELER, RAYMOND	--	--	U	U	377LDGR
2721	400137C75390201	WATERLOO GARDENS	THOMAS G. KEYES	1982	U	U	377LDGR
2722	400130C75394501	BETZ, FRED	--	--	W	H	377LDGR
2723	400103C75395801	PARKE, CAROLINE	--	--	W	H	367CNSG
2724	400033C754C0901	GENERAL CRUSHED STONE	C. S. GARBER & SONS, INC.	1973	W	C	377LDGR
2725	400058C75384801	MAGEE, JAMES	--	--	W	H	367CNSG
2726	400022C75395601	MERRION, RICHARD	BARRY LEE MYERS	1981	W	H	367CNSG
2727	400026C754C2401	NATIONAL BY-PRODUCTS	BARRY LEE MYERS	1981	W	C	371ELBK
2728	400053C75391801	COLONA, VINCENT	BROOKOVER WELL DRLG. CO.	1983	W	C	377LDGR
2729	400012C75413401	PEPPERIDGE FARM INC	THOMAS G. KEYES	1976	I	U	367CNSG
2730	400108C75382501	PRECISION CRAFT	BROOKOVER WELL DRLG. CO.	1979	W	C	377LDGR

Depth of well (feet)	Depth cased (feet)	Casing diameter (inches)	Elevation of land surface (feet)	Water level (feet)		Date water level measured	Discharge (gallons per minute)	Specific capacity (gpm/ft)	Specific conductance (micro-siemens)	pH	Local number
--	--	--	180	21.4	P	10-27-1983	--	--	--	--	CH-2661
223	84	6	270	19.2	M	11-01-1983	15	.07	--	--	2662
150	--	--	220	11.2	M	01-19-1984	150	--	--	--	2663
105	56	6	490	15.8	M	02-29-1984	60	10.7	190	5.8	2664
340	--	--	380	2.65		05-11-1978	126	--	--	7.0	2665
360	20	10	380	2.38		05-16-1981	49	--	--	6.3	2666
266	23	14	490	35.7	P	10-20-1980	66	6.6	250	5.4	2667
--	--	--	380	--		--	--	--	--	--	2668
600	141	10	340	47.0		03-01-1979	203	7.20	--	--	2669
158	128	8	55.8	61.0		04-05-1978	292	24.0	--	--	2670
5	--	--	295	--		--	--	--	--	--	2671
--	--	--	370	--		--	--	--	--	--	2672
--	--	--	540	--		--	--	--	--	--	2673
--	--	--	340	--		--	--	--	--	--	2674
--	--	--	320	--		--	--	--	--	--	2675
--	--	--	200	--		--	--	--	--	--	2676
--	--	--	190	--		--	--	--	--	--	2677
--	--	--	530	--		--	--	--	--	--	2678
--	--	--	550	--		--	--	--	--	--	2679
--	--	--	180	--		--	--	--	245	6.3	2680
--	--	--	220	--		--	--	--	--	--	2681
175	90	6	420	3.40	M	05-21-1984	3	--	--	--	2682
--	--	6	320	17.3	M	05-21-1984	--	--	--	--	2683
--	--	6	310	8.27	M	05-21-1984	--	--	--	--	2684
--	--	6	350	38.9	M	05-21-1984	--	--	--	--	2685
205	--	6	340	12.0	M	05-21-1984	--	--	--	--	2686
--	--	6	300	12.8	M	06-04-1984	--	--	--	--	2687
30	--	6	280	7.78		05-21-1984	--	--	--	--	2688
160	147	6	340	38.0	M	06-07-1984	50	--	--	--	2689
120	75	6	285	13.2	M	05-21-1984	75	.75	--	--	2690
200	70	6	480	23.7	M	05-18-1984	60	3.00	--	--	2691
95	60	6	350	13.6	M	11-27-1984	200	2.50	--	--	2692
90	80	6	335	20.5	M	05-19-1984	100	1.40	--	--	2693
83	60	6	335	17.0	M	11-27-1984	20	.32	--	--	2694
95	75	6	325	15.3	M	05-19-1984	50	--	--	--	2695
95	42	6	340	4.68	M	05-21-1984	60	.71	--	--	2696
120	65	6	340	7.73	M	05-24-1984	50	.70	--	--	2697
95	30	6	320	23.0	M	05-24-1984	50	--	--	--	2698
126	126	6	335	19.7	M	05-24-1984	1	--	--	--	2699
144	140	6	320	35.7	M	05-24-1984	100	2.30	--	--	2700
35	--	6	300	16.1	M	05-24-1984	8	--	--	--	2701
60	--	6	260	9.30	M	05-24-1984	5	--	--	--	2702
220	126	6	290	5.56	M	05-24-1984	17	.08	--	--	2703
243	65	6	330	1.86	M	06-03-1984	50	.27	--	--	2704
170	21	6	270	18.9	M	05-24-1984	2	--	--	--	2705
--	--	6	270	43.5	M	06-01-1984	--	--	--	--	2706
220	25	6	330	24.4	M	06-05-1984	--	--	--	--	2707
146	134	8	255	26.8	M	06-04-1984	400	--	--	--	2708
140	100	6	330	34.7	M	06-05-1984	80	.91	--	--	2709
85	72	6	255	--		--	--	--	--	--	2710
250	40	12	255	--		--	325	--	--	--	2711
79	76	12	270	--		--	200	--	--	--	2712
330	40	12	285	--		--	--	--	--	--	2713
12	--	--	250	.00		06-04-1984	500	--	--	--	2714
220	20	6	350	59.7	R	06-04-1984	2	.02	--	--	2715
370	48	6	355	55.0	M	06-04-1984	1	.01	--	--	2716
--	--	10	300	12.0	M	06-05-1984	--	--	--	--	2717
--	--	10	290	4.25	M	06-05-1984	--	--	--	--	2718
100	60	6	305	35.0	M	06-05-1984	20	--	--	--	2719
11	--	--	275	6.68	M	06-06-1984	--	--	--	--	2720
197	165	6	315	21.7	M	06-06-1984	231	15.0	--	--	2721
--	--	6	320	26.0	M	06-06-1984	--	--	--	--	2722
180	--	6	340	29.8	M	06-06-1984	--	--	--	--	2723
100	71	6	280	28.5	M	06-07-1984	25	.33	--	--	2724
40	--	6	280	5.60	M	06-07-1984	--	--	--	--	2725
95	20	6	260	7.44	M	06-07-1984	8	--	--	--	2726
145	20	6	300	18.0	M	06-07-1984	--	--	--	--	2727
62	21	6	295	19.8	M	06-07-1984	24	1.30	--	--	2728
83	66	8	270	37.0	R	06-07-1976	300	--	--	--	2729
43	27	6	300	7.58	M	06-08-1984	60	6.00	--	--	2730

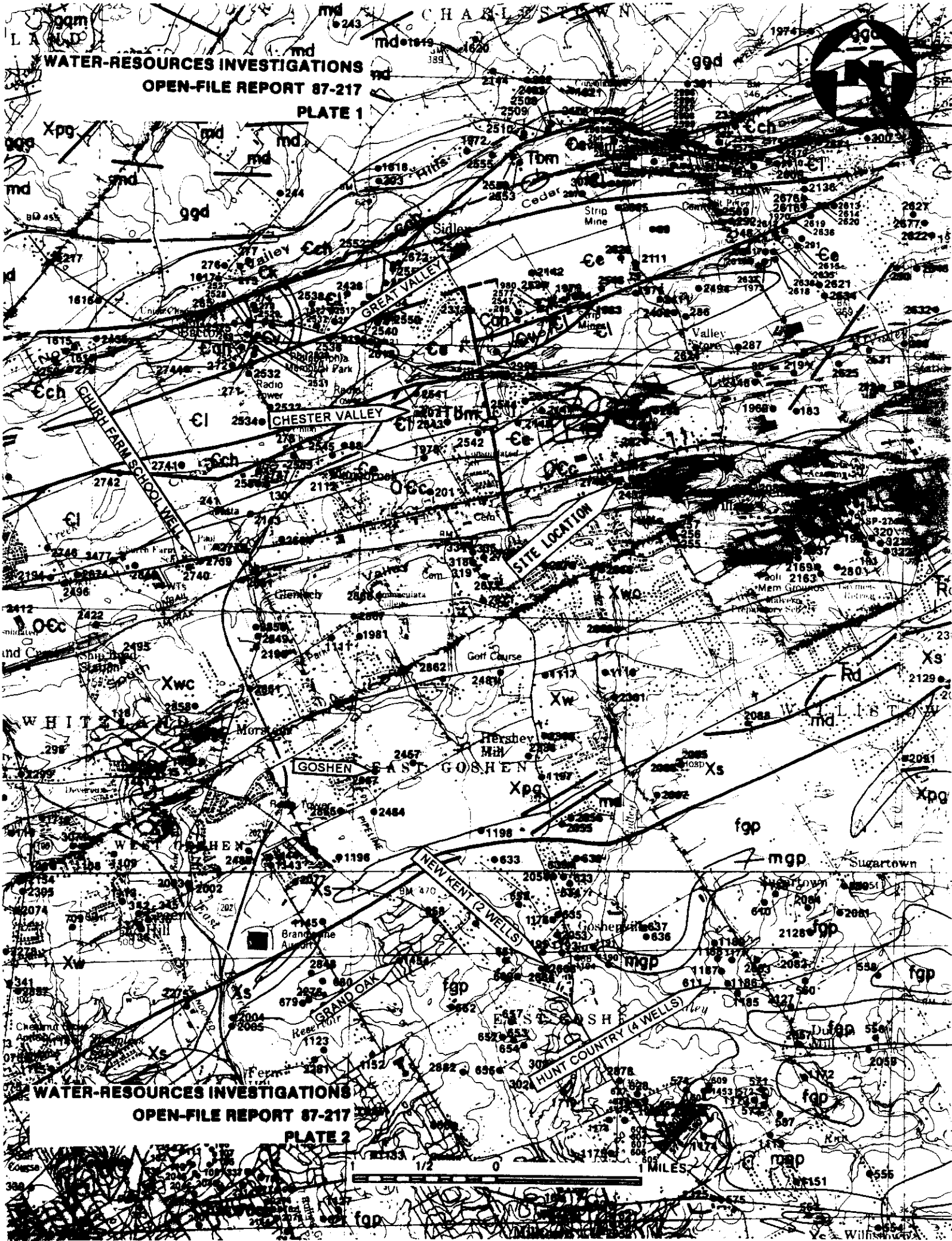
Table 2.-- Records of wells -- Continued

Local number	Site identification number	Owner	Driller	Date drilled	Use of site	Use of water	Aquifer code
CH-2731	400100075381701	MEINHART, R	BROOKOVER WELL DRLG. CO.	1983	W	C	367CNSG
2732	400042075365901	PULCINI, ROCK	BROOKOVER WELL DRLG. CO.	1981	W	C	367CNSG
2733	395716C75442601	MOORE, ALVIN	--	--	W	C	300PRCX
2734	400128C75381001	COMMUNICATIONS TEST DESIGN	BROOKOVER WELL DRLG. CO.	1981	W	C	367CNSG
2735	400132075373501	ROBERTS, GEORGE	MCELHANEY & GRIFFITHS	1973	U	U	367CNSG
2736	400127C75372101	BLACKWELL, WILLIAM	THOMAS G. KEYES	1977	W	I	367CNSG
2737	400114075372201	SCHAVNIS, ANDREW	--	--	W	H	367CNSG
2738	403753C75015301	MAIR EXPRESS	BROOKOVER WELL DRLG. CO.	1975	W	C	377LDGR
2739	400153075353501	CHURCH FARM SCHOOL	--	1919	W	T	367CNSG
2740	400153C75353502	CHURCH FARM SCHOOL	--	1919	W	T	367CNSG
2741	400228075354401	CHURCH FARM SCHOOL	--	--	W	H	377CCKS
2742	400227C75361301	CHURCH FARM SCHOOL	--	--	W	H	377LDGR
2743	400224075370501	CHURCH FARM SCHOOL	--	--	W	H	377LDGR
2744	400304C75354101	CHURCH FARM SCHOOL	THOMAS G. KEYES	1970	W	H	377MRPR
2745	400158075352801	ST PAUL'S CHURCH	THOMAS G. KEYES	--	W	C	367CNSG
2746	400200075345001	MEDBERG, ROBERT	THOMAS G. KEYES	1977	W	H	377LDGR
2747	400226C75350702	FOOTE MINERAL CO	--	1940	U	U	377LDGR
2748	395631C75343701	WEDGEWOOD SWIM CLUB	--	--	W	R	400FLCGM
2749	400223075321901	BISHOP TUBE	--	--	W	N	300WSCKA
2750	395725075352001	SHRIVER CONSTRUCTION	--	--	W	N	400FLCGP
2751	405649075344001	W GOSHEN TWP MUN AUTHORITY	--	--	W	D	400FLCGM
2752	395753C75374201	PENNINGTON BODY SHOP	--	--	W	I	400FLCGM
2753	400038C754C1101	GENERAL CRUSHED STONE	C. S. GARBER & SONS, INC.	1974	W	A	377LDGR
2754	395158C75510301	DIPROSPERO, C	--	--	W	H	300WSCKO
2755	395137075501001	YARNER, E	--	--	W	H	400FLCGM
2756	394937075511501	PARSON , T	--	--	W	H	300WSCKO
2757	394944075495701	WATSON	--	--	W	H	300WSCKO
2758	394947C755C5201	GLASCO , E	--	--	W	H	300WSCKO
2759	394944C755C0901	GLASCO , E	--	--	W	H	300WSCKO
2760	394939075501001	ANGELL, R	--	--	W	H	300WSCKO
2761	394957075503001	STEVENS	--	--	W	H	300WSCKO
2762	394955075502301	MACAULEY , R	--	--	W	H	300WSCKO
2763	395002C755C2301	BIPILIPPO	--	--	W	H	300WSCKO
2764	395016C755C2501	REMLEY	--	--	W	H	300CCKV
2765	395059075503101	LEWIS , D	--	--	W	H	300STRS
2766	395100075503101	WHITE	--	--	W	H	300STRS
2767	395120C755C3201	GRUGAN , L	--	--	W	H	300STRS
2768	395123075503301	CONNERY , L	--	--	W	H	300STRS
2769	395131C755C3401	YARNALL	--	--	W	H	300STRS
2770	394956075493301	BRANDE , R	--	--	W	H	300WSCKO
2771	395C02075493001	SCLIWODA	--	--	W	H	300WSCKO
2772	395014075492601	KAVANAGH , E	--	--	W	H	300CCKV
2773	395014075492901	KAVANAGH , E	--	--	W	H	300CCKV
2774	395C15C75490202	LAMBERT , C	--	--	W	H	300WSCKO
2775	395C19C75484001	PAGAN , W	--	--	W	H	300STRS
2776	395043C75475901	BROSURE	--	--	W	H	300CCKV
2777	395C45C75474201	STEGER	--	--	W	H	300CCKV
2778	395134075465901	PEIRSON , S	--	--	W	H	300STRS
2779	395130075465601	BOTT , T	--	--	W	H	300STRS
2780	395133C75465601	BOTT , T	--	--	W	H	300STRS
2781	395056075463201	SHARPLESS	--	--	U	U	300CCKV
2782	395107C75463301	SHARPLESS	--	--	W	H	300CCKV
2783	395125075461101	MALMOTO , M	--	--	W	H	300CCKV
2784	395124075461701	MALMOTO , M	--	--	W	H	300CCKV
2785	395132C75455301	UNIVERSITY OF PA	--	--	U	U	300CCKV
2786	395206075452501	UNIVERSITY OF PA	--	--	U	U	400FLCGM
2787	395204075452801	UNIVERSITY OF PA	--	--	W	T	400FLCGM
2788	395156075452601	UNIVERSITY OF PA	--	--	W	T	300STRS
2789	395133075451401	UNIVERSITY OF PA	--	--	W	T	400FLCGM
2790	395112075450801	UNIVERSITY OF PA	--	--	W	T	400FLCGM
2791	394938075452301	FREZZO , E	--	--	U	U	300WSCKO
2792	394951075471301	AVONDALE W W TREATMENT PLANT	--	--	U	U	300STRS
2793	394910075491201	WEST GROVE BORO	--	--	W	P	300WSCKO
2794	395613075 4C1101	GOODFELLOW	--	--	W	H	400FLCGP
2795	395035075471501	LLOYD , A	--	--	W	H	300CCKV
2796	395010075454301	GEIST , J	--	--	W	H	300STRS
2797	394726075580701	BOROUGH OF OXFORD	F. L. BOLLINGER & SONS	--	W	P	300WSCKO
2798	394718075581401	BOROUGH OF OXFORD	--	1981	W	P	300WSCKO
2799	394922075491801	WEST GROVE BORO	R. WALTER SLAUCH & SONS	1977	W	P	300WSCKO
2800	400337075495601	GABEL, CHARLES	--	--	W	H	377CCKS

CHURCH FARM SCHOOL WELL

Depth of well (feet)	Depth cased (feet)	Casing diameter (inches)	Elevation of land surface (feet)	Water level (feet)	Date water level measured	Discharge (gallons per minute)	Specific capacity (gpm/ft)	Specific conductance (micro-siemens)	pH	Local number
50	--	6	320	6.50 M	06-08-1984	--	--	--	--	CH-2731
117	--	6	300	33.6 M	06-11-1984	--	--	--	--	2732
--	--	6	390	34.1 M	07-07-1987	--	--	--	--	2733
230	20	6	290	15.9 M	07-09-1981	36	.21	--	--	2734
376	22	6	345	23.3 M	06-11-1984	<1	--	--	--	2735
240	40	6	375	21.6	06-11-1984	1	.01	--	--	2736
--	--	6	375	18.2 M	06-11-1984	--	--	--	--	2737
75	72	6	315	17.9 M	06-11-1984	60	1.60	--	--	2738
130	--	6	410	17.6 M	06-12-1984	--	--	--	--	2739
150	--	6	410	--	--	--	--	--	--	2740
--	--	6	380	33.8 M	06-12-1984	--	--	--	--	2741
--	--	6	540	3.60	06-12-1984	--	--	--	--	2742
--	--	6	355	18.8 M	06-12-1984	--	--	--	--	2743
--	--	6	415	.04 M	06-12-1984	--	--	--	--	2744
--	--	6	410	19.0 M	06-12-1984	1	--	--	--	2745
220	40	6	330	18.2 M	06-12-1984	30	.17	--	--	2746
225	92	10	380	62.0 M	06-13-1984	144	9.00	--	--	2747
--	--	--	460	--	--	--	--	--	--	2748
200	--	--	400	--	--	--	--	--	--	2749
--	--	--	400	--	--	--	--	--	--	2750
--	--	--	370	--	--	--	--	--	--	2751
--	--	--	330	--	--	--	--	--	--	2752
225	67	6	300	25	03-19-1975	--	--	--	--	2753
--	--	--	400	42.9 M	06-26-1984	--	--	--	--	2754
117	--	--	540	24.8 M	06-26-1984	--	--	--	--	2755
187	--	--	500	24.0 M	06-26-1984	6	--	--	--	2756
--	--	--	490	27.0 M	06-26-1984	--	--	--	--	2757
185	--	--	500	24.1 M	06-26-1984	5	--	--	--	2758
121	--	--	470	21.6 M	06-26-1984	8	--	--	--	2759
--	--	--	450	.00 M	06-26-1984	--	--	--	--	2760
--	--	--	440	13.4 M	06-26-1984	--	--	--	--	2761
--	--	--	470	3.31 M	06-26-1984	--	--	--	--	2762
--	--	--	490	40.7 M	06-26-1984	--	--	--	--	2763
--	--	--	440	33.4 M	06-26-1984	--	--	--	--	2764
--	--	--	490	8.75 M	06-26-1984	--	--	--	--	2765
--	--	--	490	8.81 M	06-26-1984	--	--	--	--	2766
--	--	--	500	7.91 M	06-25-1984	7	--	--	--	2767
--	--	--	510	16.9 M	06-24-1984	--	--	--	--	2768
--	--	--	540	--	06-24-1984	--	--	--	--	2769
120	--	--	450	24.0 M	06-27-1984	--	--	--	--	2770
124	--	--	470	30.6 M	06-27-1984	--	--	--	--	2771
--	--	--	360	14.0 M	06-27-1984	--	--	--	--	2772
--	--	--	370	15.7 M	06-27-1984	--	--	--	--	2773
70	--	--	400	20.7 M	06-27-1984	--	--	--	--	2774
--	--	--	350	68.5 M	06-27-1984	--	--	--	--	2775
70	--	--	330	8.73 M	06-27-1984	7	--	--	--	2776
42	--	--	350	26.5 M	06-27-1984	--	--	--	--	2777
26	--	--	340	17.7 M	06-27-1984	--	--	--	--	2778
280	--	--	350	1.92 M	06-27-1984	--	--	--	--	2779
200	--	--	350	13.5 M	06-27-1984	--	--	--	--	2780
--	--	--	320	3.65 M	06-28-1984	--	--	--	--	2781
--	--	--	330	8.02 M	06-28-1984	--	--	--	--	2782
--	--	--	350	17.2 M	06-28-1984	--	--	--	--	2783
--	--	--	360	2.63 M	06-28-1984	--	--	--	--	2784
--	--	--	390	23.1 M	06-28-1984	--	--	--	--	2785
--	--	--	420	2.05 M	06-28-1984	--	--	--	--	2786
--	--	--	400	7.05 M	06-28-1984	--	--	--	--	2787
--	--	--	390	13.9 M	06-28-1984	--	--	--	--	2788
--	--	--	390	57.2 M	06-28-1984	--	--	--	--	2789
--	--	--	470	18.1 M	06-28-1984	--	--	--	--	2790
--	--	--	370	26.6 M	07-16-1984	--	--	--	--	2791
--	--	--	270	10.7 M	09-18-1984	--	--	--	--	2792
--	--	--	380	12.4 M	09-18-1984	--	--	--	--	2793
--	--	6	290	26.0 M	07-08-1987	--	--	--	--	2794
--	--	--	300	10.7 M	07-16-1984	--	--	--	--	2795
--	--	--	440	.00	07-16-1984	--	--	--	--	2796
400	--	--	480	11.5	12-02-1981	--	--	--	6.3	2797
400	--	--	485	7.75	12-14-1981	--	--	--	6.2	2798
--	41	12	350	15.0 P	06-20-1977	250	11.4	--	--	2799
185	--	--	740	--	--	--	--	--	--	2800

WATER-RESOURCES INVESTIGATIONS
OPEN-FILE REPORT 87-217
PLATE 1



WATER-RESOURCES INVESTIGATIONS
OPEN-FILE REPORT 87-217
PLATE 2

ORIGINAL (Red)

REFERENCE NO. 41

TELEPHONE CONVERSATION REPORTING FORM

ISSUE DATE	
FILE NUMBER	3620-21-03-0
RECORDED BY	TIMOTHY UNGRADY, GEOLOGIST
TELEPHONE NUMBER	610 971-0900
CALL ☐ TO ☒ FROM — NAME	LEROY COER (LC) PHYSICAL PLANT MANAGER
TELEPHONE NUMBER	610 363-7500
COMPANY	CHURCH FARM SCHOOL
DATE OF CALL	5/4/95
ADDRESS	EXTON, PA
TIME	8:45 ☒ A.M. ☐ P.M.
CONFERENCE CALL ☒ NO ☐ YES (If YES, list conferees, conferees company, etc. in notes.)	
JOB NUMBER	3620-21
CLIENT/PROJECT	ALLISTER COMPANY HRS
SUBJECT	WATER SUPPLY

CONVERSATION NOTES:

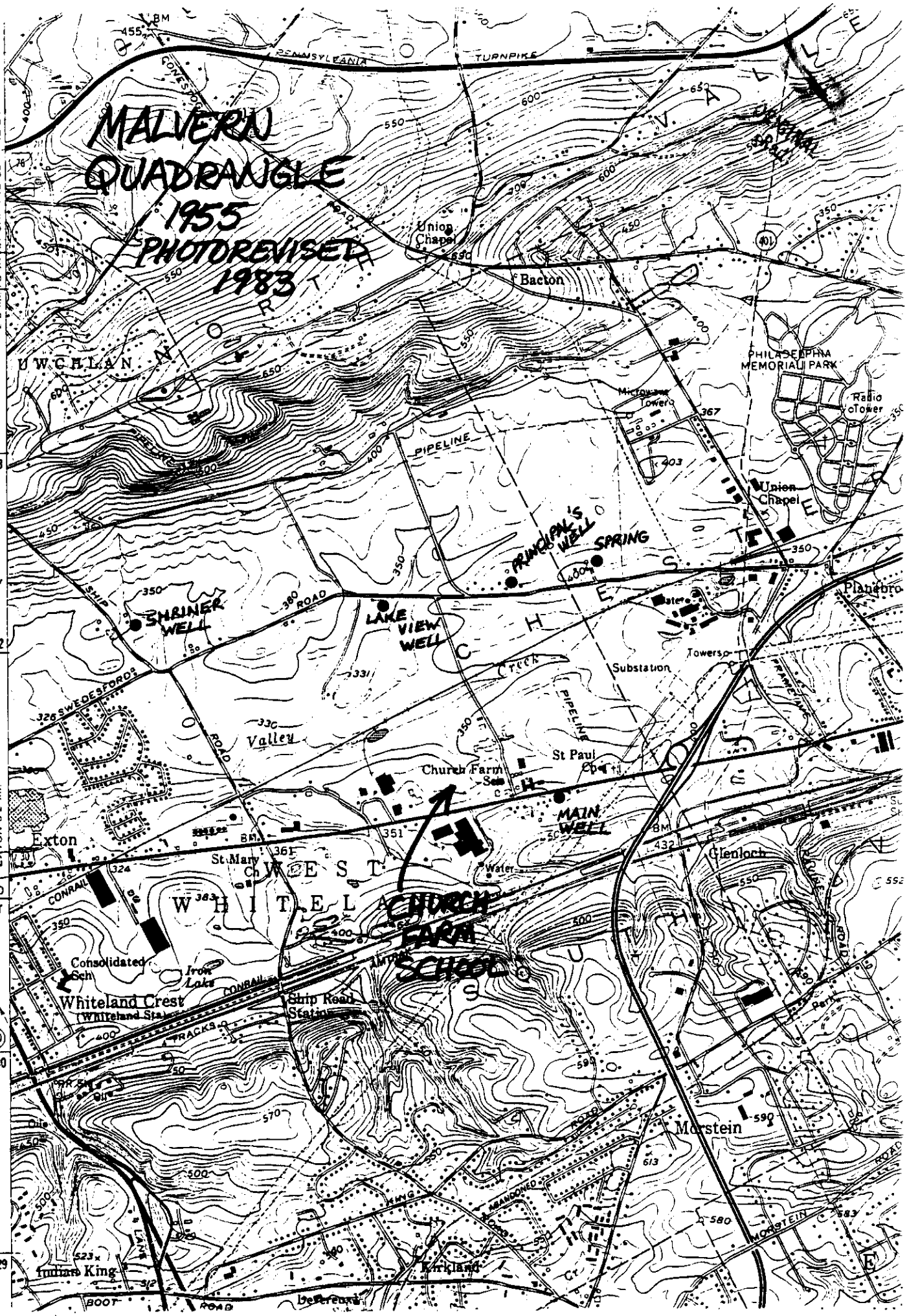
LC returned my call of 5/3/95. Church Farm School receives its water from two main sources. The first is a well that, according to LC, has pumps at about a depth of 90 feet. The well depth is estimated to be 100 to 150 feet deep. This well produces at 12,000 to 15,000 gallons per day and pumps to a 50,000 gallon reservoir. This main well serves the dorms and school and supplies 200 to 240 persons with water. LC helped me locate this well, as well as the following wells/spring, on the Malvern Quadrangle topographic map. The other main source of water is a spring house located on the North side of Swedesford Road next to a barn at the end of a small lane. Water from the spring house is stored in a 3,000 gallon fiber glass tank. The spring house water serves the faculty (40 to 50 persons). Three other wells are located north of Swedesford Road: the Shriner well (serves two houses), the Lake View well (serves one house), and the "principal's well" (serves main house and 6 other houses, 7 houses total). All of the water sources discussed above are located on the attached map. LC helped me locate the water sources. TBU 5/4/95

ACTION/RESPONSE		
RESPONSIBLE PERSON	ACTION NEEDED	DUE DATE

~~COPIES TO:~~ Note: Water from the main well and spring are not mixed. TBU 5/4/95

(b) (4) [redacted]

Order No. 11028 (12-90)


MALVERN QUADRANGLE 1955 PHOTOREVISED 1983
PRINCIPAL'S WELL
SPRING
SHRINER WELL
LAKE VIEW WELL
MAIN WELL
CHURCH FARM SCHOOL
PENNSYLVANIA TURNPIKE
Union Chapel
Bacton
PHILADELPHIA MEMORIAL PARK
Radio Tower
Microwave Tower
PIPELINE
Planebro
Substation
Towers
Creek
Valley
St Paul Ch
Church Farm Sch
Exton
St Mary Ch
WEST WHITELAND
Glenloch
Consolidated Sch
Iron Lake
Whiteland Crest
(Whiteland Sta)
Ship Road Station
Morstein
Kirkland
Indian King
Devereux
CONRAIL
TRACKS
SWEDESFORD ROAD
SHIP ROAD
KING ROAD
MORSTEIN ROAD
BOOT ROAD
5864 II SW (DOWNINGTOWN)
HARRISBURG 70 MI TO INTERCHANGE 23
2.6 MI.
LANCASTER (CIVIC CENTER) 36 MI.
EXTON 0.2 MI.
0.6 MI. TO U.S. 30
2'30"
260 000 FEET
4433
4432
4430
4429

ORIGINAL (Red)

REFERENCE NO. 42

RECEIVED
OCT 26 1983
ENVIRONMENTAL
WATER QUALITY
NORRISTOWN

PREPAREDNESS, PREVENTION AND CONTINGENCY PLAN

BISHOP TUBE COMPANY

FRAZER, PENNSYLVANIA

Prepared By

Resource Management Int'l., Inc.

July 20, 1981

Update By

Bishop Tube Company

October 1983

BISHOP TUBE COMPANY

PREPAREDNESS, PREVENTION AND CONTINGENCY PLAN

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 *Partial Copies

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*Partial Copies

SECTION 3

Material and Waste Inventory

Materials used at Bishop Tube Company fall into the following categories:

1. oils and lubricants
2. drawing compounds
3. solvents/cleaners/thinners

The chemical name, manufacturer and quantity used for each material are listed below. The Material Safety Data Sheets are compiled in a separate document. The respective page number in the document is included for reference.

Chemical Name	Manufacturer	Quantity Used	Reference Page No.
Acetone	East Falls Chemical	50 gal/yr	1
Al Draw J2	Hangsterfer's Labs	2 drum/yr	2
Anhydrous Ammonia	USS Agri-Chemicals Div.	minimal	3
Apex 205 Drawing Oil	Apex Alkali Products Co.	16 drum/yr	4
Apex 415 Cleaning Compound	Apex Alkali Products Co.	3 drum/yr	5
Calgon P-3576	Calgon Corp.	2 drum/yr	12
Chemtrol #176	Precision Finishing Co.	2 drum/yr	14
Chemtrol #229	Precision Finishing Co.	15 gal/yr	15
Chemtrol #400	Precision Finishing Co.	1 drum/yr	16
Die Gard 84	Reilly-Whiteman Inc.	minimal	18
Draw Compound #100	Algonquin Chemical Co.	5 drum/yr	20
Entec	Betz-Entec Co.	gal/yr	6

Chemical Name	Manufacturer	Quantity Used	Reference Page No.
Entec 747	Betz-Entec Co.	10 gal/yr	10
Entec 701	Betz-Entec Co.	45 gal/yr	6
Entec 733	Betz-Entec Co.	30 gal/yr	8
Freon T.F.	E.I. DuPont deNemours	minimal	23
Fuel Oil #2	Sun Petroleum Products Co.	375,000 gal/yr	24
Genesolv D	Allied Chemical Corp.	24 drum/yr	25
Hydrofluoric Acid (70%)	Allied Chemical Corp.	9,000 gal/yr	26
Lube-A-Tube	G. Whitfield Richards Corp.	14 drum/yr	28
Mobil Regular 10	Mobile Oil Corp.	1 drum/yr	30
Mobil Regular 40	Mobile Oil Corp.	1 drum/yr	31
Molub-Alloy 90	Imperial Oil and Grease Co.	minimal	33
Molub-Alloy 170	Imperial Oil and Grease Co.	minimal	34
Nitric Acid (42%)	Allied Chemical Corp.	14,000 gal/yr	35
P.C. #5	Hangsterfer's Labs	600 gal/yr	36
P.C. #614	Hangsterfer's Labs	360 gal/yr	37
Perchlorethylene	Vulcan Materials Co.	5 gal/yr	38
Rochester Formula 260	Rochester Germicide Co.	3 drum/yr	40
Rycosol 66	Reilly-Whiteman Inc.	5 drum/yr	41
Rycosol 69	Reilly-Whiteman Inc.	5 drum/yr	42
Solnus 150	Sun Petroleum Products Co.	1 drum/yr	49
Sulfuric Acid (Reagent)	E.I. DuPont deNemours	54 lb/yr	48
Sunaplex EP GR992	Sun Petroleum Products Co.	2 drum/yr	51

Chemical Name	Manufacturer	Quantity Used	Reference Page No.
Sunicut 351	Sun Petroleum Products Co.	36 drum/yr	56
Sunfleet 20W40	Sun Petroleum Products Co.	6 drum/yr.	55
Trichlorethylene	PPG Industries	20,000 gal/yr	59
UconLubricant 700	Union Carbide Corp.	20 gal/yr	62
Vydex AR	E. I. DuPont deNemours	330 gal/yr	64

Three (3) parts washers owned, installed and maintained by Safety Kleen Corporation are located in the production areas (2) and maintenance shop (1). Solvent used is mineral spirits and is transferred and recycled by Safety Kleen personnel.

The hazardous wastes which have been removed from this site since implementation of the manifest system are earth from a previous spill, spent acids, spent acid rinse water, acid sludge, spent TCE and spent transformer oil containing PCB. These wastes have been shipped for treatment and disposal at approved treatment and/or disposal facilities. The quantity of each is recorded, and manifests are retained at Bishop Tube Co. Waste acid pickling solution and waste acid rinsewater are stored in outdoor storage tanks and removed two or three loads per week by a licensed hazardous waste hauler to a licensed waste treatment facility for treatment and disposal.

The remainder of the wastes generated are contained in 55 gallon drums meeting D.O.T. specifications. These wastes have been analyzed to permit contracting with permitted disposal firm(s) for removal and disposal or recycling when enough drums have been accumulated.

The location of the use of each material and the process using the material are described in Section 4, Plant Operations, and on Drawing No. 3, Page 4-4

SECTION 4

Plant Operations

Flow of materials through the facility as described below is shown on Drawing No. 3, Process Identification, Page 4-4

Stainless steel hollow tubes are transported from the yard to the weigh out area (1) and assigned to orders by weight or specific lengths. Materials then move to the pickle house (2) for cleaning prior to processing. The first production operation is pointing (3). This operation allows the tubes to enter dies so they can be drawn to a smaller diameter. Tubes are then moved to draw benches (4) and drawn to specific size. Some tubes are drawn onto a mandrel bar to reduce both outside diameter and wall thickness. These tubes, in turn, are run through a derodder that allows the mandrel bars to be removed. Other types of drawing operations do not use a mandrel.

After drawing, tubes are moved to the cut-off and degreaser area (5) where they are trimmed or cut to specific length, then cleaned in a tank containing TCE to remove all dirt, lubricants or oils before continuing with processing. Tubes are then annealed (6) at a specified temperature and heat soak period. Annealing is performed in a gas-fired, open hearth furnace or in one of four controlled atmosphere furnaces. After annealing, tubes are straightened (7) for further processing.

After straightening, if tubes are finish size, they are moved to trim, ream and deburr (8). When tubes are finished they are pickled (2) as a final

cleaning operation and moved to finish and inspection (10) to perform necessary finishing and testing required by specifications for that order. Defects are cut out and the tubes are measured and stamped, then transported to shipping (11) for wrapping and boxing.

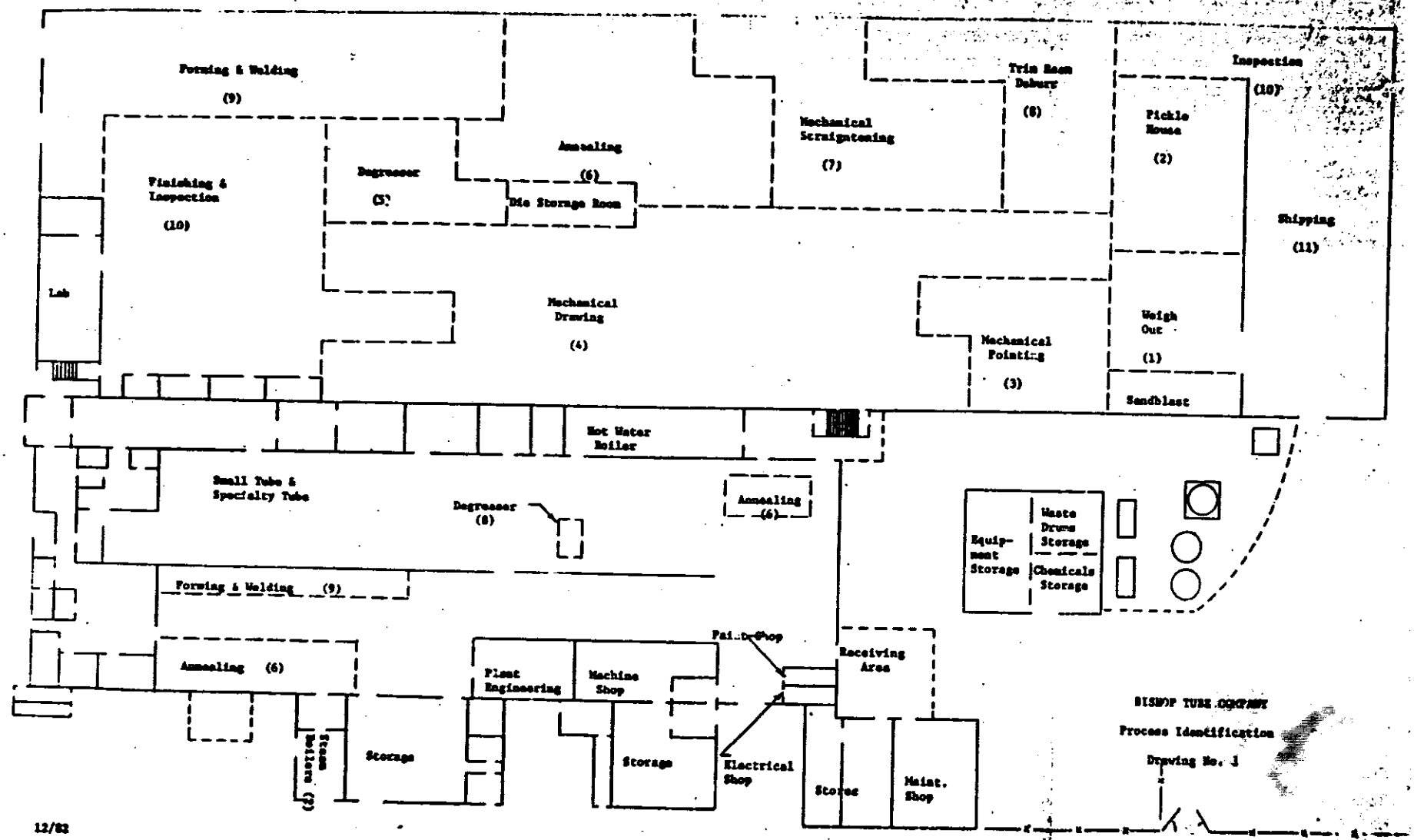
Welded pipe and tubing is produced from stainless steel strip by forming and welding (9), annealing (6), straightening (7), trim and deburr (8), pickling (2) and inspection (10) before going to shipping (11).

Some orders require auxiliary operations as follows:

1. Sandblast - Abrasive grit is blown through the tubes under pressure to clean the inside of the tubes.
2. Spray lube - Liquid lubricant is sprayed into the tubes to prevent gouging the inside of tubes during a plug-draw operation.
3. Polishing - A polisher uses abrasive belts to remove outside defects or reduce wall thickness.

The materials listed in Section 3 which are used in the respective process areas are described below. The process areas are referenced on Drawing No.3.

Process Area	Chemicals/Substances
1 - Weighout	No chemicals used
2 - Pickle House	Pickle solution of nitric and hydrofluoric acids in water.
	Scrubber solution containing NaOH
3 - Mechanical Pointing	Motor oil, 20W40
4 - Mechanical Drawing	Motor oils, gear oils and drawing lubes including: Apex 205 Draw Compound 100 Lube-A-Tube T210D #[illegible] PC #614 PC Solnus 1[illegible]0 Die Guard 84 Al Draw J2 Vydax [illegible] Freon [illegible]/Genesolv D
5 - Degreaser	Trichloroethylene
6 - Annealing	Ammonia (minimal use) or hydrogen
7 - Mechanical Straightening	No chemicals used
8 - Trim, Ream, Deburr	No chemicals used
9 - Form and Weld	Rycosol 66 (lubricant/coolant)
10 - Finishing and Inspection	Rycosol 69 (polishing lubricant/coolant)
11 - Shipping	No chemicals used.


Forming & Welding
(9)
Finishing & Inspection
(10)
Degreaser
(5)
Annealing
(6)
Die Storage Room
Mechanical Straightening
(7)
Trim Room Deburr
(8)
Pickle House
(2)
Inspection
(10)
Shipping
(11)
Lab
Mechanical Drawing
(4)
Mechanical Painting
(3)
Weigh Out
(1)
Sandblast
Hot Water Boiler
Small Tube & Specialty Tube
Degreaser
(8)
Annealing
(6)
Equipment Storage
Waste Drums Storage
Chemicals Storage
Forming & Welding (9)
Annealing (6)
Plant Engineering
Machine Shop
Paint Shop
Receiving Area
Storage
Storage
Electrical Shop
Stores
Maint. Shop
Boilers (2)
Steam
12/82
BISHOP TUBE COMPANY
Process Identification
Drawing No. 1

0 0 0 9 9 5

SECTION 5

Material Compatibility

This section describes the bulk process and storage tanks. Drawing No. 4 identifies the locations of these areas. All tanks, containers, valves, piping and containments have been designed to be compatible with materials they will contact.

Tank specifications are as follows:

Bulk TCE Storage Tank

Capacity: 4000 gallons (64" Dia x 24' L)

Construction: Carbon steel, thickness 7 gauge, three (3) supports of 3 inch pipe (one at each end, one center) on concrete pads.

Transfer: TCE is piped to the main degreaser via 1-1/4" carbon steel pipe. An in-line 1-1/4" Jenkins cut-off valve is used in addition to a locking cut-off valve, both at the storage tank.

Loading: Filling is accomplished by an outside contractor through a port on the tank top. The port is locked when not in use.

Pickling Rinse Water Sump Tank

Capacity: 1250 gallons (86" Dia x 45" H)

Construction: High density crosslinked polyolefin, 3/8" thick; tank rests inside acid resistant coated cinderblock and concrete containment area.

Transfer: Spent acid rinse water is gravity drained from rinse tanks in the pickling area to the sump tank via a lined drainage trench and 4" PVC pipe.

Spent acid rinse water is transferred from the sump tank to the storage tanks via two pumps (one operational, one standby). Both pumps are constructed of acid resistant materials and are equipped with automatic interlocking level controls.

Pickling Rinsewater Storage Tanks (2)

Capacity: 5600 gallons each (9'2" Dia x 12'5"H)

Construction: High density crosslinked polyolefin, 5/8" thick; tanks rest on compacted crushed stone and limestone fines. The two tanks are interconnected.

Transfer: Waste rinsewater is transferred to tank trucks by an acid resistant pump.

Note: Waste fume scrubber water containing caustic soda is also stored in the waste rinsewater storage tanks.

Spent Acid Storage Tank

Capacity: 4000 gallons (9' Dia x 9'H)

Construction: Carbon steel, 1/4" thick, open top, 3/32" Atlastaflex (PVC) liner; mounted on concrete pad with angle steel supports.

Transfer: Spent acid is pumped directly from the pickling tanks to the storage tanks via 2" and 4" PVC pipe. The pump is of acid resistant material. The same pump as for waste rinsewater pumps the waste acid into tank trucks for treatment and disposal.

Plant 8 Boiler Fuel Oil Tank

Capacity: 20,000 gallons (10' Dia x 34'2"L)

Construction: Carbon steel, thickness unknown

Loading: Filling is accomplished by outside supplier through a port adjacent to boiler room. An open drum is used under the filler port to prevent spillage.

Plant 5 Boiler Fuel Oil Tanks

Capacity: 5,000 gallons each (2)

Construction: Carbon steel, thickness unknown

Loading: Filling is accomplished by outside supplier at loading ports in the macadam driveway adjacent to the boiler room.

Anhydrous Ammonia Storage Tank

Capacity: 8,000 gallons (84" Dia x 370"L)

Construction: Carbon steel, shell-SA455B, .573" thick
heads-SA455A, .328" thick

Transfer: The ammonia is gravity fed under pressure (approx. 100 psi) by a 1" carbon steel pipe to the ammonia dissociator for use in the annealing process. Locked shut-off valve: Located at the storage tank.

Loading: Filling is accomplished by outside supplier into 2" fill located on the tank top. The filler port is locked when not in use.

Nitric Acid Tank

Capacity: 4000 gallons (7' Dia x 15'L)

Construction: Stainless Steel Type 304L, 3/16" thick; two (2) steel support saddles on concrete foundations.

Transfer: Acid is gravity fed via a 1 1/4", stainless steel pipe to the pickle house and metered into the pickle tanks with PVC valves at each tank. A locked valve and a manual valve are located at the storage tank.

Loading: Filling is by outside supplier through port on top of tank. Fill line consists of three 90° elbows with internal discharge above liquid level.

Venting: A one-inch PVC pipe connects the storage tank to a pickle tank hood opening to the fume scrubber.

Hydrofluoric Acid Tank

Storage Tank Capacity: 5100 gallons (8' Dia x 15"L)

Tank construction: Carbon steel, 1/2" thick shell and head; two (2) steel support saddles on concrete foundations.

Transfer: Acid is gravity fed via a 1 1/2", teflon lined pipeline to the pickle house and metered to each pickle tank with PVC valves. A locked valve and a manual valve are located at the storage tank.

Venting: A one inch PVC pipe connects the storage tank to a pickle tank hood opening to the fume scrubber.

Pickling Tanks

#1 Capacity: 3200 gallon maximum (33" W x 647"L x 36"H)
2600 gallon operating

Construction: Carbon steel, 1/4" thick; completely lined with 3/4" cement welded polypropylene tank insert.

Transfer: Pickling acid solution is circulated through a heat exchanger and/or to or from other pickle tanks by the same pump used to transfer waste acid solution to the storage tank.

#2 Pickling tank (not currently used)

Capacity: 1600 gallon maximum (28"W x 420"L x 30"H)
1000 gallon operating

Construction: Carbon steel, 3/8" thick, 3/32" Koroseal (PVC) liner.

#3 Capacity: 1450 gallon maximum (28" W x 401" L x 30"H)
1000 gallon operating

Construction: Carbon steel, 3/8" thick, completely lined with 3/32" Koroseal (PVC) and carbon brick.

Transfer: Same as Tank #1

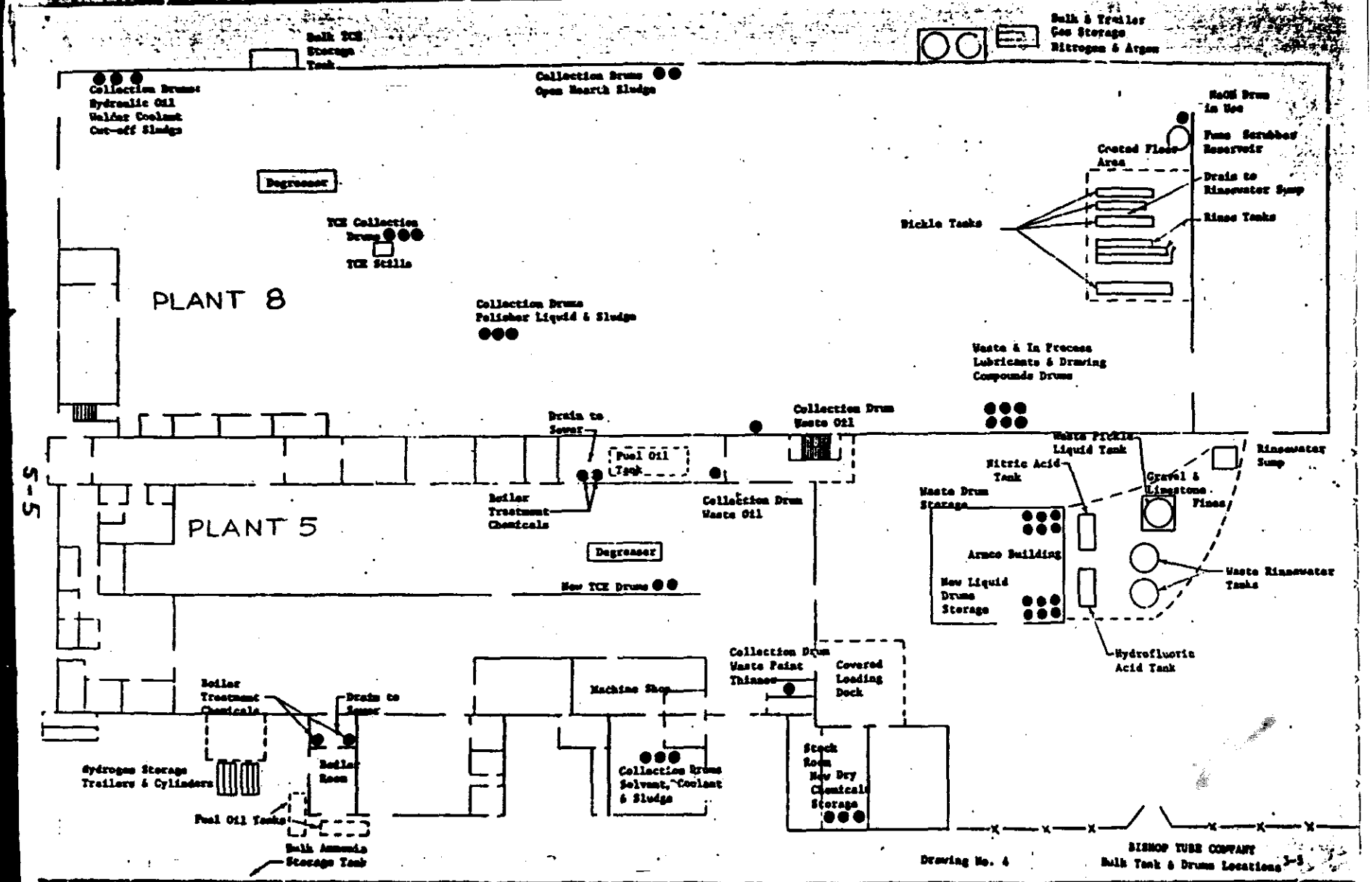
#4 Capacity: 1500 gallon maximum (29" W x 420"L x 29"H)
1000 gallon operating

Construction: Carbon steel, 3/8" thick, completely lined with 3/4" polypropylene

Transfer: Same as Tank #1

No substances are mixed prior to use in the respective process areas. In the pickling tanks water, HNO_3 and HF are introduced in that order in accordance with accepted handling practices to produce the pickling solution. Each acid is introduced at a rate so as not to produce potentially hazardous fumes. Fumes so produced are scrubbed by the packed tower fume scrubber in the attic.

The raw acid, waste acid and waste rinsewater are currently stored in storage tanks described above. In the near future it is planned to contain the storage tanks area by means of a reinforced concrete floor, curbing and, probably, a concrete sump, all lined, with piping facilities to both eliminate rainwater into the stream (after pH testing) and to pump acidic spillage into an undamaged storage tank or unused pickle tank(s) or into a tank truck.


Bulk TCE Storage Tank
Collection Drums: Hydraulic Oil Water Coolant Cut-off Sludge
Collection Drums Open Hearth Sludge
Bulk & Trailer Gas Storage Nitrogen & Argon
NaOH Drum in Use
Fume Scrubber Reservoir
Coated Floor Area
Drain to Rinsewater Sump
Rinse Tanks
Pickle Tanks
Degreaser
TCE Collection Drums
TCE Stills
PLANT 8
Collection Drums Polisher Liquid & Sludge
Waste & In Process Lubricants & Drawing Compounds Drums
Drain to Sewer
Collection Drum Waste Oil
Fuel Oil Tank
Waste Pickle Liquid Tank
Nitric Acid Tank
Rinsewater Sump
Gravel & Limestone Fines
Waste Drum Storage
Boiler Treatment Chemicals
Collection Drum Waste Oil
PLANT 5
Armco Building
New Liquid Drums Storage
Waste Rinsewater Tanks
Degreaser
New TCE Drums
Hydrofluoric Acid Tank
Collection Drum Waste Paint Thinner
Covered Loading Dock
Boiler Treatment Chemicals
Drain to Sewer
Machine Shop
Hydrogen Storage Trailers & Cylinders
Boiler Room
Collection Drums Solvent, Coolant & Sludge
Stock Room New Dry Chemical Storage
Fuel Oil Tanks
Bulk Ammonia Storage Tank
Drawing No. 4
BISHOP TUBE COMPANY
Bulk Tank & Drums Locations
S-5

ORIGINAL
(Red)

REFERENCE NO. 43

Please print or type in the unshaded areas only
(fill-in areas are spaced for elite type, i.e., 12 characters/inch).

Form Approved OMB No. [illegible]0175

FORM 1 GENERAL

U.S. ENVIRONMENTAL PROTECTION AGENCY

GENERAL INFORMATION

Consolidated Permits Program

(Read the "General Instructions" before starting.)

I. EPA I.D. NUMBER

F P A D 0 8 1 8 6 8 3 0 9

LABEL ITEMS

I. EPA I.D. NUMBER

III. FACILITY NAME

V. FACILITY MAILING ADDRESS

VI. FACILITY LOCATION

DER - RECEIVED NORRISTOWN JAN 13 1988

PLEASE PLACE LABEL IN THIS SPACE

GENERAL INSTRUCTIONS

If a preprinted label has been provided, affix it in the designated space. Review the information carefully; if any of it is incorrect, cross through it and enter the correct data in the appropriate fill-in area below. Also, if any of the preprinted data is absent *(the area to the left of the label space lists the information that should appear)*, please provide it in the proper fill-in area(s) below. If the label is complete and correct, you need not complete Items I, III, V, and VI *(except VI-B which must be completed regardless)*. Complete all items if no label has been provided. Refer to the instructions for detailed item descriptions and for the legal authorizations under which this data is collected.

II. POLLUTANT CHARACTERISTICS

INSTRUCTIONS: Complete A through J to determine whether you need to submit any permit application forms to the EPA. If you answer "yes" to any questions, you must submit this form and the supplemental form listed in the parenthesis following the question. Mark "X" in the box in the third column if the supplemental form is attached. If you answer "no" to each question, you need not submit any of these forms. You may answer "no" if your activity is excluded from permit requirements; see Section C of the instructions. See also, Section D of the instructions for definitions of bold-faced terms.

SPECIFIC QUESTIONS	MARK 'X' YES	NO	FORM ATTACHED
A. Is this facility a **publicly owned treatment works** which results in a **discharge** to waters of the U.S.? (FORM 2A)		X	
B. Does or will this facility *(either existing or proposed)* include a **concentrated animal feeding operation** or **aquatic animal production facility** which results in a **discharge** to waters of the U.S.? (FORM 2B)		X	
C. Is this a facility which currently results in **discharges** to waters of the U.S. other than those described in A or B above? (FORM 2C)	X		X
D. Is this a proposed facility *(other than those described in A or B above)* which will result in a **discharge** to waters of the U.S.? (FORM 2D)		X	
E. Does or will this facility treat, store, or dispose of **hazardous wastes**? (FORM 3)	X		
F. Do you or will you inject at this facility industrial or municipal effluent below the lowermost stratum containing, within one quarter mile of the well bore, underground sources of drinking water? (FORM 4)		X	
G. Do you or will you inject at this facility any produced water or other fluids which are brought to the surface in connection with conventional oil or natural gas production, inject fluids used for enhanced recovery of oil or natural gas, or inject fluids for storage of liquid hydrocarbons? (FORM 4)		X	
H. Do you or will you inject at this facility fluids for special processes such as mining of sulfur by the Frasch process, solution mining of minerals, in situ combustion of fossil fuel, or recovery of geothermal energy? (FORM 4)		X	
I. Is this facility a proposed **stationary source** which is one of the 28 industrial categories listed in the instructions and which will potentially emit 100 tons per year of any air pollutant regulated under the Clean Air Act and may affect or be located in an **attainment area**? (FORM 5)		X	
J. Is this facility a proposed stationary source which is NOT one of the 28 industrial categories listed in the instructions and which will potentially emit 250 tons per year of any air pollutant regulated under the Clean Air Act and may affect or be located in an **attainment area**? (FORM 5)		X	

III. NAME OF FACILITY

1 SKIP B I S H O P T U B E C O.

IV. FACILITY CONTACT

A. NAME & TITLE *(last, first, & title)*	B. PHONE *(area code & no.)*
2 M O L E T O N, D A V I D P R O J E C T E N G I N E E R	2 1 5 6 4 7 3 4 5 0

V. FACILITY MAILING ADDRESS

A. STREET OR P.O. BOX

3 B O X 1 1 8 9

B. CITY OR TOWN	C. STATE	D. ZIP CODE
4 F R A Z E R	P A	1 9 3 5 5

VI. FACILITY LOCATION

A. STREET, ROUTE NO. OR OTHER SPECIFIC IDENTIFIER

5 R T 3 0 & M A L I N R D.

B. COUNTY NAME

C H E S T E R

C. CITY OR TOWN	D. STATE	E. ZIP CODE	F. COUNTY CODE *(if known)*
6 F R A Z E R	P A	1 9 3 5 5	

1

CONTINUED FROM THE FRONT

VII. SIC CODES *(4-digit, in order of priority)*

A. FIRST		B. SECOND	
7	STAINLESS STEEL TUBING	7	03 3 5 6 NON-FERROUS TUBING

C. THIRD		D. FOURTH	
7		7	

VIII. OPERATOR INFORMATION

A. NAME: 8 BISHOP TUBE CO.

B. Is the name listed in Item VIII-A also the owner? ☐ YES ☒ NO

C. STATUS OF OPERATOR (Enter the appropriate letter into the answer box; if "Other", specify.)
F = FEDERAL, M = PUBLIC (other than federal or state), S = STATE, O = OTHER (specify), P = PRIVATE: P

D. PHONE (area code & number): A 215 647 3450

E. STREET OR P.O. BOX: ROUTE 30 & MALIN RD

F. CITY OR TOWN: 8 FRAZER

G. STATE: PA

H. ZIP CODE: 19355

IX. INDIAN LAND

Is the facility located on Indian lands? ☐ YES ☒ NO

X. EXISTING ENVIRONMENTAL PERMITS

A. NPDES (Discharges to Surface Water)	9 N	PA 0013641	
B. UIC (Underground Injection of Fluids)	9 U		
C. RCRA (Hazardous Wastes)	9 R		
D. PSD (Air Emissions from Proposed Sources)	9 P		
E. OTHER (specify)	9		(specify)
E. OTHER (specify)	9		(specify)

XI. MAP

Attach to this application a topographic map of the area extending to at least one mile beyond property boundaries. The map must show the outline of the facility, the location of each of its existing and proposed intake and discharge structures, each of its hazardous waste treatment, storage, or disposal facilities, and each well where it injects fluids underground. Include all springs, rivers and other surface water bodies in the map area. See instructions for precise requirements.

XII. NATURE OF BUSINESS *(provide a brief description)*

Bishop Tube produces welded, and seamless tubing, comprised of stainless steel, titanium and nickel based alloys.

Sworn to and s[illegible] before me this 5th DAY of JAN. 19 88

Harry Eckman

HARRY ECKMAN, Notary Public
East Whiteland Twp., Chester Co.
My Commission Expires March 27, 1990

XIII. CERTIFICATION *(see instructions)*

I certify under penalty of law that I have personally examined and am familiar with the information submitted in this application and all attachments and that, based on my inquiry of those persons immediately responsible for obtaining the information contained in the application, I believe that the information is true, accurate and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment.

A. NAME & OFFICIAL TITLE (type or print)	B. SIGNATURE	C. DATE SIGNED
General Manager	George W. Menner	11/12/87

COMMENTS FOR OFFICIAL USE ONLY

C

Please print or type in the unshaded areas only.

EPA I.D. NUMBER (copy from Item 1 of Form 1)
PAD 081868309

Form Approved OMB No. 158-R0173

FORM 2C NPDES

EPA

U.S. ENVIRONMENTAL PROTECTION AGENCY
APPLICATION FOR PERMIT TO DISCHARGE WASTEWATER
EXISTING MANUFACTURING, COMMERCIAL, MINING AND SILVICULTURAL OPERATIONS
Consolidated Permits Program

I. OUTFALL LOCATION

For each outfall, list the latitude and longitude of its location to the nearest 15 seconds and the name of the receiving water.

A. OUTFALL NUMBER (list)	B. LATITUDE			C. LONGITUDE			D. RECEIVING WATER (name)
	1. DEG.	2. MIN.	3. SEC.	1. DEG.	2. MIN.	3. SEC.	
001	40	02	30	75	32	15	LITTLE VALLEY CREEK

II. FLOWS, SOURCES OF POLLUTION, AND TREATMENT TECHNOLOGIES

A. Attach a line drawing showing the water flow through the facility. Indicate sources of intake water, operations contributing wastewater to the effluent, and treatment units labeled to correspond to the more detailed descriptions in Item B. Construct a water balance on the line drawing by showing average flows between intakes, operations, treatment units, and outfalls. If a water balance cannot be determined *(e.g., for certain mining activities)*, provide a pictorial description of the nature and amount of any sources of water and any collection or treatment measures.

B. For each outfall, provide a description of: (1) All operations contributing wastewater to the effluent, including process wastewater, sanitary wastewater, cooling water, and storm water runoff; (2) The average flow contributed by each operation; and (3) The treatment received by the wastewater. Continue on additional sheets if necessary.

1. OUTFALL NO. (list)	2. OPERATION(S) CONTRIBUTING FLOW		3. TREATMENT		
	a. OPERATION (list)	b. AVERAGE FLOW (include units)	a. DESCRIPTION	b. LIST CODES FROM TABLE 2C-1	
	Non-Contact Cooling Water		N/A		
001	Cooling Water				
	Run Off	60,038/GPD			

OFFICIAL USE ONLY *(effluent guidelines sub-categories)*

EPA Form 3510-2C (9-85)

CONTINUE ON REVERSE

(complete the following table)

1. OUTFALL NUMBER (list)	2. OPERATION(s) CONTRIBUTING FLOW (list)	3. FREQUENCY		4. FLOW				
		a. DAYS PER WEEK (specify average)	b. MONTHS PER YEAR (specify average)	a. FLOW RATE (in mgd)		b. TOTAL VOLUME (specify with units)		c. DURATION (in days)
				1. LONG TERM AVERAGE	2. MAXIMUM DAILY	1. LONG TERM AVERAGE	2. MAXIMUM DAILY	

III. MAXIMUM PRODUCTION

A. Does an effluent guideline limitation promulgated by EPA under Section 304 of the Clean Water Act apply to your facility?

☐ YES *(complete Item-III-B)* ☒ NO *(to to Section IV)*

B. Are the limitations in the applicable effluent guideline expressed in terms of production *(or other measure of operation)*?

☐ YES *(complete Item III-C)* ☐ NO *(go to Section IV)*

C. If you answered "Yes" to Item III-B, list the quantity which represents an actual measurement of your maximum level of production, expressed in the terms and units used in the applicable effluent guideline, and indicate the affected outfalls.

1. MAXIMUM QUANTITY			2. AFFECTED OUTFALLS (list outfall numbers)
a. QUANTITY PER DAY	b. UNITS OF MEASURE	c. OPERATION, PRODUCT, MATERIAL, ETC. (specify)	

IV. IMPROVEMENTS

A. Are you now required by any Federal, State or local authority to meet any implementation schedule for the construction, upgrading or operation of wastewater treatment equipment or practices or any other environmental programs which may affect the discharges described in this application? This includes, but is not limited to, permit conditions, administrative or enforcement orders, enforcement compliance schedule letters, stipulations, court orders, and grant or loan conditions.

☐ YES *(complete the following table)* ☒ NO *(go to Item IV-B)*

1. IDENTIFICATION OF CONDITION, AGREEMENT, ETC.	2. AFFECTED OUTFALLS		3. BRIEF DESCRIPTION OF PROJECT	4. FINAL COMPLIANCE DATE	
	a. NO.	b. SOURCE OF DISCHARGE		a. REQUIRED	b. PROJECTED

B. OPTIONAL: You may attach additional sheets describing any additional water pollution control programs *(or other environmental projects which may affect your discharges)* you now have underway or which you plan. Indicate whether each program is now underway or planned, and indicate your actual or planned schedules for construction. ☐ MARK "X" IF DESCRIPTION OF ADDITIONAL CONTROL PROGRAMS IS ATTACHED

EPA I.D. NUMBER (copy from Item 1 of Form 1)
PAD 0818683309

Form Approved OMB No. 158-R0173

V. INTAKE AND EFFLUENT CHARACTERISTICS

A, B, & C: See instructions before proceeding — Complete one set of tables for each outfall — Annotate the outfall number in the space provided. NOTE: Tables V-A, V-B, and V-C are included on separate sheets numbered V-1 through V-9.

D. Use the space below to list any of the pollutants listed in Table 2c-3 of the instructions, which you know or have reason to believe is discharged or may be discharged from any outfall. For every pollutant you list, briefly describe the reasons you believe it to be present and report any analytical data in your possession.

1. POLLUTANT	2. SOURCE	1. POLLUTANT	2. SOURCE
N/A			

VI. POTENTIAL DISCHARGES NOT COVERED BY ANALYSIS

A. Is any pollutant listed in Item V-C a substance or a component of a substance which you do or expect that you will over the next 5 years use or manufacture as an intermediate or final product or byproduct?

☐ YES *(list all such pollutants below)* ☒ NO *(go to Item VI-B)*

B. Are your operations such that your raw materials, processes, or products can reasonably be expected to vary so that your discharges of pollutants may during the next 5 years exceed two times the maximum values reported in Item V?

☐ YES *(complete Item VI-C below)* ☒ NO *(go to Section VII)*

C. If you answered "Yes" to Item VI-B, explain below and describe in detail the sources and expected levels of such pollutants which you anticipate will be discharged from each outfall over the next 5 years, to the best of your ability at this time. Continue on additional sheets if you need more space.

CONTINUED FROM THE FRONT

VII. BIOLOGICAL TOXICITY TESTING DATA

Do you have any knowledge or reason to believe that any biological test for acute or chronic toxicity has been made on any of your discharges or on a receiving water in relation to your discharge within the last 3 years?

☐ YES *(identify the test(s) and describe their purposes below)* ☑ NO *(go to Section VIII)*

VIII. CONTRACT ANALYSIS INFORMATION

Were any of the analyses reported in Item V performed by a contract laboratory or consulting firm?

☑ YES *(list the name, address, and telephone number of, and pollutants analyzed by, each such laboratory or firm below)* NO *(go to Section IX)*

A. NAME	B. ADDRESS	C. TELEPHONE (area code & no.)	D. POLLUTANTS ANALYZED (list)
AGES Laboratories	1151 S. Trooper Rd. Norristown, PA. 19403 (See AGES analytical report att'd.)	(215) 666-7404	

Sworn to and subscribed before me this 4th day of JAN. 1988

Harry Eckman

HARRY ECKMAN, Notary Public
East Whiteland Twp., Chester Co.
My Commission Expires March 27, 1990

IX. CERTIFICATION

I certify under penalty of law that I have personally examined and am familiar with the information submitted in this application and all attachments and that, based on my inquiry of those individuals immediately responsible for obtaining the information, I believe that the information is true, accurate and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment.

A. NAME & OFFICIAL TITLE (type or print)

(b) (4) [redacted]

B. PHONE NO. (area code & no.)

(215) 647-3450

D. DATE SIGNED

11/12/87

PLEASE PRINT OR TYPE IN THE UNSHADED AREAS ONLY. You may report some or all of this information on separate sheets *(use the same format)* instead of completing these pages.
SEE INSTRUCTIONS

EPA I.D. NUMBER *(copy from Item I of Form 1)*: PAD 081868309

Form Approved OMB No. 158-R0173

V. INTAKE AND EFFLUENT CHARACTERISTICS *(continued from page 3 of Form 2-C)*

OUTFALL NO. 001

PART A - You must provide the results of at least one analysis for every pollutant in this table. Complete one table for each outfall. See instructions for additional details.

1. POLLUTANT	2. EFFLUENT a. MAXIMUM DAILY VALUE (1) CONCENTRATION	(2) MASS	b. MAXIMUM 30 DAY VALUE (if available) (1) CONCENTRATION	(2) MASS	c. LONG TERM AVRG. VALUE (if available) (1) CONCENTRATION	(2) MASS	d. NO. OF ANALYSES	3. UNITS (specify if blank) a. CONCENTRATION	b. MASS	4. INTAKE (optional) a. LONG TERM AVERAGE VALUE (1) CONCENTRATION	(2) MASS	b. NO. OF ANALYSES
a. Biochemical Oxygen Demand *(BOD)*	5.	1.91lbs.					1	mg/1	7.6 lbs	/day		
b. Chemical Oxygen Demand *(COD)*	4.	1.91lbs					1	mg/1	7.6 lbs	/day		
c. Total Organic Carbon *(TOC)*	11.	1.91lbs.					1	mg/1	7.6 lbs	/day		
d. Total Suspended Solids *(TSS)*	7.	1.91lbs.										
e. Ammonia *(as N)*												
f. Flow	VALUE 60,038 GPD		VALUE		VALUE					VALUE		
g. Temperature *(winter)*	VALUE 16.1		VALUE		VALUE			°C		VALUE		
h. Temperature *(summer)*	VALUE 26.1		VALUE		VALUE			°C		VALUE		
i. pH	MINIMUM 6.0	MAXIMUM 9.0	MINIMUM	MAXIMUM				STANDARD UNITS				

PART B - Mark "X" in column 2-a for each pollutant you know or have reason to believe is present. Mark "X" in column 2-b for each pollutant you believe to be absent. If you mark column 2-a for any pollutant, you must provide the results of at least one analysis for that pollutant. Complete one table for each outfall. See the instructions for additional details and requirements.

1. POLLUTANT AND CAS NO. *(if available)*	2. MARK "X" a. BELIEVED PRESENT	b. BELIEVED ABSENT	3. EFFLUENT a. MAXIMUM DAILY VALUE (1) CONCENTRATION	(2) MASS	b. MAXIMUM 30 DAY VALUE (if available) (1) CONCENTRATION	(2) MASS	c. LONG TERM AVRG. VALUE (if available) (1) CONCENTRATION	(2) MASS	d. NO. OF ANALYSES	4. UNITS a. CONCENTRATION	b. MASS	5. INTAKE (optional) a. LONG TERM AVERAGE VALUE (1) CONCENTRATION	(2) MASS	b. NO. OF ANALYSES
a. Bromide (24959-67-9)		X												
b. Chlorine, Total Residual		X												
c. Color		X												
d. Fecal Coliform		X												
e. Fluoride (16984-48-8)	X		(0.39	1.9 lbs.					1	mg/1	7.6 lbs./day			
f. Nitrate-Nitrite *(as N)*														

* See attached analysis

CONTINUE ON REVERSE

ITEM V B CONTINUED FROM FRONT

1. POLLUTANT AND CAS NO. (if available)	2. MARK 'X' a. BELIEVED PRESENT	b. BELIEVED ABSENT	3. EFFLUENT a. MAXIMUM DAILY VALUE (1) CONCENTRATION	(2) MASS	b. MAXIMUM 30 DAY VALUE (if available) (1) CONCENTRATION	(2) MASS	c. LONG TERM AVRG. VALUE (if available) (1) CONCENTRATION	(2) MASS	d. NO. OF ANALYSES	4. UNITS a. CONCENTRATION	b. MASS	5. INTAKE (optional) a. LONG TERM AVERAGE VALUE (1) CONCENTRATION	(2) MASS	b. NO. OF ANALYSES
g. Nitrogen, Total Organic (as N)		X												
h. Oil and Grease		X												
i. Phosphorus (as P), Total (7723-14-0)		X												
j. Radioactivity														
(1) Alpha, Total		X												
(2) Beta, Total		X												
(3) Radium, Total		X												
(4) Radium 226, Total		X												
k. Sulfate (as SO_4) (14808-79-8)		X												
l. Sulfide (as S)		X												
m. Sulfite (as SO_3) (14265-45-3)		X												
n. Surfactants		X												
o. Aluminum, Total (7429-90-5)		X												
p. Barium, Total (7440-39-3)		X												
q. Boron, Total (7440-42-8)		X												
r. Cobalt, Total (7440-48-4)		X												
s. Iron, Total (7439-89-6)		X												
t. Magnesium, Total (7439-95-4)		X												
u. Molybdenum, Total (7439-98-7)		X												
v. Manganese, Total (7439-96-5)		X												
w. Tin, Total (7440-31-5)		X												
x. Titanium, Total (7440-32-6)		X												

~~(16)~~ (8)

CONTINUE ON PAGE V-3

EPA I.D. NUMBER (copy from Item 1 of Form 1)	OUTFALL NUMBER
PAD 081868309	001

CONTINUED FROM PAGE 3 OF FORM 2-C

Form Approved OMB No. 158-R0173

PART C - If you are a primary industry and this outfall contains process wastewater, refer to Table 2c-2 in the instructions to determine which of the GC/MS fractions you must test for. Mark "X" in column 2-a for all such GC/MS fractions that apply to your industry and for ALL toxic metals, cyanides, and total phenols. If you are not required to mark column 2-a *(secondary industries, non-process wastewater outfalls, and non-required GC/MS fractions)*, mark "X" in column 2-b for each pollutant you know or have reason to believe is present. Mark "X" in column 2-c for each pollutant you believe to be absent. If you mark either columns 2-a or 2-b for any pollutant, you must provide the results of at least one analysis for that pollutant. Note that there are seven pages to this part; please review each carefully. Complete one table *(all seven pages)* for each outfall. See instructions for additional details and requirements.

1. POLLUTANT AND CAS NUMBER *(if available)*	2. MARK "X"			3. EFFLUENT							4. UNITS		5. INTAKE *(optional)*		
	a. TESTING REQUIRED	b. BELIEVED PRESENT	c. BELIEVED ABSENT	a. MAXIMUM DAILY VALUE (1) CONCENTRATION	(2) MASS	b. MAXIMUM 30 DAY VALUE *(if available)* (1) CONCENTRATION	(2) MASS	c. LONG TERM AVRG. VALUE *(if available)* (1) CONCENTRATION	(2) MASS	d. NO. OF ANALYSES	a. CONCENTRATION	b. MASS	a. LONG TERM AVERAGE VALUE (1) CONCENTRATION	(2) MASS	b. NO. OF ANALYSES
METALS, CYANIDE, AND TOTAL PHENOLS															
1M. Antimony, Total (7440-36-0)			X												
2M. Arsenic, Total (7440-38-2)			X												
3M. Beryllium, Total, 7440-41-7)			X												
4M. Cadmium, Total (7440-43-9)			X												
5M. Chromium, Total (7440-47-3)			X												
6M. Copper, Total (7550-50-8)			X												
7M. Lead, Total (7439-97-6)			X												
8M. Mercury, Total (7439-97-6)			X												
9M. Nickel, Total (7440-02-0)			X												
10M. Selenium, Total (7782-49-2)			X												
11M. Silver, Total (7440-22-4)			X												
12M. Thallium, Total (7440-28-0)			X												
13M. Zinc, Total (7440-66-6)			X												
14M. Cyanide, Total (57-12-5)			X												
15M. Phenols, Total			X												
DIOXIN															
2,3,7,8-Tetrachlorodibenzo-P-Dioxin (1764-01-6)			X	DESCRIBE RESULTS											

CONTINUE ON REVERSE

1. POLLUTANT AND CAS NUMBER (if available)	2. MARK "X" a. TEST INCLUDED	b. BELIEVED PRESENT	c. BELIEVED ABSENT	EFFLUENT a. MAXIMUM DAILY VALUE (1) CONCENTRATION	(2) MASS	b. MAXIMUM 30 DAY VALUE (if available) (1) CONCENTRATION	(2) MASS	c. LONG TERM AVRG. VALUE (if available) (1) CONCENTRATION	(2) MASS	NO. OF ANALYSES	4. UNITS a. CONCENTRATION	b. MASS	5. INTAKE (optional) a. LONG TERM AVERAGE VALUE (1) CONCENTRATION	(2) MASS	b. NO. OF ANALYSES
GC/MS FRACTION – VOLATILE COMPOUNDS															
1V. Acrolein (107-02-8)			X												
2V. Acrylonitrile (107-13-1)			X												
3V. Benzene (71-43-2)			X												
4V. Bis (Chloromethyl) Ether (542-88-1)			X												
5V. Bromoform (75-25-2)			X												
6V. Carbon Tetrachloride (56-23-5)			X												
7V. Chlorobenzene (108-90-7)			X												
8V. Chlorodibromomethane (124-48-1)			X												
9V. Chloroethane (75-00-3)			X												
10V. 2-Chloroethylvinyl Ether (110-75-8)			X												
11V. Chloroform (67-66-3)			X												
12V. Dichlorobromomethane (75-27-4)			X												
13V. Dichlorodifluoromethane (75-71-8)			X												
14V. 1,1-Dichloroethane (75-34-3)			X												
15V. 1,2-Dichloroethane (107-06-2)			X												
16V. 1,1-Dichloroethylene (75-35-4)			X												
17V. 1,2-Dichloropropane (78-87-5)			X												
18V. 1,2-Dichloropropylene (542-75-6)			X												
19V. Ethylbenzene (100-41-4)			X												
20V. Methyl Bromide (74-83-9)			X												
21V. Methyl Chloride (74-87-3)			X												

CONTINUE ON PAGE V-5

CONTINUED FROM PAGE V-4

EPA I.D. NUMBER (copy from Item 1 of Form 1): PAD 081868309

OUTFALL NUMBER: 001

Form Approved OMB No. 158-R0173.

1. POLLUTANT AND CAS NUMBER (if available)	2. MARK "X" a. TESTING REQUIRED	b. BELIEVED PRESENT	c. BELIEVED ABSENT	3. EFFLUENT a. MAXIMUM DAILY VALUE (1) CONCENTRATION	(2) MASS	b. MAXIMUM 30 DAY VALUE (if available) (1) CONCENTRATION	(2) MASS	c. LONG TERM AVRG. VALUE (if available) (1) CONCENTRATION	(2) MASS	d. NO. OF ANALYSES	4. UNITS a. CONCENTRATION	b. MASS	5. INTAKE (optional) a. LONG TERM AVERAGE VALUE (1) CONCENTRATION	(2) MASS	b. NO. OF ANALYSES
GC/MS FRACTION – VOLATILE COMPOUNDS *(continued)*															
22V. Methylene Chloride (75-09-2)			X												
23V. 1,1,2,2-Tetrachloroethane (79-34-5)			X												
24V. Tetrachloroethylene (127-18-4)			X												
25V. Toluene (108-88-3)			X												
26V. 1,2-Trans-Dichloroethylene (156-60-5)			X												
27V. 1,1,1-Trichloroethane (71-55-6)			X												
28V. 1,1,2-Trichloroethane (79-00-5)			X												
29V. Trichloroethylene (79-01-6)			X												
30V. Trichlorofluoromethane (75-69-4)			X												
31V. Vinyl Chloride (75-01-4)			X												
GC/MS FRACTION – ACID COMPOUNDS															
1A. 2-Chlorophenol (98-57-8)			X												
2A. 2,4-Dichlorophenol (120-83-2)			X												
3A. 2,4-Dimethylphenol (105-67-9)			X												
4A. 4,6-Dinitro-O-Cresol (534-52-1)			X												
5A. 2,4-Dinitrophenol (51-28-5)			X												
6A. 2-Nitrophenol (88-75-5)			X												
7A. 4-Nitrophenol (100-02-7)			X												
8A. P-Chloro-M-Cresol (59-50-7)			X												
9A. Pentachlorophenol (87-86-5)			X												
10A. Phenol (108-95-2)			X												
11A. 2,4,6-Trichlorophenol (88-06-2)			X												

CONTINUE ON REVERSE

1. POLLUTANT AND CAS NUMBER (if available)	2. MARK 'X'			3. EFFLUENT							4. UNITS		5. INTAKE (optional)		
	a. TESTING REQUIRED	b. BELIEVED PRESENT	c. BELIEVED ABSENT	a. MAXIMUM DAILY VALUE		b. MAXIMUM 30 DAY VALUE (if available)		c. LONG TERM AVRG. VALUE (if available)		d. NO. OF ANALYSES	a. CONCENTRATION	b. MASS	a. LONG TERM AVERAGE VALUE		b. NO. OF ANALYSES
				(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS				(1) CONCENTRATION	(2) MASS	
GC/MS FRACTION – BASE/NEUTRAL COMPOUNDS															
1B. Acenaphthene (83-32-9)			X												
2B. Acenaphtylene (208-96-8)			X												
3B. Anthracene (120-12-7)			X												
4B. Benzidine (92-87-5)			X												
5B. Benzo (a) Anthracene (56-55-3)			X												
6B. Benzo (a) Pyrene (50-32-8)			X												
7B. 3,4-Benzo-fluoranthene (205-99-2)			X												
8B. Benzo (ghi) Perylene (191-24-2)			X												
9B. Benzo (k) Fluoranthene (207-08-9)			X												
10B. Bis (2-Chloro-ethoxy) Methane (111-91-1)			X												
11B. Bis (2-Chloro-ethyl) Ether (111-44-4)			X												
12B. Bis (2-Chloro-isopropyl) Ether (39638-32-9)			X												
13B. Bis (2-Ethyl-hexyl) Phthalate (117-81-7)			X												
14B. 4-Bromo-phenyl Phenyl Ether (101-55-3)			X												
15B. Butyl Benzyl Phthalate (85-68-7)			X												
16B. 2-Chloro-naphthalene (91-58-7)			X												
17B. 4-Chloro-phenyl Phenyl Ether (7005-72-3)			X												
18B. Chrysene (218-01-9)			X												
19B. Dibenzo (a,h) Anthracene (53-70-3)			X												
20B. 1,2-Dichloro-benzene (95-50-1)			X												
21B. 1,3-Dichloro-benzene (541-73-1)			X												

1201 (12)

CONTINUE ON PAGE V-7

1. POLLUTANT AND CAS NUMBER (if available)	2. MARK "X" a. Testing Required	b. Believed Present	c. Believed Absent	3. EFFLUENT a. MAXIMUM DAILY VALUE (1) Concentration	(2) Mass	b. MAXIMUM 30 DAY VALUE (if available) (1) Concentration	(2) Mass	c. LONG TERM AVRG. VALUE (if available) (1) Concentration	(2) Mass	d. NO. OF ANALYSES	4. UNITS a. CONCENTRATION	b. MASS	5. INTAKE (optional) a. LONG TERM AVERAGE VALUE (1) Concentration	(2) Mass	b. NO. OF ANALYSES
GC/MS FRACTION – BASE/NEUTRAL COMPOUNDS *(continued)*															
43B. N-Nitrosodiphenylamine (86-30-6)			X												
44B. Phenanthrene (85-01-8)			X												
45B. Pyrene (129-00-0)			X												
46B. 1,2,4-Trichlorobenzene (120-82-1)			X												
GC/MS FRACTION – PESTICIDES															
1P. Aldrin (309-00-2)			X												
2P. α-BHC (319-84-6)			X												
3P. β-BHC (319-85-7)			X												
4P. γ-BHC (58-89-9)			X												
5P. δ-BHC (319-86-8)			X												
6P. Chlordane (57-74-9)			X												
7P. 4,4'-DDT (50-29-3)			X												
8P. 4,4'-DDE (72-55-9)			X												
9P. 4,4'-DDD (72-54-8)			X												
10P. Dieldrin (60-57-1)			X												
11P. α-Endosulfan (115-29-7)			X												
12P. β-Endosulfan (115-29-7)			X												
13P. Endosulfan Sulfate (1031-07-8)			X												
14P. Endrin (72-20-8)			X												
15P. Endrin Aldehyde (7421-93-4)			X												
16P. Heptachlor (76-44-8)			X												

(427) (13)

CONTINUE ON PAGE V-9

(5)

CONTINUED FROM PAGE V-6

EPA I.D. NUMBER (copy from Item 1 of Form 1): PAD 0818683U9

OUTFALL NUMBER: 001

Form Approved OMB No. 158-R0173

1. POLLUTANT AND CAS NUMBER (if available)	2. MARK "X" a. BELIEVED PRESENT	b. BELIEVED ABSENT	c. BELIEVED ABSENT	3. EFFLUENT a. MAXIMUM DAILY VALUE (1) CONCENTRATION	(2) MASS	b. MAXIMUM 30 DAY VALUE (if available) (1) CONCENTRATION	(2) MASS	c. LONG TERM AVRG. VALUE (if available) (1) CONCENTRATION	(2) MASS	d. NO. OF ANALYSES	4. UNITS a. CONCENTRATION	b. MASS	5. INTAKE (optional) a. LONG TERM AVERAGE VALUE (1) CONCENTRATION	(2) MASS	b. NO. OF ANALYSES
GC/MS FRACTION – BASE/NEUTRAL COMPOUNDS (continued)															
22B. 1,4-Dichlorobenzene (106-46-7)			X												
23B. 3,3'-Dichlorobenzidine (91-94-1)			X												
24B. Diethyl Phthalate (84-66-2)			X												
25B. Dimethyl Phthalate (131-11-3)			X												
26B. Di-N-Butyl Phthalate (84-74-2)			X												
27B. 2,4-Dinitrotoluene (121-14-2)			X												
28B. 2,6-Dinitrotoluene (606-20-2)			X												
29B. Di-N-Octyl Phthalate (117-84-0)			X												
30B. 1,2-Diphenylhydrazine (as Azobenzene) (122-66-7)			X												
31B. Fluoranthene (206-44-0)			X												
32B. Fluorene (86-73-7)			X												
33B. Hexachlorobenzene (118-71-1)			X												
34B. Hexachlorobutadiene (87-68-3)			X												
35B. Hexachlorocyclopentadiene (77-47-4)			X												
36B. Hexachloroethane (67-72-1)			X												
37B. Indeno (1,2,3-cd) Pyrene (193-39-5)			X												
38B. Isophorone (78-59-1)			X												
39B. Naphthalene (91-20-3)			X												
40B. Nitrobenzene (98-95-3)			X												
41B. N-Nitrosodimethylamine (62-75-9)			X												
42B. N-Nitrosodi-N-Propylamine (621-64-7)			X												

CONTINUE ON REVERSE

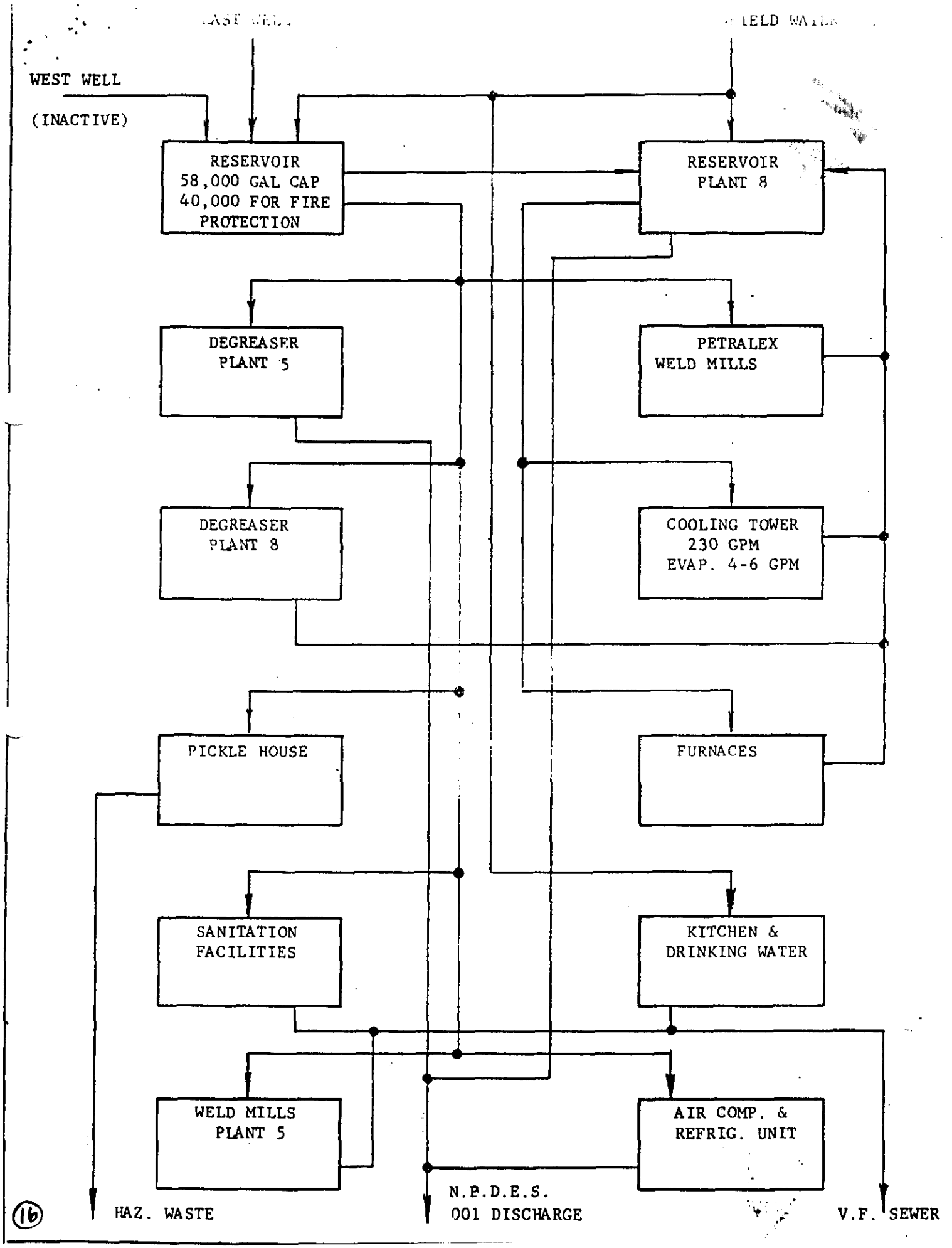
CONTINUED FROM PAGE V-8

EPA I.D. NUMBER (copy from Item 1 of Form 1)	OUTFALL NUMBER
PAD 081868309	001

Form Approved OMB No. 158-R0173

1. POLLUTANT AND CAS NUMBER (if available)	2. MARK "X" a. TEST INCLUDED	b. BELIEVED PRESENT	c. BELIEVED ABSENT	3. EFFLUENT a. MAXIMUM DAILY VALUE (1) CONCENTRATION	(2) MASS	b. MAXIMUM 30 DAY VALUE (if available) (1) CONCENTRATION	(2) MASS	c. LONG TERM AVRG. VALUE (if available) (1) CONCENTRATION	(2) MASS	d. NO. OF ANALYSES	4. UNITS a. CONCENTRATION	b. MASS	5. INTAKE (optional) a. LONG TERM AVERAGE VALUE (1) CONCENTRATION	(2) MASS	b. NO. OF ANALYSES
GC/MS FRACTION – PESTICIDES *(continued)*															
17P. Heptachlor Epoxide (1024-57-3)			X												
18P. PCB-1242 (53469-21-9)			X												
19P. PCB-1254 (11097-69-1)			X												
20P. PCB-1221 (11104-28-2)			X												
21P. PCB-1232 (11141-16-5)			X												
22P. PCB-1248 (12672-29-6)			X												
23P. PCB-1260 (11096-82-5)			X												
24P. PCB-1016 (12674-11-2)			X												
25P. Toxaphene (8001-35-2)			X												

(5)


WEST WELL
(INACTIVE)
RESERVOIR
58,000 GAL CAP
40,000 FOR FIRE
PROTECTION
RESERVOIR
PLANT 8
DEGREASER
PLANT 5
PETRALEX
WELD MILLS
DEGREASER
PLANT 8
COOLING TOWER
230 GPM
EVAP. 4-6 GPM
PICKLE HOUSE
FURNACES
SANITATION
FACILITIES
KITCHEN &
DRINKING WATER
WELD MILLS
PLANT 5
AIR COMP. &
REFRIG. UNIT
HAZ. WASTE
N.P.D.E.S.
001 DISCHARGE
V.F. SEWER

AGES LABORATORIES
1151 S. Trooper Road, Norristown, PA 19403 (215) 666-7404

Engineering Consultants — Analytical Services

CLIENT NUMBER 26011.01

08-18-1987

ANALYTICAL REPORT

BISHOP TUBE
P.O. BOX 1189
ROUTE 30 MALIN ROAD
FRAZER, PA 19355

DAVE MOLETON

RE: ANALYSIS OF WATER SAMPLE
FOR NPDES PERMIT TESTING
TAKEN BY CLIENT
SUBMITTED
AGES LAB ID # 873522

	WATER SAMPLE NPDES SAMPLE
BOD (5DAY @ 20C)	5.
COD	4.
TOC	11.
PH	7.56
COLOR (Pt-Co)	<5.
CYANIDE	<0.001
PHENOL	<0.001
OIL & GREASE	6.
DETERGENTS	<0.01
AMMONIA NITROGEN AS N	<0.1
NITRATE NITROGEN AS N	1.7
NITRITE NITROGEN AS N	0.03
TOTAL KJEDAHL NITROGEN	0.22
PHOSPHATE TOTAL AS P	0.86
SULFATE	32.
SULFIDE	<0.2

THE RESULTS ARE EXPRESSED AS mg/l EXCEPT pH OR OTHERWISE INDICATED.

LABORATORY SAMPLES ARE RETAINED BY AGES LABORATORIES
FOR 30 DAYS FROM THE DATE OF THIS ANALYTICAL REPORT.

RE: ANALYSIS OF WATER SAMPLE
FOR NPDES PERMIT TESTING
TAKEN BY CLIENT
SUBMITTED
AGES LAB ID # 873522

	WATER SAMPLE NPDES SAMPLE
TOTAL SUSPENDED SOLIDS	7.
FECAL COLIFORM/100ML	<2.2
BROMIDE	0.95
TOTAL RESIDUAL CHLORINE	<0.1

THE RESULTS ARE EXPRESSED AS mg/l EXCEPT pH OR OTHERWISE INDICATED.

AGES

RE: ANALYSIS OF WATER SAMPLE
FOR NPDES PERMIT TESTING
TAKEN BY CLIENT
SUBMITTED
AGES LAB ID # 873522

	WATER SAMPLE NPDES SAMPLE
ALUMINUM	<0.010
ANTIMONY	<0.005
ARSENIC	<0.001
BARIUM	0.030
BERYLLIUM	<0.001
BORON	<0.217
CADMIUM	<0.001
CHROMIUM TOTAL	0.004
COBALT	0.002
COPPER	0.005
IRON	<0.001
LEAD	0.006
MAGNESIUM	10.8
MANGANESE	0.002
MERCURY	<0.0001
MOLYBDENUM	<0.007
NICKEL	0.008
SELENIUM	<0.001
SILVER	0.001
THALLIUM	<0.006
TIN	<0.028
TITANIUM	<0.032
ZINC	0.007

THE RESULTS ARE EXPRESSED AS mg/l EXCEPT pH OR OTHERWISE INDICATED.

AGES

RE: ANALYSIS OF WATER SAMPLE
FOR NPDES PERMIT TESTING
TAKEN BY CLIENT
SUBMITTED
AGES LAB ID # 873522

	WATER SAMPLE NPDES SAMPLE
CHLOROMETHANE	<10.
BROMOMETHANE	<10.
CHLOROETHANE	<10.
DICHLORODIFLUOROMETHANE	<10.
1 1-DICHLOROETHANE	<10.
CHLOROFORM	<10.
1 2-DICHLOROETHANE	<10.
CARBON TETRACHLORIDE	<10.
1 2 DICHLOROPROPENE	<10.
1 2-DICHLOROPROPANE	<10.
DIBROMOCHLOROMETHANE	<10.
BENZENE	<10.
2-CHLOROETHYLVINYL ETHER	<10.
BROMOFORM	<10.
CHLOROBENZENE	<10.
ETHYL BENZENE	<10.
ACROLEIN	<10.
ACRYLONITRILE	<10.
1 1 DICHLOROETHYLENE	<10.
1 2-DICHLOROBENZENE	<10.
1 3 DICHLOROBENZENE	<10.
1 4-DICLOROBENZENE	<10.
HEXACHLOROETHANE	<10.
BIS(2-CHLOROETHYL)ETHER	<10.
BIS(2-CHLOROISOPROPYL)ETHER	<10.
N NITROSODI-N-PROPYLAMINE	<10.
NITROBENZENE	<10.
HEXACHLOROBUTADIENE	<10.
1 2 4-TRICHLOROBENZENE	<10.
ISOPHORONE	<10.
NAPHTHALENE	<10.

THE RESULTS ARE EXPRESSED AS ug/l EXCEPT pH OR OTHERWISE INDICATED.

AGES

RE: ANALYSIS OF WATER SAMPLE
FOR NPDES PERMIT TESTING
TAKEN BY CLIENT
SUBMITTED
AGES LAB ID # 873522

	WATER SAMPLE NPDES SAMPLE
BIS(2-CHLOROETHOXY)METHANE	<10.
HEXACHLOROCYCLOPENTADIENE	<10.
CHLORONAPHTHALENE	<10.
ACENAPHTHYLENE	<10.
ACENAPHTHENE	<10.
DIMETHYL PHTHALATE	<10.
2 4-DINITROTOLUENE	<10.
2 6-DINITROTOLUENE	<10.
FLUORENE	<10.
4-CHLOROPHENYL PHENYL ETHER	<10.
2 4-DINITROBENZENE	<10.
DIETHYL PHTHALATE	<10.
BIS(CHLOROMETHYL) ETHER	<10.
N-NITROSODIPHENYLAMINE	<10.
HEXACHLOROBENZENE	<10.
4-BROMOPHENYL PHENYL ETHER	<10.
PHENANTHRENE	<10.
ANTHRACENE	<10.
DI-N-BUTYL PHTHALATE	<10.
FLUORANTHENE	<10.
PYRENE	<10.
BENZIDINE	<10.
BUTYL BENZYL PHTHALATE	<10.
BIS(2-ETHYLHEXYL) PHTHALATE	<10.
CHRYSENE	<10.
BENZO(A)ANTHRACENE	<10.
BENZO(B)FLUORANTHENE	<10.
BENZO(K)FLUORANTHENE	<10.
BENZO(A)PYRENE	<10.
3 3'-DICHLOROBENZENE	<10.
DI-N-OCTYL PHTHALATE	<10.

THE RESULTS ARE EXPRESSED AS ug/l EXCEPT pH OR OTHERWISE INDICATED.

AGES

...MENT
...ITED
...S LAB ID # 873522

	WATER SAMPLE NPDES SAMPLE
DIBENZO(A H)ANTHRACENE	<10.
BENZO(G H I)PERYLENE	<10.
1 2-DIPHENYLHYDRAZINE	<10.
N-NITROSODIMETHYLAMINE	<10.
2 3 7 8-TERTACHLORODIBENZO-P-DIOXIN	<10.

THE RESULTS ARE EXPRESSED AS ug/l EXCEPT pH OR OTHERWISE INDICATED.

AGES

RE: ANALYSIS OF WATER SAMPLE
FOR NPDES PERMIT TESTING
TAKEN BY CLIENT
SUBMITTED
AGES LAB ID # 873522

ACID EXTRACTABLES

	WATER SAMPLE NPDES SAMPLE
2-CHLOROPHENOL	<10.
2-NITRO PHENOL	<10.
PHENOL.	<10.
2 4-DIMETHYLPHENOL	<10.
2 4-DICHLOROPHENOL	<10.
2 4 6-TRICHLOROPHENOL	<10.
4-CHLORO-3-METHYLPHENOL	<10.
2 4-DINITROPHENOL	<10.
2-METHYL 4 6-DINITROPHENOL	<10.
PENTACHLOROPHENOL	<10.
4-NITROPHENOL	<10.
A-BHC	<0.003
B-BHC	<0.005
G-BHC (LINDANE)	<0.005
D-BHC	<0.005
ALDRIN	<0.005
HEPTACHLOR	<0.005
HEPTACHLOR EPOXIDE	<0.10
ENDOSULFAN I	<0.01
ENDOSULFAN II	<0.01
ENDOSULFAN SULFATE	<0.005
TOXAPHENE	<0.10
ENDRIN ALDEHYDE	<0.005
CHLORDANE	<0.01
DIELDRIN	<0.005
ENDRIN	<0.005
4 4'-DDD	<0.01
4 4'-DDE	<0.01

THE RESULTS ARE EXPRESSED AS ug/l EXCEPT pH OR OTHERWISE INDICATED.

AGES

ANALYSIS OF WATER SAMPLE
FOR NPDES PERMIT TESTING
TAKEN BY CLIENT
SUBMITTED
AGES LAB ID # 373522

	WATER SAMPLE NPDES SAMPLE
4 4'-DDT	<0.01
POLYCHLORINATED BIPHENYLS AS 1242	<0.10
POLYCHLORINATED BIPHENYLS AS 1248	<0.10
POLYCHLORINATED BIPHENYLS AS 1254	<0.10
POLYCHLORINATED BIPHENYLS AS 1260	<0.10
POLYCHLORINATED BIPHENYLS AS 1016	<0.10
POLYCHLORINATED BIPHENYLS AS 1221	<0.10
POLYCHLORINATED BIPHENYLS AS 1232	<0.10
METHOXYCHLOR	<0.10
O P-DDT	<0.10

THE RESULTS ARE EXPRESSED AS ug?l EXCEPT pH OR OTHERWISE INDICATED.

RESPECTFULLY SUBMITTED,

AGES Laboratories

(b) (4) [redacted]

LABORATORY MANAGER

AGES

ORIGINAL
(Red)

REFERENCE NO. 44

3600-PM-WQ0003 4/94

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL RESOURCES
WATER MANAGEMENT PROGRAM

AUTHORIZATION TO DISCHARGE UNDER THE NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM

INDUSTRIAL NPDES PERMIT NO. PA 0013641 Amendment 1

In compliance with the provisions of the Clean Water Act, 33 U.S.C. Section 1251 et seq. (the "Act") and Pennsylvania's Clean Streams Law, as amended, 35 P.S. Section 691.1 et seq.,

Damascus - Bishop Tube Company, Inc.

is authorized to discharge from a facility located at

Route 30 & Malin Road, Frazer, PA 19355

Municipality East Whiteland Township County Chester County

to receiving waters named

Little Valley Creek tributary

in accordance with effluent limitations, monitoring requirements and other conditions set forth in Parts A, B, and C hereof.

THIS PERMIT SHALL EXPIRE AT MIDNIGHT, 7/29/99.

The authority granted by this permit is subject to the following further qualifications:

1. If there is a conflict between the application, its supporting documents and/or amendments and the terms and conditions of this permit, the terms and conditions shall apply.

2. Failure to comply with the terms, conditions, or effluent limitations of this permit is grounds for enforcement action; for permit termination, revocation and reissuance, or modification; or for denial of a permit renewal application.

3. Complete application for renewal of this permit, or notification of intent to cease discharging by the expiration date, must be submitted to the Department at least 180 days prior to the above expiration date (unless permission has been granted by the Department for submission at a later date), using the appropriate NPDES permit application form.

   In the event that a timely and complete application for renewal has been submitted and the Department is unable, through no fault of the permittee, to reissue the permit before the above expiration date, the terms and conditions of this permit, including submission of the Discharge Monitoring Reports, will be automatically continued and will remain fully effective and enforceable pending the grant or denial of the application for permit renewal.

4. This NPDES permit does not constitute authorization to construct or make modifications to wastewater treatment facilities necessary to meet the terms and conditions of this permit.

DATE PERMIT ISSUED _____

DATE PERMIT AMENDMENT ISSUED 2-23-95

DATE EFFECTIVE 3-1-95

ISSUED BY _____

TITLE: Water Management Program Manager

(RN)3

1. EFFLUENT LIMITATIONS AND MONITORING REQUIREMENTS, FOR DISCHARGE 001; LOCATED AT LATITUDE 40° 2'30", LONGITUDE 75°32'15", WHICH RECEIVES WASTE FROM: Damascus-Bishop Tube Company, Inc. noncontact cooling water.

A. The permittee is authorized to discharge during the period from issuance through expiration.
B. Based on production data and anticipated wastewater characteristics and flows described in the permit application and its supporting documents and/or amendments, the following effluent limitations and monitoring requirements apply:

DISCHARGE PARAMETER	DISCHARGE LIMITATIONS*						MONITORING REQUIREMENTS		
	MASS UNITS (lbs/day)		CONCENTRATIONS (mg/l)						
	AVERAGE MONTHLY	MAXIMUM DAILY	AVERAGE ANNUAL	AVERAGE MONTHLY	MAXIMUM DAILY	INSTANTANEOUS MAXIMUM	MEASUREMENT FREQUENCY	SAMPLE TYPE	24 HOUR REPORT UNDER A.3.C
FLOW							1/Week	Measured	
TEMPERATURE						87°F	1/Week	I-S	
pH	Within limits of 6 to 9 Standard Units at all times						1/Week	Grab	
TOTAL RESIDUAL CHLORINE **				Monitor/ Report			1/Week	Grab	

There shall be no discharge of floating solids or visible foam in other than trace amounts.

Samples taken in compliance with the monitoring requirements specified above shall be taken at the following location(s): 001

*Unless otherwise indicated, these are gross discharge limitations.

** Instantaneous minimum and instantaneous maximum concentration shall also be reported on Discharge Monitoring Report along with Average Monthly Concentration.

(RN).7

1. EFFLUENT LIMITATIONS AND MONITORING REQUIREMENTS, FOR DISCHARGE 002; LOCATED AT LATITUDE 40°02'30", LONGITUDE 75°32'15", WHICH RECEIVES WASTE FROM: storm water
   A. The permittee is authorized to discharge during the period from issuance through expiration.
   B. Based on production data and anticipated wastewater characteristics and flows described in the permit application and its supporting documents and/or amendments, the following effluent limitations and monitoring requirements apply:

DISCHARGE PARAMETER	DISCHARGE LIMITATIONS*						MONITORING REQUIREMENTS		
	MASS UNITS (lbs/day)		CONCENTRATIONS (mg/l)						
	AVERAGE MONTHLY	MAXIMUM DAILY	AVERAGE ANNUAL	AVERAGE MONTHLY	MAXIMUM DAILY	INSTANTANEOUS MAXIMUM	MEASUREMENT FREQUENCY	SAMPLE TYPE	24 HOUR REPORT UNDER A.3.C
CBOD-5				Monitor/ Report		Monitor/ Report	1/6 Month	1 Grab 1 Comp.	
CHEMICAL OXYGEN DEMAND				Monitor/ Report		Monitor/ Report	1/6 Month	1 Grab 1 Comp.	
OIL & GREASE				Monitor/ Report		Monitor/ Report	1/6 Month	1 Grab 1 Comp.	
TOTAL SUSPENDED SOLIDS				Monitor/ Report		Monitor/ Report	1/6 Month	1 Grab. 1 Comp.	
pH				Monitor/ Report		Monitor/ Report	1/6 Month	1 Grab 1 Comp.	
LEAD (Total)				Monitor/ Report		Monitor/ Report	1/6 Month	1 Grab 1 Comp.	
CHROMIUM (Total)				Monitor/ Report		Monitor/ Report	1/6 Month	1 Grab 1 Comp.	
COPPER (Total)				Monitor/ Report		Monitor/ Report	1/6 Month	1 Grab 1 Comp.	
CADMIUM, (Total)				Monitor/ Report		Monitor/ Report	1/6 Month	1 Grab 1 Comp.	
ARSENIC (Total)				Monitor/ Report		Monitor/ Report	1/6 Month	1 Grab 1 Comp.	

There shall be no discharge of floating solids or visible foam in other than trace amounts.
Samples taken in compliance with the monitoring requirements specified above shall be taken at the following location(s): Outfall 002
*Unless otherwise indicated, these are gross discharge limitations. (RN)18

Continued from Page 2a of 14

DISCHARGE PARAMETER	DISCHARGE LIMITATIONS*						MONITORING REQUIREMENTS		
	MASS UNITS (lbs/day)		CONCENTRATIONS (mg/l)						
	AVERAGE MONTHLY	MAXIMUM DAILY	AVERAGE ANNUAL	AVERAGE MONTHLY	MAXIMUM DAILY	INSTAN-TANEOUS MAXIMUM	MEASUREMENT FREQUENCY	SAMPLE TYPE	24 HOUR REPORT UNDER A.3.C
IRON (Dissolved)				Monitor/ Report		Monitor/ Report	1/6 Month	1 Grab 1 Comp.	
FLUORIDE (Total)				Monitor/ Report		Monitor/ Report	1/6 Month	1 Grab 1 Comp.	

* Unless otherwise indicated, these are gross discharge limitations.

(1) This discharge shall consist solely of storm water runoff

(2) There shall be no discharge of floating solids or visible foam in other than trace amounts.

(3) This discharge is also subject to the terms and conditions of the General Permit for Discharges of storm water from industrial activities PAG-3, as issued on November 7, 1992 which is attached and made part of this permit.

Samples taken in compliance with the monitoring requirements specified above shall be taken at the following location(s): Outfall 002

(RN) 19

I. EFFLUENT LIMITATIONS AND MONITORING REQUIREMENTS FOR DISCHARGE 003;
LOCATED AT LATITUDE 40°02'25", LONGITUDE 75°32'19", WHICH RECEIVES WASTE FROM: Storm Water

A. The permittee is authorized to discharge during the period from issuance through expiration.
B. Based on production data and anticipated wastewater characteristics and flows described in the permit application and its supporting documents and/or amendments, the following effluent limitations and monitoring requirements apply:

1. This discharge shall consist solely of storm water runoff.

2. There shall be no discharge of floating solids or visible foam in other than trace amounts.

3. This discharge is subject to the terms and conditions of the General Permit for Discharges of Storm Water from Industrial Activities, PAG-3, as issued on November 7, 1992 which is attached and made part of this permit.

Samples taken in compliance with the monitoring requirements specified above shall be taken at the following location(s): 003 not monitored

(RN)20

2. Definitions

a. The term "Bypass" means the intentional diversion of wastes from any portion of a treatment facility.

b. The term "severe property damage" means substantial physical damage to property, damage to the treatment facilities which causes them to become inoperable, or substantial and permanent loss of natural resources which can reasonably be expected to occur in the absence of a bypass. Severe property damage does not mean economic loss caused by delays in production.

c. The "average monthly" mass discharge means the total discharge by weight during a calendar month divided by the number of days in the month that the production or commercial facility was operating. Where less than daily sampling is required by this permit, the average monthly mass discharge shall be determined by the summation of all the measured daily discharges by weight divided by the number of days during the calendar month when the measurements were made.

d. The "maximum daily" mass discharge means the total discharge by weight during any calendar day.

e. The "average monthly' concentration means the arithmetic average of all the daily determinations of concentration made during a calendar month.

f. The "daily determination of concentration" means either the concentration of a composite sample taken during a calendar day or the arithmetic average of all grab samples taken during a calendar day.

g. The "maximum daily" concentration means the daily determination of concentration for any calendar day.

h. The "instantaneous maximum" concentration means the concentration not to be exceeded at any time in any grab sample.

i. The term "Composite Sample" means a combination of individual samples obtained at regular intervals over a time period. Either the volume of each individual sample is proportional to discharge flow rates, or the sampling interval (for constant volume samples) is proportional to the flow rates over the time period used to produce the composite. The maximum time period between individual samples shall not exceed two hours, except that for wastes of a uniform nature the samples may be collected on a frequency of at least twice per working shift and shall be equally-spaced over a 24-hour period (or over the operating day if flows are of a shorter duration).

j. The term "Grab Sample" means an individual sample collected in less than 15 minutes.

k. The term "i-s" means immersion stabilization - in which a calibrated device is immersed in the effluent stream until the reading is stabilized.

l. The "average monthly" temperature means the arithmetic mean of temperature measurement made on an hourly basis, or the mean value plot of the record of a continuous automated temperature recording instrument, either during a calendar month or during the operating month if flows are of a shorter duration.

m. The "maximum daily" temperature means the highest arithmetic mean of the hourly temperatures observed for any two (2) consecutive hours during a 24-hour day, or during the operating day if flows are of a shorter duration.

n. The term "Measured Flow" means any method of liquid volume measurement, the accuracy of which has been previously demonstrated in engineering practice, or for which a relationship to absolute volume has been obtained.

o. The term "At outfall XXX" means a sampling location in outfall line XXX downstream from the last point at which wastes are added to outfall line XXX, or otherwise specified.

p. The term "Estimate" means to be based on a technical evaluation of the sources contributing to the discharge including, but not limited to, pump capabilities, water meters and batch discharge volumes.

q. The term "non-contact cooling water" shall mean water which is used in a cooling system designed so as to maintain constant separation of the cooling medium from all contact with process chemicals but which may on occasion, as a result of corrosion, cooling system leakage or similar cooling system failures contain small amounts of process chemicals: provided, that all reasonable measures have been taken to prevent, reduce, eliminate and control to the maximum extent feasible such contamination: and provided further, that all reasonable measures have been taken that will mitigate the effects of such contamination once it has occurred.

3. SELF-MONITORING, REPORTING, AND RECORDS KEEPING

a. Representative Sampling

Samples and measurements taken as required herein shall be representative of the volume and nature of the monitored discharge.

b. Reporting of Monitoring Results

(1) Monitoring results obtained during each month shall be summarized for that month and reported on a Discharge Monitoring Report (DMR) Form postmarked no later than the 28th day of the following month. Duplicate signed copies of these and all other reports required herein, shall be submitted to:

Regional Water Quality Manager
Dept. of Environmental Resources
Lee Park, Suite 6010
555 North Lane
Conshohocken, PA 19428

(2) If the permittee monitors any pollutant, using analytical methods described in A.3.e. below, more frequently that the permit requires, the results of this monitoring shall be incorporated, as appropriate, into the calculations used to report self-monitoring data on the DMR.

c. Non-Compliance Reporting

(1) 24-Hour Reporting - The permittee shall orally report to the Department within 24-hours of becoming aware of the following:

(a) Actual or anticipated non-compliance with any term or condition of this permit which may endanger health or the environment.

(b) Actual or anticipated non-compliance with any "maximum daily" discharge limitation which is identified in Part A.1 of this permit as being either:

(i) A toxic pollutant effluent standard established by EPA pursuant to Section 307(a) of the Clean Water Act,

(ii) For a toxic or hazardous polutant which, if not adequately treated, could constitute a threat to human health, welfare, or the environment, or

(iii) Any pollutant identified as the method to control a toxic pollutant or hazardous substance (i.e. indicator pollutant).

(c) Any unanticipated bypass which exceeds any effluent limitations in the permit.

(d) Where the permittee orally reports this information within the above mentioned 24-hour time period, a written submission outlining the above information must be submitted to the Department within 5-days of becoming aware of such a condition, unless this requirement is waived by the Department upon receipt of the oral report.

(2) Other Non-Compliance Reporting

(a) The permittee shall give advance notice to the Department of any planned changes to the permitted activity or facility which may result in non-compliance with permit requirements.

(b) Where the permittee knows in advance of the need for a by-pass which will exceed effluent limitations, it shall submit prior notice to the Department at least 10 days, if possible, before the date of the bypass.

(c) The permittee shall report all instances of non-compliance which are not reported above at the time of DMR submission.

(3) The reports and notifications required above shall contain the following information:

(a) A description of the discharge and cause of non-compliance;

(b) The period of non-compliance, including exact dates and times and/or the anticipated time when the discharge will return to compliance; and

(c) Steps being taken to reduce, eliminate, and prevent recurrence of the non-complying discharge.

d. Specific Toxic Substance Notification Levels - The permittee shall notify the Department as soon as it knows or has reason to believe the following:

(1) That any activity has occurred, or will occur, which would result in the discharge of any toxic pollutant which is not limited in the permit, if that discharge will exceed the highest of the following "notification levels".

(a) One hundred micrograms per liter

(b) Two hundred micrograms per liter for acrolein and acrylonitrile

(c) Five hundred micrograms per liter for 2, 4-dinitrophenol and 2-methyl -4, 6-dinitrophenol

(d) One milligram per liter for antimony

(e) Five (5) times the maximum concentration value reported for that pollutant in the permit application

(f) Any other notification level established by the Department

(2) That it has begun, or expects to begin, to use or manufacture as an intermediate or final product or byproduct any toxic pollutant which was not reported in the permit application.

e. Test Procedures

Unless otherwise specified in this permit, the test procedures for the analysis of pollutants shall be those contained in 40 CFR Part 136, or alternate test procedures approved pursuant to that part.

f. Recording of Results

For each measurement or sample taken pursuant to the requirements of this permit, the permittee shall record the following information:

(1) The exact place, date, and time of sampling or measurements;

(2) The person(s) who performed the sampling or measurements;

(3) The dates the analyses were performed;

(4) The person(s) who performed the analyses;

(5) The analytical techniques or methods used; and

(6) The results of such analyses.

g. Records Retention

All records of monitoring activities and results (including all original strip chart recordings for continuous monitoring instrumentation and calibration and maintenance records), copies of all reports required by this permit, and records of all data used to complete the application for this permit shall be retained by the permittee for three (3) years. The three year period shall be extended as requested by the Department or the EPA Regional Administrator.

4. SCHEDULE OF COMPLIANCE

a. The permittee shall achieve compliance with the effluent limitations specified for discharges in accordance with the following schedule:

b. Periodic Reports Required

No later than 14 calendar days following a date identified in the above schedule of compliance, the permittee shall submit to the Department a written notice of compliance or non-compliance with the specific schedule requirement. In the case of non-compliance, the notice shall include the cause of non-compliance, any remedial actions taken, the estimated date when compliance with the elapsed date shall occur, and the probability of meeting the next scheduled requirement.

1. MANAGEMENT REQUIREMENTS

a. Permit Modification, Termination, or Revocation and Reissuance

(1) This permit may be modified, terminated, or revoked and reissued during its term for any of the causes specified in 25 Pa. Code, Chapter 92.

(2) The filing of a request by the permittee for a permit modification, revocation and reissuance, or termination, or a notification of planned changes or anticipated non-compliance, does not stay any permit condition.

(3) Toxic Pollutants

Notwithstanding the above, if a toxic effluent standard or prohibition (including any schedule of compliance specified in such effluent standard or prohibition) is established under Section 307(a) of the Act for a toxic pollutant which is present in the discharge, and such standard or prohibition is more stringent than any limitation for such pollutant in this permit, then this permit shall be modified or revoked and reissued by the Department to conform with the toxic effluent standard or prohibition and the permittee so notified.

In the absence of a Departmental action to modify or to revoke and reissue this permit, any toxic effluent standard or prohibition established under Section 307(a) of the Act is considered to be effective and enforceable against the permittee.

b. Duty to Provide Information

(1) The permittee shall furnish to the Department, within a reasonable time, any information which the Department may request to determine whether cause exists for modifying, revoking and reissuing, or terminating this permit, or to determine compliance with this permit.

(2) The permittee shall furnish to the Department, upon request, copies of records required to be kept by this permit.

(3) Other Information - Where the permittee becomes aware that it failed to submit any relevant facts in a permit application, or submitted incorrect information in a permit application or in any report to the Department, it shall promptly submit such facts or information to the Department.

(4) The permittee shall give advance notice to the Department of any planned physical alterations or additions to the permitted facility.

c. Facilities Operation

The permittee shall at all times maintain in good working order and properly operate all facilities and systems (and related appurtenances) for collection and treatment which are installed or used by the permittee for water pollution control and abatement to achieve compliance with the terms and conditions of the permit. Proper operation and maintenance includes but is not limited to effective performance based on designed facility removals, adequate funding, effective management, adequate operator staffing and training, and adequate laboratory and processing controls including appropriate quality assurance procedures. This provision includes the operation of backup or auxiliary facilities or similar systems when necessary to achieve compliance with this permit.

d. Adverse Impact

The permittee shall take all reasonable steps to minimize or correct any adverse impact on the environment resulting from non-compliance with this permit.

e. Bypassing

(1) *Bypassing not Exceeding Permit Limitations* - The permittee may allow any bypass to occur which does not cause effluent limitations to be exceeded, but only if the bypass is for essential maintenance to assure efficient operation. This type of bypassing is not subject to the reporting and notification requirements of Part A.3.c above.

(2) Other Bypassing - In all other situations bypassing is prohibited unless the following conditions are met:

(a) A bypass is unavoidable to prevent loss of life, personal injury or "severe property damage";

(b) There are no feasible alternatives to a bypass, such as the use of auxiliary treatment facilities, retention of untreated wastes, or maintenance during normal periods of equipment down-time. (This condition is not satisfied if the permittee could have installed adequate backup equipment to prevent a bypass which occurred during normal periods of equipment downtime or preventive maintenance); and

(c) The permittee submitted the necessary reports required under Part A.3.c above.

(3) The Department may approve an anticipated bypass, after considering its adverse effects, if the Department determines that it will meet the three conditions listed above.

f. Reduction, Loss, or Failure of the Treatment Facilities

Upon reduction, loss, or failure of the treatment facilities, in order to maintain compliance with its permit, the permittee shall control production and all discharges until either the facility is restored or an alternative method of treatment is provided. This requirement applies in the situation where, among other things,the primary source of power of the treatment facility is reduced, lost, or fails.

g. Removed Substances

Solids, sludges, filter backwash, or other pollutants removed in the course of treatment or control of wastewaters shall be disposed of in a manner such as to prevent any pollutant from such materials from adversely affecting the environment.

2. RESPONSIBILITIES

a. Right of Entry

Pursuant to Sections 5(b) and 305 of Pennsylvania's Clean Streams Law and 25 Pa. Code, Chapter 92, the permittee shall allow the head of the Department, the EPA Regional Administrator, and/or their authorized representatives, upon the presentation of credentials and other documents as may be required by law:

(1) To enter upon the permittee's premises where an effluent source is located or in which any records are required to be kept under the terms and conditions of this permit; and

(2) At reasonable times to have access to and copy any records required to be kept under the terms and conditions of this permit; to inspect any monitoring equipment or monitoring method required in this permit; to inspect any collection, treatment, pollution management, or discharge facilities required under the permit; and to sample any substances or parameters at any location.

b. Transfer of Ownership or Control

(1) No permit may be transferred unless approved by the Department.

(2) In the event of any pending change in control or ownership of facilities from which the authorized discharges emanate, the permittee shall notify the Department by letter of such pending change at least 30 days prior to the change in ownership or control.

(3) The letter shall be accompanied by the appropriate Department forms for transfer of the permit and a written agreement between the existing permittee and the new owner or controller stating that the existing permittee shall be liable for violations of the permit up to and until the date of permit transfer and that the new owner or controller shall be liable for permit violations from that date on.

(4) After receipt of the documentation above, the Department shall notify the existing permittee and the new owner or controller of its decision concerning approval of the transfer. In approving a transfer the Department may modify or revoke and reissue the permit.

(5) In the event the Department does not approve transfer of the permit, the new owner or controller must submit a new permit application.

c. Confidentiality of Reports

Except for data determined to be confidential under 25 Pa. Code, Chapter 92 all reports prepared in accordance with the terms of this permit shall be available for public inspection at the offices of the Department and the EPA Regional Administrator. Effluent data shall not be considered confidential.

d. Penalties and Liability

Nothing in this permit shall be construed to relieve the permittee from civil or criminal penalties for non-compliance pursuant to Section 309 of the Clean Water Act or Sections 602 or 605 of the Clean Streams Law.

Nothing in this permit shall be construed to preclude the institution of any legal action or relieve the permittee from any responsibilities, liabilities, or penalties to which the permittee is or may be subject under Section 311 of the Act.

e. Property Rights

The issuance of this permit does not convey any property rights in either real or personal property, or any exclusive privileges; nor does it authorize any injury to private property or any invasion of personal rights.

f. Other Laws

Nothing herein contained shall be construed to be an intent on the part of the Department to approve any act made or to be made by the permittee inconsistent with the permittee's lawful powers or with existing laws of the Commonwealth regulating industrial wastes and the practice of professional engineering, nor shall this permit be construed to sanction any act otherwise forbidden by federal or state law or regulation, or by local ordinance. Nor does it pre-empt any duty to obtain state or local assent required by law for the discharge(s).

g. Severability

The provisions of this permit are severable, and if any provision of this permit, or the application of nay provision of this permit to any circumstances, is held invalid, the application of such provision to other circumtances, and the remainder of this permit, shall not be affected thereby.

PART C

OTHER REQUIREMENTS

1. If at anytime the Department determines that the discharge permitted herein creates a public nuisance or causes environmental harm to the receiving water of the Commonwealth, the Department may require the Permittee to adopt such remedial measures as will produce a satisfactory effluent. If the Permittee fails to adopt such remedial measures within the time specified by the Department, the right to discharge herein granted shall, upon notice by the Department, cease and become null and void.

2. The attention of the permittee is directed to the fact that the herein approved discharge is directed to a small stream which affords a limited dilution potential. If the effluent creates a health hazard or nuisance, the permittee shall upon notice from the Department of Environmental Resources, provide such additional treatment as may be required by the Department.

3. No chemical addition for control of corrosion, scaling, algae, slime, fouling or oxygen, etc., shall be made to the cooling or boiler water system which has a discharge covered by this permit, without approval by the Department.

4. If there is a change in ownership of this facility or in permittee name, an application for transfer of permit must be submitted to the Department.

5. The Department may identify and require certain discharge specific data to be submitted before the expiration date of this permit. Upon notification by the Department, the permittee will have 12 months from the date of the notice to provide the required data. These data, along with any other data available to the Department, will be used in completing the Watershed TMDL/WLA Analysis and in establishing discharge effluent limits.

6. The permittee will ensure that applied chlorine dosages, used for disinfection or other purposes, are optimized to the degree necessary such that the total residual chlorine (TRC) in the discharge effluent does not cause an adverse stream impact. In doing so, the permittee shall consider relevant factors affecting required chlorine dosage, such as wastewater characteristics, mixing and contact times, desired result of chlorination, and expected impact on the receiving water body. The TRC data shall be recorded daily and maintained at the facility. For municipal facilities the data shall be summarized annually as part of the Chapter 94 - Municipal Wasteload Management Report.

   If the Department determines or receives documented evidence that levels of TRC in the permittee's effluent are causing adverse water quality impacts in the receiving water, the permittee shall be required to institute necessary additional steps to reduce or eliminate such impact.

APPLICATION COMPLETION AND SUBMITTAL CHECKLIST

Page	Included?	Item
	✓	Three (3) copies of application package submitted
	✓	Original copy of application notarized
	✓	Application Fee
	✓	Proper evidence of Act 14 municipality, county notification
	✓	Proof of local newspaper public notice (for new and substantially changed discharges only)

SECTION A - PHYSICAL LOCATION AND GENERAL INFORMATION
(To be completed by All Applicants)

1	✓	1.	Name of Facility
1	✓	2.	Facility Location
1	✓	3.	Facility Operator and Ownership Information
1	✓	4.	SIC Codes
1	✓	5.	General Description and Nature of Business
1	✓	6.	Past and Current NPDES and WQM Part II Permits
2	✓	7.	Topographic Map
2	✓	8.	Outfall Location (submit copy of Topo Map with discharge location)
2	—	9.	Preparedness, Prevention, and Contingency (PPC) Plans Currently being revis.
3	✓	10.	Line Drawing
4	✓	11.	Site Plan and Stormwater Runoff for outfalls discharging BOTH stormwater and process wastewater

SECTION B - NEW SOURCE DETERMINATION
(To be Completed by All Applicants if Applicable)

5 NA

SECTION C - DATA REQUIREMENTS FOR PROCESS, NCCW, AND SANITARY WASTEWATER DISCHARGES

6	NA	I.	OUTFALLS AND ASSOCIATED WASTEWATER TREATMENT TECHNOLOGIES
7	NA	II.	SOURCES OF WASTEWATER CONTRIBUTING TO OUTFALLS
7	NA	1.	Process Wastewater
8	NA	2.	Other Wastewater
8	NA	3.	Total Process, Miscellaneous, NCCW and Sanitary Wastewater
8	NA	4.	Process Wastewater Combined with Storm Water
9	NA	III.	REQUIRED AND OPTIONAL ANALYSES
9	NA	1.	Optional Site-Specific Toxics Data
10	NA	2.	Summary of Required Analyses Worksheet
11-23	NA	3.	Analyses Results
24	NA	IV.	INFORMATION ON OTHER POTENTIALLY TOXIC POLLUTANTS KNOWN OR EXPECTED TO BE PRESENT IN THE DISCHARGE
24	NA	1.	Chemical Additives
25	NA	2,3	Other Potentially Toxic Pollutants
26	NA	4a.	GC/MS Five Peaks Pollutants
27	NA	4b.	Other Chemicals

-18-

APPLICATION COMPLETION AND SUBMITTAL CHECKLIST (continued)

SECTION C - (continued)

28 NA V. HAZARDOUS SUBSTANCE SPILL REPORTING REQUIREMENT EXEMPTION

29 NA VI. ANTICIPATED ENVIRONMENTAL PROTECTION IMPROVEMENTS

29 NA VII. BIOLOGICAL TOXICITY TEST DATA

SECTION D - "STORM WATER DISCHARGES ASSOCIATED WITH INDUSTRIAL ACTIVITY"

30 ✓ I. IF REQUIRED TO COMPLETE THIS SECTION, ALL PARTS ARE COMPLETE

SECTION E - MISC. INFORMATION SUBMISSION (To be Completed by All Applicants)

36 ✓ I. CONTRACTED ANALYTICAL ASSISTANCE

37 NA II. OTHER INFORMATION

SECTION F - CERTIFICATION AND SIGNATURES OF APPLICANT (To Be Completed by All Applicants)

38 ✓

NPDES Number PA 0013641

SECTION A - PHYSICAL LOCATION AND GENERAL INFORMATION

1. Name of Facility Damascus-Bishop Tube Company, Inc.

2. Facility Location (Street) P.O. Box 1189, Route 30 and Malin Road

   City or Town Frazer Zip Code 19355

   County Chester

3. Facility Operator (PERMIT APPLICANT) Information. (For correspondence concerning permit application review and permit action).

   Operator (PERMIT APPLICANT) Name Damascus-Bishop Tube Company, Inc.

   Phone (215) 647 - 3450

   Street P.O. Box 1189, Route 30 and Malin Road

   City or Town Frazer State PA Zip Code 19355

   Does the Operator own the facility? yes ☐ no ☒

   Status of Operator: Federal Gov't. ☐ State Gov't. ☐ Private ☒ Local Gov't. ☐

   Other

4. SIC Codes — Corresponding SIC Description

   1st 3317 Iron adn Steel Industry - Steel Pipe and Tubes

   2nd

   3rd

   4th

5. General Description and Nature of Business

   Coils of flat stainless steel strips are formed into various lengths of pipes and tubes.

6. List all NPDES and Part II Water Quality Management Permits presently held for this facility

   NPDES Permit No. PA 0013641 (renewal pending)

SECTION A (continued) NPDES Number PA 0013641

7. Attach Topographic Map. See instructions.

8. Outfall Location: For each outfall, list the latitude and longitude of its location to the nearest second and the name of the receiving water. Where available, the receiving stream width and depth should also be provided using actual measurements or topographic map and navigational charts.

FINAL OUTFALL NUMBER (list)	LATITUDE			LONGITUDE			RECEIVING WATER (Name)	Low Flow Stream	
	1. DEG.	2. MIN.	3. SEC.	1. DEG.	2. MIN.	3. SEC.		Ft. Width	Ft. Depth
002*	40	02	30	75	32	15	Little Valley Creek Tributary	10	1.5
003	40	02	30	75	32	15	Unnamed tributary to Little Valley Creek Tributary	10	1.5

9. Preparedness, Prevention, and Contingency (PPC) Planning

Does the facility have a PPC plan which has been reviewed and approved by the Department?

☒ Yes _____ Date of Approval
☐ No (attach 2 copies for review and approval)

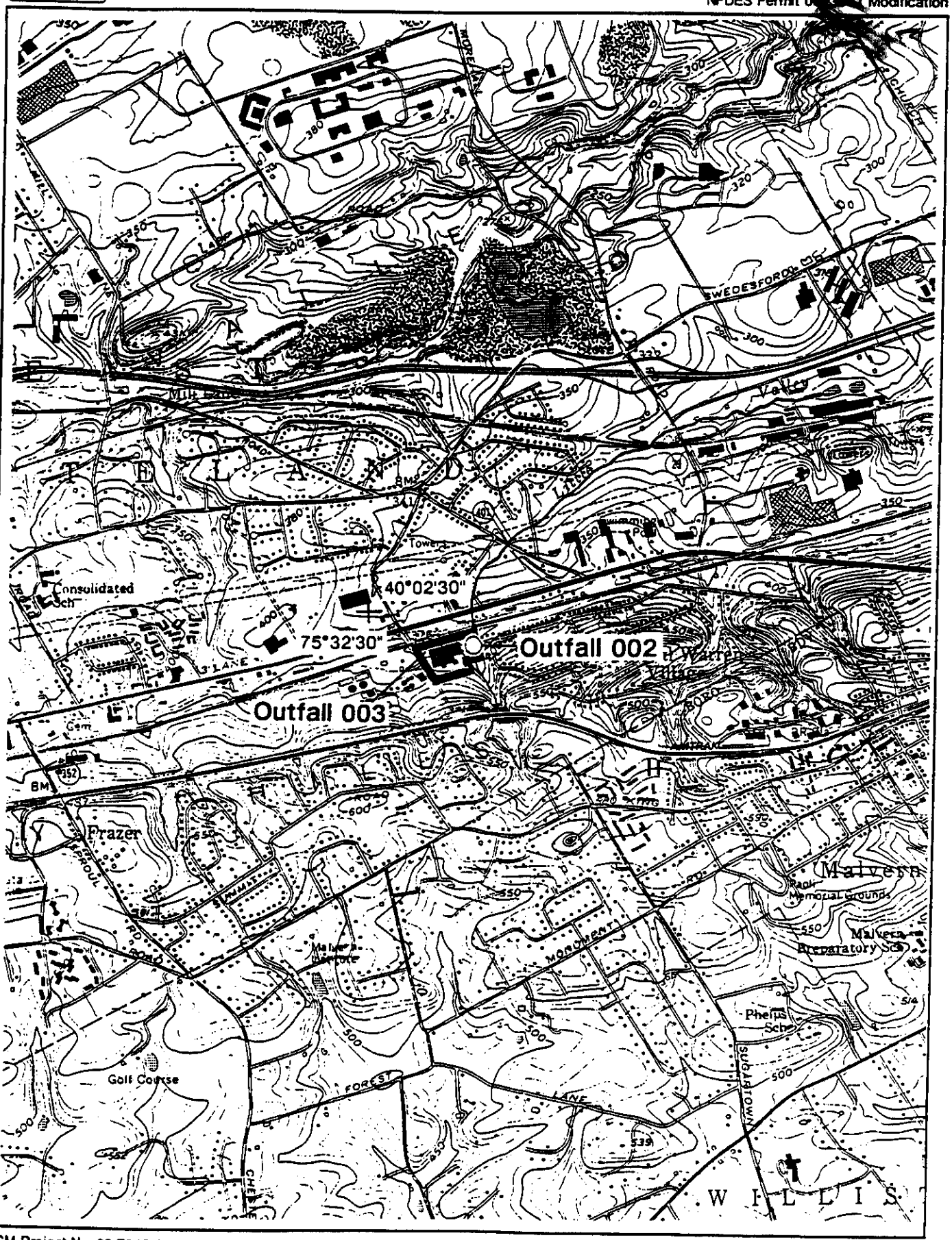
Does the facility have any other related plans, such as a Pollution Incident Prevention (PIP) Plan or a Spill Prevention Control and Counter Measure (SPCC) Plan? ☐ Yes ☒ No

If yes, identify and indicate date(s) approved by the Department or EPA.

* A request has been made to separate the existing NPDES noncontact cooling water discharge outfall from the stormwater discharge and to move the noncontact cooling water outfall approximately 60 feet north of its present location as shown on Figure 2. However, this is not a large enough distance to change the existing latitude and longitude coordinates.

BCM

DAMASCUS-BISHOP TUBE COMPANY, INC.
NPDES Permit 0[illegible] Modification



SOURCE: USGS Topo Quadrangle: Malvern, PA (Photorevised 1983)

BCM Project No. 00-7913-01

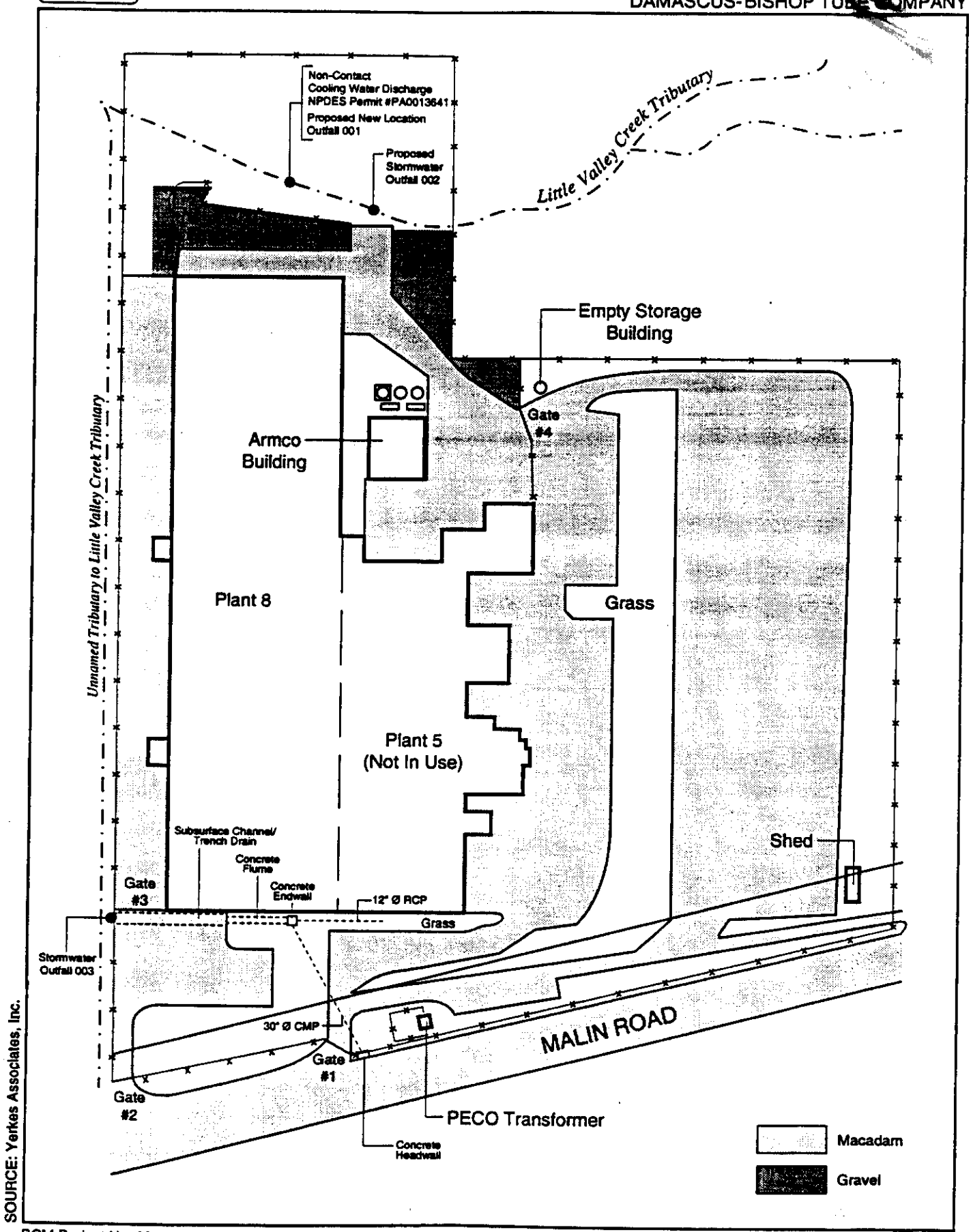
0 2000 FT

NORTH

Figure 1
Site Location Map

BCM

DAMASCUS-BISHOP TUBE COMPANY



SOURCE: Yerkes Associates, Inc.

BCM Project No. 00-7913-01

0 125 FT

NORTH

Figure1-2
Site Map

SECTION A (continued) NPDES Number PA 00136[redacted]

10. Line Drawing. See instructions.

Stormwater Runoff → Outfall 002
Parking lot, roofs, vegetated areas → Little Valley Creek Tributary

Stormwater Runoff → Outfall 003
Parking lot, roofs, vegetated areas → Unnamed tributary to Little Valley Creek Tributary

SECTION A (continued) NPDES Number PA 0013641

11. Site Plan and Stormwater Runoff - Use space below or an attachment. See instructions.

Complete this part for outfalls discharging process, non-contact cooling or sanitary wastewater in combination with stormwater.

The Department strongly recommends the separation of stormwater and other wastewaters. However, if this is impossible, complete this part. Section C must be completed for the other wastewater contribution. Complete Section D for the stormwater contribution. If the stormwater can be separated, complete Section D for the stormwater outfall, and Section C for any other wastewater outfalls.

Not Applicable*

* Damascus-Bishop Tube Company, Inc. has requested approval from PADER to separate its noncontact cooling water outfall and stormwater outfall. Upon NPDES Permit 0013641 renewal, Damascus-Bishop Tube will immediately separate its noncontact cooling water outfall (new Outfall 001) and stormwater outfall (new Outfall 002).

NPDES Number PA 0013641

SECTION B - NEW SOURCE DETERMINATION Not applicable

Referring to the instructions for this question, indicate when "construction" (as defined by EPA) and discharge began for the facilities causing each discharge? If "construction" has not begun, state when it will begin.

Do not complete this table for outfalls which only discharge sanitary wastewater or stormwater runoff (unless considered "process wastewater" under an EPA effluent guideline regulation).

Date "Construction" Began*	Date Discharge Began**	Facilities Causing Discharge	Outfall(s)

* If "construction" began on different dates for facilities which contribute to the same outfall, list these dates separately (use additional sheets if necessary).

** If not yet discharging, indicate date on which discharge is expected to begin.

SECTION D (continued)

IV. Narrative Description of Pollutant Sources

A. For each outfall, provide an estimate of the area (include units) of impervious surfaces (including paved areas and building roofs) drained to the outfall, and an estimate of the total surface area drained by the outfall.

Outfall Number	Area of Impervious Surface (provide units)	Total Area Drained (provide units)	Outfall Number	Area of Impervious Surface (provide units)	Total Area Drained (provide units)
002	Parking lots, roofs, Veg. Areas	5.6 acres			
003	Same	5.6 acres			

B. Provide a narrative description of significant materials that are currently or in the past three years have been treated, stored or disposed in a manner to allow exposure to storm water; method of treatment, storage, or disposal; past and present materials management practices employed, in the last three years, to minimize contact by these materials with storm water runoff; materials loading and access areas; and the location, manner, and frequency in which pesticides, herbicides, soil conditioners, and fertilizers are applied.

The Damascus-Bishop Tube Company has reason to believe that small quantities of fluoride may be discharged through storm water discharge Outfall No. 002. Damascus-Bishop believes that fluoride located in the soil occasionally leaches into the storm water discharge pipe and is thereby discharging with the stormwater.

C. For each outfall, provide the location and a description of existing structural and nonstructural control measures to reduce pollutants in storm water runoff; and a description of the treatment the storm water receives, including the schedule and type of maintenance for control and treatment measures and the ultimate disposal of any solid or fluid wastes other than by discharge.

Outfall Number	Treatment	List Codes from Table 1 (EPA Table no. 2 F1)
002	Not Applicable	
003	Not Applicable	

V. Nonstormwater Discharges

A. I certify under penalty of law that the outfall(s) covered by this application have been tested or evaluated for the presence of nonstormwater discharges, and that all nonstormwater discharges from these outfall(s) are identified in Section C of this application for the outfall.

Name and Official Title (type or print)	Signature	Date Signed

B. Provide a description of the method used, the date of any testing, and the onsite drainage points that were directly observed during a test.

VI. Significant Leaks or Spills

Provide existing information regarding the history of significant leaks or spills of toxic or hazardous pollutants at the facility in the last three years, including the approximate date and location of the spill or leak, and the type and amount of material released.

Not Applicable

NPDES # PA: 0013641

SECTION D - Stormwater Discharges Associated with Industrial Activity

I. Outfall Location

For each outfall, list the latitude and longitude of its location to the nearest 15 seconds and the name of the receiving water.

A. Outfall Number (list)	B. Latitude			C. Longitude			D. Receiving Water (name)
002	40	02	30	75	32	15	Little Valley Creek Tributar
003	40	02	30	75	32	15	Unnamed tributary to Little Valley Creek Tributary

II. Improvements

A. Are you now required by any Federal, State, or local authority to meet any implementation schedule for the construction, upgrading or operation of wastewater treatment equipment or practices or any other environmental programs which may affect the discharges described in this application? This includes, but is not limited to, permit conditions, administrative or enforcement orders, enforcement compliance schedule letters, stipulations, court orders, and grant or loan conditions. ☐ Yes ☒ No

1. Identification of Conditions, Agreements, Etc.	2. Affected Outfalls		3. Brief Description of Project	4. Final Compliance Date	
	number	source of discharge		a. req.	b. proj.

B. You may attach additional sheets describing any additional water pollution (or other environmental projects which may affect your discharges) you now have under way or which you plan. Indicate whether each program is now under way or planned, and indicate your actual or planned schedules for construction.

III. Site Drainage Map

Attach a site map showing topography (or indicating the outline of drainage areas served by the outfall(s) covered in the application if a topographic map is unavailable) depicting the facility including: each of its intake and discharge structures; the drainage area of each storm water outfall; paved areas and buildings within the drainage area of each storm water outfall, each known past or present areas used for outdoor storage or disposal of significant materials, each existing structural control measure to reduce pollutants in storm water runoff, materials loading and access areas, areas where pesticides, herbicides, soil conditioners and fertilizers are applied; each of its hazardous waste treatment, storage or disposal units (including each area not required to have a RCRA permit which is used for accumulating hazardous waste under 40 CFR 262.34); each well where fluids from the facility are injected underground; springs, and other surface water bodies which receive storm water discharges from the facility.

See Figure 2

NPDES # PA: 0013641

SECTION D (continued)

VII. Discharge Information *(Continued from previous page)*

Part A - You must provide the results of at least one analysis for every pollutant in this table. Complete one table for each outfall. See instructions for additional details.

Pollutant and CAS Number *(if available)*	Maximum Values *(include units)*		Average Values *(include units)*		Number of Storm Events Sampled	Sources of Pollutants
	Grab Sample Taken During First 30 Minutes	Flow-weighted Composite	Grab Sample Taken During First 30 Minutes	Flow-weighted Composite		
Oil and Grease						
Biological Oxygen Demand (BOD5)						
Chemical Oxygen Demand (COD)						
Total Suspended Solids (TSS)						
Total Kjeldahl Nitrogen						
Nitrate plus Nitrite Nitrogen						
Total Phosphorus						
pH (Min./Max.)						

Part B - List each pollutant that is limited in an effluent guideline which the facility is subject to or any pollutant listed in the facility's NPDES permit for its process wastewater (if the facility is operating under an existing NPDES permit). Complete one table for each outfall. See the instructions for additional details and requirements.

Pollutant and CAS Number *(if available)*	Maximum Values *(include units)*		Average Values *(include units)*		Number of Storm Events Sampled	Sources of Pollutants
	Grab Sample Taken During First 30 Minutes	Flow-weighted Composite	Grab Sample Taken During First 30 Minutes	Flow-weighted Composite		
Total Lead*						
Total Chromium*						
Total Copper*						
Total Cadmium*						
Total Arsenic*						
Dissolved Iron*						

*As required by PADER PAG-3 General Permit for Discharges of Storm Water from Industrial Activities, Appendix B, Monitoring Requirements for All Primary Metal Industry-Facilities.

ER-BWQ-288.10: Rev. 6/93

NPDES # PA: 0013641

SECTION D (continued)

Part C - List each pollutant shown in Tables 5, 6 and 7 (EPA Table Nos. 2F-2, 2F-3, and 2F-4 respectively) that you know or have reason to believe is present. See the instructions for additional details and requirements. Complete one table for each outfall.

Pollutant and CAS Number (if available)	Maximum Values (include units)		Average Values (include units)		Number of Storm Events Sampled	Sources of Pollutants
	Grab Sample Taken During First 30 Minutes	Flow-weighted Composite	Grab Sample Taken During First 30 Minutes	Flow-weighted Composite		
Fluoride						

Part D - Provide data for the storm event(s) which resulted in the maximum values for the flow weighted composite sample.

1. Date of Storm Event	2. Duration of Storm (in minutes)	3. Total rainfall during storm event (in inches)	4. Number of hours between beginning of storm measured and end of previous measurable rain event	5. Maximum flow rate during rain event (gallons per minute or specify units)	6. Total flow from rain event (gallons or specify units)	7. Season sample was taken	8. Form of Precipitation (rainfall, snowmelt)

9. Provide a description of the method of flow measurement or estimate.

NPDES Number PA 0013641

SECTION E - MISCELLANEOUS INFORMATION SUBMISSION

I. CONTRACTED ANALYTICAL ASSISTANCE

Did a contract laboratory or consulting firm perform any of the analyses required by this application?

☒ Yes, their name(s), address(es) and list(s) of the analyses performed are given below: ☐ No

Name BCM Laboratory Division
Address 1850 Gravers Road
Norristown, PA 19401
Phone (215) 275 - 0281
Types of Analyses Performed: All

Name
Address
Phone ( ) -
Types of Analyses Performed:

Name
Address
Phone ( ) -
Types of Analyses Performed:

SECTION E (continued) NPDES Number PA 0073641

II. OTHER INFORMATION

1. For New Dischargers Only: ☒ Check if Not Applicable

   a. Have there been any technical evaluations performed concerning your anticipated wastewater treatment or control facilities (including engineering reports or pilot plant studies)? Check the appropriate box below.

   ☐ Yes ☐ No

   b. If yes, briefly describe such evaluations and the resulting reports which have been prepared.

   c. Provide the name and location of any existing plant(s) which, to the best of your knowledge, resembles your planned operation with respect to items produced, production processes, wastewater constituents or wastewater treatment.

   Name _____ Location _____

2. For All Dischargers: (Optional)

   If necessary, use attached sheets to expand upon responses to any of the above Questions, or to call attention to any other information you feel should be considered in establishing permit limitations for the proposed or existing facility.

ORIGINAL
(Red)

REFERENCE NO. 45

ER-BWQ-168

Department of Environmental Resources	NPDES Compliance Inspection Report	Bureau of Water Quality Management

Section A: National Data System Coding

Transaction Code	NPDES	Yr/Mo/Day	Inspection Type	Inspector	Fac Type
1 N 2 5	3 PA0013641 11	12 940512 17	18 R	19	20

Section B: Facility Data

Name and Location of Facility Inspected	Entry Time/Date	Permit Effective Date
(Damascus) - Bishop Tube Company Inc Rt 30 + Malin Rd	12:48 5-12-94	3-20-89
Municipality: East Whiteland — County: Chester	Exit Time/Date: 2:00 5-12-94	Permit Expiration Date: 3-20-94 (renewal receive)

Name, Address of Responsible Official		Title	
Russel G. Levering (Plant Engineer / Buyer) P.O. Box 1139 Frazer PA 19355	Craig Fuller, Treasurer c/o Corporate Planning Associates Inc Suite 100 125 Strafford Ave Wayne Pa 19087	Plant Engineer / Buyer Telephone 215 647-3450	Russ Levering Contacted Yes [X] No [ ]

Section C: Areas Evaluated During Inspection
(S = Satisfactory, I = Improvement Needed, U = Unsatisfactory, D = Does Not Apply, Blank = Not Evaluated)

____ Permit Verification	I Flow Measurement	____ Effluent/Receiving Waters
____ Compliance Schedule	____ Laboratory/QA	____ Operation/Maintenance
I Records/Reports	S JD 5/12 Self-Monitoring Program	____ Pretreatment
____ Other (Specify):		

Section D: Summary of Violations/Recommendations/Comments *(Attach additional sheets if necessary)*

- DMR's have been submitted late - (they should be submitted within 28 days from the end of the reporting period)
- Flow measurement was omitted from some of the DMRs submitted recently
- NPDES permit + PA Clean Streams Law Violations

Inspector Name	Inspector Signature	Title	Date / Telephone
JoAnn Dolchak	JoAnn Dolchak 5/13/94	WQS	Date 5-12-94 Telephone 215 832-6130
Name of Person Interviewed	**Signature of Person Interviewed**	**Title**	**Date / Telephone**
RUSSELL G. LEVERING	[signature]	PLANT ENGR.	Date 5/12/94 Telephone

THIS DOCUMENT IS OFFICIAL NOTIFICATION THAT A REPRESENTATIVE OF THE DEPARTMENT OF ENVIRONMENTAL RESOURCES, BUREAU OF WATER QUALITY MANAGEMENT, INSPECTED THE ABOVE FACILITY. THE FINDINGS OF THIS INSPECTION ARE SHOWN ABOVE AND ON ANY ATTACHED PAGES.

ANY VIOLATIONS WHICH WERE UNCOVERED DURING THE INSPECTION ARE INDICATED. VIOLATIONS MAY ALSO BE DISCOVERED UPON EXAMINATION OF THE RESULTS OF LABORATORY ANALYSES OF THE DISCHARGE AND REVIEW OF DEPARTMENT RECORDS. NOTIFICATION WILL BE FORTHCOMING, IF SUCH VIOLATIONS ARE NOTED.

ER–BWQ–168: 9/87

Department of Environmental Resources

NPDES Compliance Inspection Report

Bureau of Water Quality Management

Additional Comments

Discharge is ~~from~~ non-contact cooling water from a heat exchange system. Most water is recycled but some overflow creates the outfall. The outfall pipe in place now combines with stormwater before discharging to the stream. Plans are to change this with the permit renewal + move the NPDES outfall about 80' downstream in a separate pipe. Flow through the outfall is intermittent - there's nothing discharging at this time - since ideally the system should be a 100% recycle.

Flow quantity estimate is based on knowledge of equipment There is no flow metering system or equipment running times to base this on.

Fluoride should no longer be present since this was part of a pickling operation that no longer exists here. Some flow metering system should be considered for more accurate flow estimates + to alert personnel when the ~~discharge~~ wastewater is discharging.

BCM is revising the PPC plan

Log sheets are kept which indicate dates and readings for weekly sampling.

Permit No.: PA 0013641

Date: 5-12-94

REGIONAL OFFICE

ORIGINAL
(Red)

REFERENCE NO. 46

Patty's Industrial Hygiene and Toxicology

THIRD REVISED EDITION

Volume 2B
TOXICOLOGY

GEORGE D. CLAYTON
FLORENCE E. CLAYTON
Editors

Contributors

D. M. Aviado
R. R. Beard
C. M. Berry
W. B. Deichmann
C. Frank
M. S. Micozzi
J. T. Noe
V. K. Rowe
E. E. Sandmeyer
H. E. Stokinger
T. R. Torkelson
R. C. Wands

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2.3.4 Hygienic Standards

The threshold limit value recommended by the ACGIH in 1980 was 5 ppm (28 mg/m^3) with a skin notation. There appear to be very limited data to support this or any other value.

2.3.5 Odor and Warning Properties

No data were found.

2.4 Methylene Chloride. Dichloromethane, Methylene Dichloride, CAS 75-09-2

$$CH_2Cl_2$$

2.4.1 Uses and Industrial Exposures

Methylene chloride is used as a blowing agent for foams and as a solvent for many applications, including coating photographic films, aerosol formulations, and to a large extent in paint stripping formulations. It is used as a solvent in a number of extraction processes, where its high volatility is desirable. It has high solvent power for cellulose esters, fats, oils, resins, and rubber. It is somewhat more water soluble than other chlorinated solvents.

Owing to its volatility, high concentrations may be rapidly attained in poorly ventilated areas. This property should be recognized in planning any operation using methylene chloride. It should also be remembered that formulations for paint stripping may contain other solvents as well as methylene chloride and that they are frequently found outside the workplace. These formulations often contain other ingredients that retard evaporation and in the process increase the likelihood of skin irritation.

2.4.2 Physical and Chemical Properties

Physical state	Colorless liquid
Molecular weight	84.94
Specific gravity	1.325 (20/4°C)
Melting point	−96.7°C
Boiling point	40.1°C
Vapor pressure	440 torr (25°C)
Refractive index	1.4237 (20°C)
Percent in "saturated" air	55 (25°C)
Solubility	2 g/100 ml water at 20°C; soluble in ethanol, ethyl ether, acetone
Flammability	No flash point or fire point by standard tests in air. The

Calingaert and Shapiro (182) have observed that ethylene dibromide can penetrate through several types of protective clothing, particularly neoprene rubber and several types of plastic gloves. Nylon was found to be the most resistant material but lacking in good physical characteristics. These authors proposed a combination of neoprene and nylon.

Human experience during manufacture of ethylene dibromide has been summarized (183). The mortality of two populations of employees was compared to that expected in an industrial population. In neither study was there evidence of increased deaths due to cancer. However, the populations were small; hence the statistical confidence ranges are very broad. Nevertheless, it is obvious that a one-hit statistical model based on animal data severely overestimates the number of tumors predicted in human populations exposed during the production of ethylene dibromide (184).

The reproductive history of 297 male employees manufacturing ethylene dibromide was also summarized (185). In this limited study, reproduction generally appeared to be unaffected by exposure to ethylene dibromide, although one of four plants had fewer children than predicted.

2.17.4 Hygienic Standards

No threshold limit value for ethylene dibromide was recommended by the ACGIH in 1980 although it was included in their list of animal carcinogens. It would appear prudent to limit exposure to a maximum time-weighted average of 5 ppm or less with careful control to minimize dermal contact.

2.17.5 Odor and Warning Properties

The odor of ethylene dibromide is not unpleasant and has been termed "chloroformlike." The odor is not detectable at a low enough concentration to be considered a good warning of excessive exposure.

2.18 **Methyl Chloroform,** 1,1,1-Trichloroethane, CAS 71-55-6

$$CH_3CCl_3$$

2.18.1 Uses and Industrial Exposures

Methyl chloroform is used almost exclusively as a solvent. Worldwide consumption is about 1 billion lb/year. Increasing consumption is due to a favorable combination of chemical, flammability, physical, and toxicologic properties, compared to many other common solvents. Most commercial methyl chloroform, which is sold under several trade names, contains inhibitors to prevent reaction of the solvent with aluminum and aluminum alloys. This reaction produces

hydrogen chlorid
Extensive testing a
ably the least toxic
use and abuse hav
in confined spaces.

2.18.2 Physical ar

Physical state
Molecular wei
Specific gravi
Boiling point
Vapor pressu
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Solubility

Flammability

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2.18.3 Physiologic

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trichloroethane iso
have indicated the
stances and docume
Concentrations in
fatalities due to a
confined spaces whe
terminated. In cases

Observations in Man. 1,2-Dichloroethylene was studied as an anesthetic in man, apparently with some success. Only one old report of one fatality was found (351).

3.4.4 Hygienic Standards

The threshold limit value recommended in 1979 by the ACGIH was 200 ppm (790 mg/m^3).

3.4.5 Odor and Warning Properties

No definitive data appear available. The odor has been described as slightly acrid.

3.5 **Trichloroethylene,** Acetylene Trichloride, Tri, Trilene, CAS 79-01-6

$$CHCl{=}CCl_2$$

3.5.1 Uses and Industrial Exposures

Trichloroethylene is widely used as an industrial solvent, particularly in metal degreasing and extraction processes. It has some use as a chemical intermediate and also as an anesthetic. By far the most likely contact with trichloroethylene in industry is with the vapors of the material when it is used as a solvent. In some industrial processes, such as vapor degreasing or hot extraction, the material may be used at elevated temperatures which increase the problem of escape of vapors into the workroom atmosphere. Deliberate inhalation of the vapors has been reported. Under certain conditions, such as in recycling anesthesia machines and in submarines, trichloroethylene has been decomposed by caustic scrubbers to produce much more toxic compounds.

3.5.2 Physical and Chemical Properties

Physical state	Colorless liquid
Molecular weight	131.4
Specific gravity	1.45560 (25/4°C)
Freezing point	−86.8°C
Boiling point	87°C
Vapor pressure	77 torr (25°C)
Refractive index	1.4777 (20°C)
Percent in "saturated" air	10.2 (25°C)
Solubility	0.1 g/100 ml water at 20°C; soluble in ethanol, ethyl ether

exposure (548 and 3643 person-years of observation, respectively). The cancer risk to man from trichloroethylene can by no means be ruled out from this study, particularly with regard to uncommon malignancies such as liver cancer. Nevertheless there is probably no serious cancer hazard at low exposures."

Numerous case reports allege diverse effects due to exposure to high concentrations of trichloroethylene. It is difficult to evaluate these reports because of inadequately described exposure, mixed exposures, or failure to eliminate other causes. One poorly understood phenomena is degreaser's flush, which occasionally occurs in the skin of the face, arms, and trunk of someone exposed to trichloroethylene who drinks alcohol (372).

3.5.4 Hygienic Standards

The tentative threshold limit for trichloroethylene recommended by the ACGIH in 1980 is 50 ppm (260 mg/m^3). This level is probably lower than needed to prevent beginning anesthetic effects and, based on the data presented, will prevent liver injury or other adverse effects.

3.5.5 Odor and Warning Properties

Trichloroethylene has a typical odor that has been characterized as ethereal or chloroformlike. It could not, however, be considered an effective warning. The following response to various concentrations is based on industrial experience and human studies (11).

100 ppm	Odor threshold, barely perceptible to unacclimated individuals
200 ppm	Odor apparent, not unpleasant. Transient mild eye irritation disappearing upon cessation of exposure
400 ppm	Odor very definite, not unpleasant. Slight eye irritation. Minimal light-headedness after 3 hr
1000 to 1200 ppm	Odor very strong, unpleasant. Definite eye and nasal irritation. Definite light-headedness, dizziness after 6 min
2000 ppm	Odor very strong, not likely to be tolerated. Markedly irritating to the eyes and respiratory tract. Drowsiness, dizziness, nausea in 5 min

3.6 **Tetrachloroethylene,** Perchloroethylene, Perc, CAS 127-18-4

$$CCl_2{=}CCl_2$$

3.6.1 Uses and Industrial Exposures

Perchloroethylene is used as an industrial solvent for a number of purposes, particularly dry cleaning and degreasing. It has been used as an anthelmintic in humans and animals. It also finds limited use as a chemical intermediate.

3.6.2 Physical and Chemical Properties

Physical state	Colorless liquid
Molecular weight	165.85
Specific gravity	1.6226 (20/4°C)
Melting point	−23.35°C
Boiling point	121.2°C
Vapor pressure	19 torr (25°C)
Refractive index	1.50534 (20°C)
Percent in "saturated" air	2.5 (25°C)
Solubility	0.015 g/100 ml water at 20°C; soluble in ethanol, ethyl ether, chloroform, benzene
Flammability	Not flammable by standard tests in air

1 mg/liter ≈ 147.4 ppm and 1 ppm ≈ 6.78 mg/m^3 at 25°C, 760 torr

3.6.3 Physiologic Response

Summary. The major response to perchloroethylene at high concentrations is CNS depression. It is not, however, sufficiently effective to be considered a useful anesthetic. Irritation of the eyes, nose, and throat may also be observed at high concentrations. There are some indications of nausea and gastrointestinal upset at high concentrations, and changes in the liver and kidneys may be seen following excessive exposure; however, the effects are not as severe or striking as they are from a material such as carbon tetrachloride. Relatively few incidences of industrial problems due to exposure to perchloroethylene have been reported. This is probably because of a number of circumstances including low vapor pressure and toxicity. Case reports relate a very inconsistent set of symptoms. Certainly anesthesia and, in cases of high exposure, liver injury appear to be related to perchloroethylene. Nausea, headache, anorexia, vertigo, dizziness, and other symptoms may be related to the CNS and hepatic effects. Sensitization of the heart to epinephrine does not appear to occur with this compound. As for many compounds, massive doses of perchloroethylene given by gavage have produced liver cancer in mice but not rats.

ORIGINAL
(Red)

REFERENCE NO. 47

MIGRATION AND DEGRADATION PATTERNS OF VOLATILE ORGANIC COMPOUNDS

PATRICIA V. CLINE
DANIEL R. VISTE
Warzyn Engineering Inc.
Madison, Wisconsin

(Presented at the Fifth National Conference on Management of Uncontrolled Hazardous Waste Sites, Washington, D.C. November 7 to 9, 1984).

INTRODUCTION

Volatile organic priority pollutants have been detected in groundwater all across the country. These compounds, widely used as solvents, are considered environmentally mobile and persistent. Improved analytical methods using gas chromotography and/or mass spectroscopy now allow their detection at extremely low levels. The presence of the synthetic organics in groundwater coupled with an improved ability to detect them has resulted in increasing numbers of contamination investigations.

Biodegradation is not typically an integral part of today's groundwater investigations. There is considerable controversy regarding whether degradation is an important factor in determining the fate of the chlorinated volatile organic priority pollutant. Increasing evidence indicates chlorinated solvents can be degraded in an anaerobic environment by reductive dehalogenation. It is reported this process occurs when the oxidation/reduction potential is less than 0.35V. The sequential removal of chlorine atoms from halogenated 1 and 2 carbon aliphatic compounds results in formation of other volatile, chlorinated priority pollutants which can be detected during investigations of solvent contamination.[1,2,3]

In this paper, the authors present data from a variety of sites having documented chlorinated solvents contamination. Three types of sites were selected to illustrate breakdown patterns which may develop as a result of diverse environmental conditions. Data from landfills are presented to demonstrate presence of degradation products in biologically active anaerobic environments. Two solvent recovery facilities which handle both chlorinated and non-chlorinated solvents showed similar migration and degradation patterns. Finally, an industrial site with no apparent degradation demonstrates conditions in which reductive dehalogenation may not be a primary degradation mechanism.

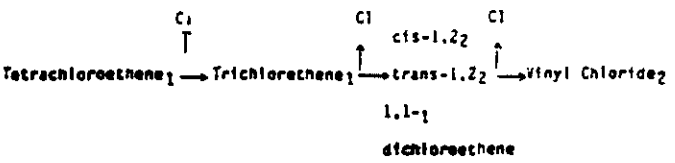
Research data indicates chlorinated solvents have varying rates of breakdown. The data were therefore evaluated for a dominance of compounds which show longer half-lives, including 1,2-dichloroethenes and vinyl chloride.[4]

BACKGROUND

For purposes of this evaluation, selected compounds were designated as "parent" compounds based on their widespread use and/or known presence at these specific sites. They include methylene chloride, 1,1,1-trichloroethane, trichlorethene and tetrachloroethene.

Breakdown products are designated as compounds which would result from reductive dehalogenation of these parent compounds and include dichloroethanes, chloroethane, dichloroethenes and vinyl chloride. For purposes of this evaluation, methylene chloride is disregarded, since it is a commonly used solvent, potential degradation product and common laboratory contaminant. Emphasis is placed on the ethene and ethane series because there is less ambiguity in the assignment of parent and breakdown products. The anaerobic breakdown sequence for the chlorinated ethenes and ethanes via reductive halogenation is shown below:

Chlorinated Ethenes



Chlorinated Ethanes

1. Research indicates substantial degradation.
2. Research indicates degradation is slow.

In work performed at the Florida International University by Parsons, Wood and DeMarco,[1] biodegradation of either trichloroethene or tetrachloroethene produced higher concentrations of cis- 1,2-dichlorethene when compared to the trans-isomer.

Trans-1,2-Dichloroethene is a priority pollutant and has a lower allowed concentration in drinking water (272 μg/l) than the cis-isomer (400 μg/l).[1] USEPA's rationale for selection of the trans-isomer as the priority pollutant was based on the availability of the analytical standard.[16]

DATA PRESENTATION

In the authors' first attempts to correlate the ethene breakdown series with data from contaminated sites, it became apparent that the dominant dichloroethene compound detected was trans-1,2-dichlorethene. The cis-isomer is not a priority pollutant and, therefore, is not mentioned in the methods for analysis of the volatile organic priority pollutants using Method 601 or Method 624.

These methods recommend the use of a column composed of 1% SP 1000 on Carbopack B. The isomer pair cannot be separated using the above column. In addition, since they have identical mass

spectra, the isomer pair will not be differentiated by mass spectrometry and will subsequently be identified as the trans-isomer.

The above theory was verified by the submittal of a standard mix containing both the cis- and trans-isomers to a prominent midwestern laboratory. Analysis by Method 624 found only the trans-isomer, but the quantitated result equalled the known total of the isomer pair.

The Michigan Department of Health can separate the cis- and trans-isomers and, in a current investigation, has determined that the major contaminant at a site is not trans-1,2-dichloroethene as found by a USEPA contract laboratory, but is the cis-isomer. They have indicated that frequently they find the cis-isomer and, if concentrations are high, they occasionally find traces of the trans-isomer.

Based on this information, the authors conclude that much of what is typically reported as the trans-isomer, which is a priority pollutant, is in fact cis-1,2-dichloroethene. In the subsequent evaluations, the authors will refer to these compounds as 1,2-dichlorethenes.

Landfills

Landfills which accept municipal waste have an anaerobic environment in which substantial breakdown of compounds occurs. At sites which have also accepted waste products containing solvents, a number of volatile organic priority pollutants can be detected in the leachate. The analyses of five leachate samples from Site #1 which accepted both municipal and industrial wastes are found in Table 1. The site also received significant quantities of hazardous and nonhazardous liquid wastes. Based on records of waste accepted, there is a dominance of "breakdown products" at this site.

The amount of breakdown products detected in groundwater at two other sites where volatile organic contaminants have migrated off-site is shown in Table 2. Site #2 is a small municipal landfill in a sand and gravel environment and Site #3 is a large clay-lined site which has accepted waste similar to Site #1. At these sites, the authors have also documented a dominance of the breakdown products in groundwater downgradient from the waste disposal boundaries.

The purpose of presenting leachate data from these landfills is to demonstrate that in an anaerobic, high-organic matrix, one is likely

Table 1
Landfill Leachate, Site #1

	Leachate Sample Number				
	1	2	3	4	5
Chlorinated Ethanes					
1 Trichlorethanes	ND[3]	68	ND	ND	ND
2 1,1-Dichloroethane	1,500	240	130	11	13
1,2-Dichloroethane	ND	12	21	ND	ND
Chloroethane	ND	21	18	160	ND
Chlorinated Ethanes					
1 Tetrachloroethene	ND	13	ND	ND	ND
Trichloroethene	ND	100	62	ND	ND
2 1,2-Dichloroethenes	3,200	990	950	150	ND
1,1-Dichloroethene	ND	ND	ND	ND	ND
Vinyl Chloride	ND	120	59	100	ND
Other Volatile Priority Pollutants					
Methylene Chloride	5,300	120	770	ND	14
Toluene	2,000	410	660	460	58
Benzene	ND	30	37	110	16
Ethylbenzene	ND	93	64	140	68
1,2-Dichloropropane	ND	18	37	ND	ND

1. Parent Compounds 3. ND — <10 µg/l
2. Breakdown Products 4. All Concentrations in Mg/l

Table 2
Breakdown Products Present in Contaminated Groundwater Near Disposal Facilities

	[illegible]	Site #3
No. of Samples from Wells showing Solvent Contamination	10	8
No. of Samples with 50% Breakdown Products*	2	0
No. of Samples with 50-75% Breakdown Products*	3	0
No. of Samples with 75- 100% Breakdown Products*	5	8

*Breakdown defined as monochloro- and dichloro- ethanes and ethenes compared to total chlorinated ethanes and ethenes.

to find compounds which are a result of reductive dehalogenation. It is unlikely that these compounds were the dominant disposal compounds at these sites based on site records, general production and common use. Of particular interest is the fact that all eight of the leachate samples from the large co-disposal facility were comprised of greater than 75% breakdown products.

Solvent Recovery Facilities

Solvent recovery facilities handle a wide variety of organic compounds including chlorinated solvents. In addition, varying hydrogeologic conditions can result in complex migration patterns. The two facilities discussed in this section differ in operation and location, but have similarities in migration and degradation patterns. Geologic and hydrologic characteristics at these solvent recovery facilities are given in Table 3.

Table 3
Solvent Recovery Site Geological Conditions

	Site 1	Site 2
Location	Connecticut	Wisconsin
Date of Investigation	1980	1983
Geology	Alluvial sands and gravel in relatively impermeable bedrock valley	Thick, sandy glacial till deposits overlying limestone bedrock
Hydrology	Shallow groundwater, 10 ft, alluvial sands constitute primary municipal aquifer	Till supports only minimal groundwithdrawal, permeability approx. 10^{-4} to 10^{-5} cm/sec. Limestone is aquifer in the area.

The analytical data for the above sites are found in Tables 4 and 5. Both sites handled chlorinated and nonchlorinated solvents. High concentrations of both the chlorinated and nonchlorinated compounds were present near the on-site handling areas. The off-site contamination showed a dominance of the chlorinated compounds. Nonchlorinated compounds detected were priority pollutants. In cases where analyses were performed, the presence of compounds like toluene and benzene were indicative of a much higher concentration of other nonpriority pollutant hydrocarbons.

At the Wisconsin site, dichlorethanes, dichlorethenes and vinyl chloride were detected in significant concentrations in the groundwater. These compounds were not handled at the facility, and this is supported by records of routine gas chromatographic analyses at the recycling facility. Further evaluation failed to indicate the presence of other possible sources of the breakdown products. Information was not available to evaluate this question at the Connecticut site.

An evaluation was then performed to assess whether data from these facilities show patterns which would be a result of anaerobic degradation. The evaluation includes an analysis of the percentage of breakdown products measured at the source and at a downgradient location.

To illustrate trends, the data have been summarized in Figure 1. Results are shown for the priority pollutant analyses for a water

table well and piezometer located on-site that had the highest concentrations, as well as a downgradient water table well and piezometer. At both of the sites, primarily horizontal hydraulic gradients were observed during the hydrogeological assessment based on water level measurements. Elevated concentrations of contaminants were anticipated at the downgradient water table wells.

Table 4
Solvent Recovery Operations
Summary of Volatile Organic Priority Pollutants Detected at On-Site and Downgradient Piezometers: Connecticut Site

	On-Site		250' Downgradient	
	Water Table	At Depth	Water Table	At Depth
Chlorinated Ethanes				
1 1,1,1-Trichloroethane	ND[3]	3,700	260	ND
2 1,1-Dichloroethane	8,300	3,000	2,500	ND
Chlorinated Ethenes				
1 Tetrachloroethene	2,900	ND	34	ND
Trichloroethene	39,000	330	ND	ND
2 1,2-Dichloroethenes	30,000	2,700	ND	4,300
1,1-Dichloroethene	ND	ND	ND	ND
Vinyl chloride	ND	200	ND	2,700
Other Solvents Detected				
Methylene Chloride	100,000	7,000	25	3,900
Ethylbenzene	12,000	440	ND	3,700
Toluene	34,000	5,100	ND	7,600

1. Parent Compounds
2. Breakdown Products
3. ND — <10 µg/l
4. All Concentrations are in µg/l

Table 5
Solvent Recovery Operations
Summary of Volatile Organic Priority Pollutants Detected at On-Site and Downgradient Piezometers: Wisconsin Site

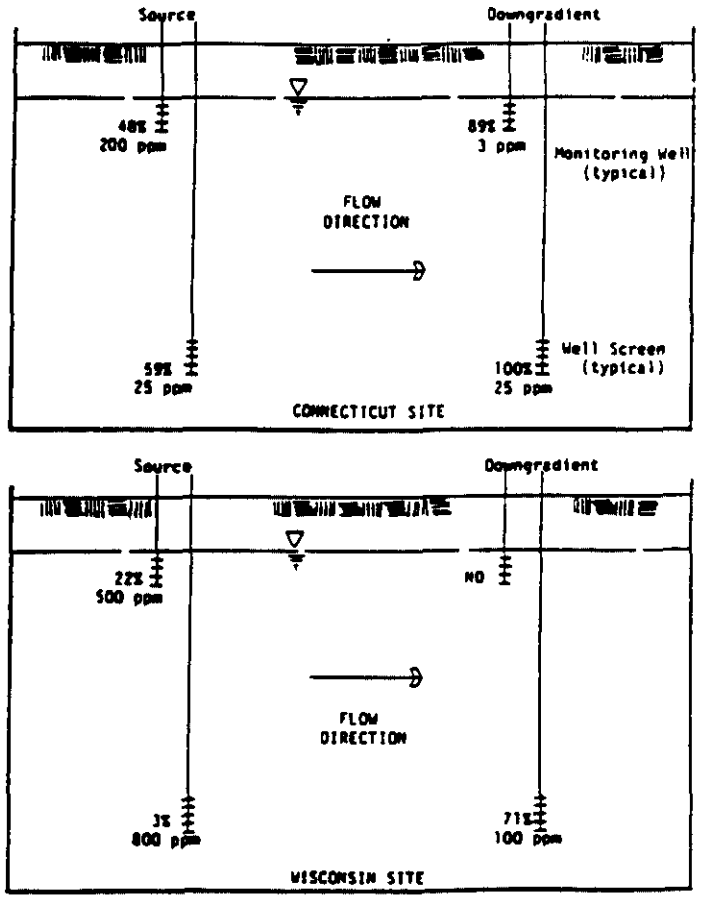
	On-Site		250' Downgradient	
	Water Table	Depth	Water Table	Depth
Chlorinated Ethanes				
1 1,1,2,2-Tetrachloroethane	19,000	ND[3]	ND	ND
1,1,2-Trichloroethane	ND	ND	ND	60
1,1,1-Trichloroethane	22,000	270,000	ND	20,000
2 1,2-Dichloroethane	ND	ND	ND	230
1,1-Dichloroethane	ND	6,200	ND	5,100
Chloroethane	ND	ND	ND	90
Chlorinated Ethenes				
1 Tetrachloroethene	ND	22,000	ND	610
Trichloroethene	63,000	250,000	ND	1,000
2 1,2-Dichloroethenes	30,000	8,700	ND	47,000
1,1-Dichloroethene	ND	ND	ND	720
Vinyl Chloride	ND	ND	ND	210
Other Solvents Detected				
Methylene Chloride	230,000	170,000	ND	20,000
Benzene	12,000	ND	ND	20
Ethylbenzene	28,000	9,200	ND	630
Toluene	100,000	42,000	ND	4,100

1. Parent Compounds
2. Breakdown Products
3. ND — <10 µg/l
4. All Concentrations are in µg/l

The figure shows the total volatile organic concentrations detected at the above described well locations for both sides and the percentage of breakdown products compared to the sum of the chlorinated ethanes and ethenes.

Both of the sites exhibited high levels of chlorinated organic contamination at the source. Nonchlorinated organics were also present at the sources in high concentrations, providing a nonchlorinated carbon source. These nonchlorinated organic compounds were present in highest concentrations at the water table. At the Wisconsin site, a floating layer of fuel oil type material was detected at one well.

With distance downgradient from the source, the contaminants were detected at greater concentrations with depth even though groundwater flow was near horizontal. There are various explanations for this phenomenon, including changing groundwater flow



% Values = % Breakdown Products ppm Values = Total of all Volatile Priority Pollutants

Figure 1
Anaerobic Breakdown Patterns of Organic Materials

patterns, recharge or impermeable barriers which may have hampered migration of contaminants to the water table wells. These parameters will be evaluated further with additional hydrogeologic study, where funding is available.

Other explanations include density effects, volatilization and selective degradation. It is well documented that chlorinated compounds will sink in the aquifer at the source when in excess of the solubility of water.[7] For subsequent density effects to be apparent in the contaminated groundwater where concentrations are lower, the overall density of that solution must be greater than that of background water quality. Preliminary calculations indicate that at the concentrations measured at the sites, the density difference would not be sufficient to account for sinking of the contaminated groundwater plumes.

The USEPA had indicated that a primary environmental fate for these compounds in aquatic systems would be volatilization.[4] Factors which affect volatilization of these compounds from a ground-

water system include: soil porosity and temperature, depth to water table and the various solubilities of the compounds in water. Although it is recognized that some volatilization will occur, it is not expected to be a primary fate of organics at these sites.

Selective degradation is presented as another possible explanation for preferential loss of the constituents at the water table wells. The biodegradation of chlorinated compounds may be affected by the co-metabolism of other carbon sources. Solvent recovery operations can provide a nonchlorinated carbon source which tends to accumulate near the water table surface. These compounds are typically not detected with distance from the source, due to rapid breakdown and may be responsible for preferential loss of the chlorinated compounds from the more shallow zone of the aquifer.

The breakdown of the chlorinated compounds can occur rapidly in the presence of a nonchlorinated carbon source which promotes rapid co-metabolism to dehalogenate the chlorinated compounds. The data suggest that degradation continues to occur deeper in the aquifer, perhaps at a slower rate.

Industrial Site

For purposes of contrast with sites which have high levels of contamination and a substantial carbon source, the authors have presented data from an industrial site having primarily sandy soils, shallow groundwater and little or no detectable nonchlorinated organic priority pollutants (Table 6).

Table 6
Industrial Site Solvent Contamination of a City Well

Well	1,1,1-Trichloroethane	Trichloroethene	1,1-Dichloroethene
1	ND	81	ND
2	13,800	2,040	250
3	2,660	410	ND
4	7	1	ND
5	8	2	ND
6	ND	68	ND
7	10	12	ND

1. All Concentrations are in µg/l 2. ND — < 1 µg/l

Three major contrasts with data from the solvent recovery facilities are noted:

- Overall contaminant concentrations detected are lower and all compounds are chlorinated
- A dominance of the parent compounds exists
- The plume was detected in highest concentrations at the water table wells. The lack of a significant carbon source to promote degradation can account for the minimal breakdown occurring at the industrial site

CONCLUSIONS

Parameters which would assist in determining biodegradation activity are typically not incorporated into standard hydrogeologic investigations. A better understanding of the role of degradation could be obtained through a more comprehensive investigative program including biological assessment as well as the standard groundwater flow and chemistry analyses

Data from the authors' investigations suggest that if a site has a substantial carbon source, anaerobic degradation will occur, resulting in the formation of dichloro- and monochloro- ethane and ethene compounds. The presence of these compounds follows the predictions in the literature regarding the degradability of the parent compounds. In addition, the dominance of the cis-isomer of 1,2-dichloroethene formed during degradation will result in its presence in these investigations rather than the priority pollutant trans-isomer.

A floating organic layer near a contamination site may enhance the rate of degradation near the water table as the chlorinated compounds would more readily be co-metabolized [illegible] zone of the aquifer.

RECOMMENDATIONS

At sites where degradation is indicated, additional measurements should be made to better understand the potential role and controlling mechanisms of biodegradation. This would include measurement of the overall organic content in water or soil and measurements of oxidation reduction potential (Eh), oxygen concentration and plate counts of bacteria.[11,12,13,14,15] Density measurements of the contaminated groundwater will allow clarification of potential density effects on migration patterns. During interpretation of the data, one can evaluate the presence of breakdown products and the pattern of their occurrence in relation to the parent compounds. One should report "1,2-dichloroethenes" without specifying the specific cis- or trans-isomer, unless that specific distinction can be made by the analytical laboratory.

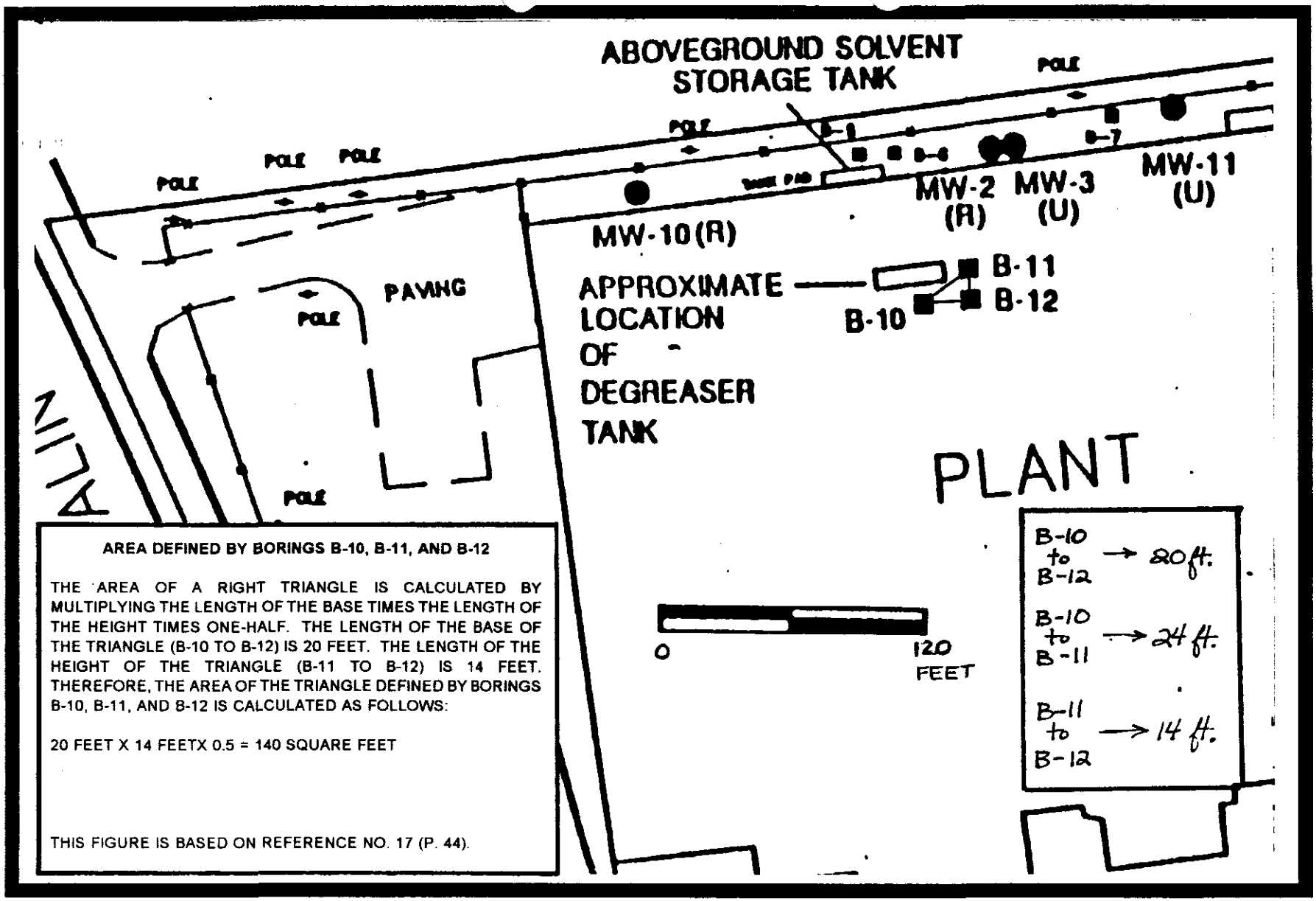
It is hoped that increased awareness of the conditions under which maximum degradation can occur will improve the approach and substantially increase the conclusions which can be drawn from groundwater contamination investigations.

REFERENCES

1. Parsons, F., Wood, P.R. and DeMarco, J., "Transformations of Tetrachloroethene and Trichloroethene in Microcosms and Groundwater," *J. AWWA*, Feb., 1984, 56-59.
2. Wood, P.R., Lang, R.F. and Payan, I.L., *Anaerobic Transformation, Transport and Removal of Volatile Chlorinated Organics in Groundwater*. Drinking Water Research Center, School of Technology, Florida International University, Tamiami Campus, Miami, FL, 1981.
3. Kobayashi, H . and Rittmann, B.E., "Microbial Removal of Hazardous Organic Compounds." *Environ. Sci. Technol., 16*, 1982, 170A-182A.
4. Tabak, H.H., Quave, S.A., Mashni, C.I. and Barth, E.F., "Biodegradability Studies with Organic Priority Pollutant Compounds." *JWPCF, 53*, 1981, 1503-1518.
5. Weiss, H., *Status of DHSS Recommendations for Drinking Water Organic Chemical Contaminants Interim Health Advisory Opinions*, 1984.
6. Brusbi, D.H., Chung, N.K. and Diesi, W.F., "Geologic Studies of Industrially-Related Contamination: Soil and Groundwater Investigations." *Proc. National Conference on Management of Uncontrolled Hazardous Waste Sites*, Washington, DC, Oct., 1980.
7. GeoTrans, Inc., *RCRA Draft Permit Writers Manual: Groundwater Protection*, 1983, 3.14-3.15.
8. USEPA, *Water Related Fate of 129 Priority Pollutants*, Vol. 1, 38.1-53.13.
9. Mackay, D., Bobra, A., Chan, D.W. and Shiu, W.Y., 1982. "Vapor Pressure Correlations for Low-Volatility Environmental Chemicals." *Environ. Sci. Technol., 16*, 1982, 645-654.
10. Wilson, J.T., Enfield, C.G., Dunlap, W.J., Cosby, R.L., Foster, D.A. and Baskin, L.B., "Transport and Fate of Selected Organic Pollutants in a Sandy Soil," *J. Environ. Quality, 10*, 1981, 501-506.
11. Wilson, J.T., McNabb, J.F., Balkwill, D.L. and Ghiorse, W.C., "Enumeration and Characterization of Bacteria Indigenous to a Shallow Water-Table Aquifer," *Ground Water, 21*, 1982, 134-142.
12. McNabb, J.F. and Dunlap, W.J., "Subsurface Biological Activity in Relation to Groundwater Pollution," *Ground Water, 13*, 1975, 33-44.
13. Ehrlich, G.G., Goerlitz, D.F., Godsy, E.M. and Hult, M.F., "Degradation of Phenolic Contaminants in Groundwater by Anaerobic Bacteria: St. Louis Park, Minnesota," *Ground Water, 20*, 1982, 703-710.
14. Allen, M.J. and Geldreich, E.E., "Bacteriological Criteria for Groundwater Quality," *Ground Water, 13*, 1975, 45-52.
15. Dul, E.F., Fellman, R.T. and Kuo, M.F., *Evaluation of Systems to Accelerate Stabilization of Waste Piles or Deposits*. Envirosphere Company, Lyndhurst, NJ. Roetzer, J.F. Woodward-Clyde Consultants, Wayne, NJ, 1984, 109-204.
16. USEPA Effluent Guidelines Section, personal communication.

ORIGINAL
(Red)

REFERENCE NO. 48



AREA DEFINED BY BORINGS B-10, B-11, AND B-12

THE AREA OF A RIGHT TRIANGLE IS CALCULATED BY MULTIPLYING THE LENGTH OF THE BASE TIMES THE LENGTH OF THE HEIGHT TIMES ONE-HALF. THE LENGTH OF THE BASE OF THE TRIANGLE (B-10 TO B-12) IS 20 FEET. THE LENGTH OF THE HEIGHT OF THE TRIANGLE (B-11 TO B-12) IS 14 FEET. THEREFORE, THE AREA OF THE TRIANGLE DEFINED BY BORINGS B-10, B-11, AND B-12 IS CALCULATED AS FOLLOWS:

20 FEET X 14 FEETX 0.5 = 140 SQUARE FEET

THIS FIGURE IS BASED ON REFERENCE NO. 17 (P. 44).

REFERENCE NO. 48

AREA DEFINED BY SOIL BORINGS NEXT TO DEGREASER TANK
BISHOP TUBE COMPANY
FRAZER, CHESTER COUNTY, PENNSYLVANIA

HALLIBURTON NUS Corporation

JUNE 1995

ORIGINAL
(Red)

REFERENCE NO. 49

United States Environmental Protection Agency

Office of Solid Waste and Emergency Response

Directive 9285.7-14FS
PB94-963311
EPA/540/F-94/028
July 1994

EPA

Using Qualified Data to Document an Observed Release

Office of Emergency and Remedial Response
Hazardous Site Evaluation Division (5204G)

Quick Reference Fact Sheet

Abstract

Data validation checks the accuracy of analytical data, and qualifies results that fall outside performance criteria of the Contract Laboratory Program (CLP). Results qualified with a "J" are estimated concentrations that may be biased, but may be used to determine an observed release in Hazard Ranking System (HRS) evaluation. This fact sheet explains the conditions for use of "J"-qualified data, and introduces factors which compensate for variability and enable their use in HRS evaluation.

Why Qualify Data?

Chemical concentration data for environmental decision-making are generated using analytical methods. EPA analytical chemistry methods are designed to provide the definitive analyte identification and quantitation needed to establish an observed release under the Hazard Ranking System (HRS). Routine operational variations in sampling and analysis inevitably introduce a degree of error into the analytical data. Data validation checks the usability of the analytical dat: for HRS evaluation and identifies the error (bias) present. The validation process qualifies the biased data. Certain types of qualified data for release and background samples may be used to determine an observed release.

EPA Data Qualifiers

EPA analytical methods (e.g., SW-846 and Contract Laboratory Program [CLP]) introduce a number of Quality Assurance/Quali'y Control (QA/QC) mechanisms during the course of sample analysis to measure qualitative and quantitative accuracy.[3,4,8,9] Such mechanisms include matrix spikes, matrix spike duplicates, laboratory control samples, surrogates, blanks, laboratory duplicates, and quarterly blind performance evaluation (PE) samples. Surrogates and spikes are chemically similar to the analytes of interest and thus behave similarly during the analytical process. They are introduced or "spiked" at a known concentration into the field samples before analysis. Comparison of the known concentrations of the surrogates and spikes with their analytical results measures accuracy, and may indicate bias caused by interferences from the sample medium (matrix effect).[1,2,9] Laboratory control samples contain known concentrations of target analytes and are analyzed in the same batch as field samples. Their results are used to measure laboratory accuracy. Blanks are analyzed to detect any extraneous contamination introduced either in the field or in the laboratory. Laboratory duplicates consist of one sample that undergoes two separate analyses; the results are compared to determine laboratory precision. Quarterly blind PE samples also evaluate lab precision.

CLP and other EPA analytical methods include specifications for acceptable identification, and minimum and maximum percent recovery of the target analytes and QA/QC compounds. Data are validated according to guidelines which set performance criteria for instrument calibration, analyte identification, and identification and recovery of the QA/QC compounds.[3,4,9] The *National Functional Guidelines for Data Review* used in EPA validation were designed for data generated under the CLP organic and inorganic analytical protocols.[1,2,3,4] The guidelines do not preclude the validation of field and non-CLP data; many EPA Regions have adapted the *National Functional Guidelines for Data Review* to validate non-CLP data. Data which do not meet the

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guidelines' performance criteria are qualified to indicate bias or QC deficiencies. The data validation report usually explains why the data were qualified and indicates the direction of bias when it can be determined. Most EPA validation guidelines use the data qualifiers presented below. [1,2] (Other data qualifiers besides these are in use; always check the validation report for the exact list of qualifiers and their meanings.)

- **"U" qualifier** -- the analyte was analyzed for, but was not detected above the reported sample quantitation limit. For practical purposes, "U" means "not detected"; the result is usable for characterizing background concentrations for HRS evaluation. [5]

- **"J" qualifier** -- the analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample. "J" data are biased, but provide definitive analyte identification, and are usually reliable. They may be used to determine an observed release under conditions specified later in this fact sheet. [5]

- **"N" qualifier** -- the analysis indicates the presence of an analyte for which there is presumptive evidence to make a "tentative identification." "N" data are not sufficiently definitive for HRS evaluation.

- **"NJ" qualifier** -- the analysis indicates the presence of an analyte that has been "tentatively identified" and the associated numerical value represents its approximate concentration. "NJ" data are not sufficiently definitive for HRS evaluation.

- **"UJ" qualifier** -- the analyte was not detected above the reported sample quantitation limit. However, the reported quantitation limit is approximate and may or may not represent the actual limit of quantitation necessary to accurately and precisely measure the analyte in the sample. "UJ" non-detects are not definite; the analyte may be present. The result can be used to document non-detects in background samples under certain conditions.

- **"R" qualifier** -- the sample results are rejected due to serious deficiencies in the ability to analyze the sample and meet quality control criteria. The presence or absence of the analyte cannot be verified. EPA does not use "R" data because they are considered unreliable. [5]

Validated data that are not qualified are unbiased, and can be used at their reported values for HRS evaluation.

Criteria for Determining an Observed Release with Chemical Data

Chemical data demonstrate an observed release when all of the following are true:

1. The release of a hazardous substance is at least partially attributable to the site under investigation.

2. The release sample concentration is greater than or equal to the appropriate detection limit (e.g., sample quantitation limit [SQL]).

3. If background levels are below detection limits, the release sample concentration must be greater than its detection limit, or, if background levels are greater than or equal to detection limits, the release sample concentration must be at least three times the background concentration. [7]

Direction of Bias in "J"-Qualified Data

It is important to understand the bias associated with "J"-qualified data when using them for HRS evaluation. "J" data may have high, low, or indeterminate bias. A low bias means that the reported concentration is most likely an underestimate of the true concentration. For example, data may be biased low when sample holding times for volatile organic compounds (VOCs) are exceeded or when the recovery of QA/QC compounds is significantly less than the true amount originally introduced into the sample. A high bias means that the reported concentration is most likely an overestimate of the true concentration. A bias is indeterminate when it is impossible to ascertain whether the concentration is an overestimate or an underestimate. For example, an indeterminate bias could result when matrix effects obscure QA/QC compounds.

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Qualified Data and Direction of Bias

Qualified data may be used when it can be demonstrated that the data meet the HRS rule for determining an observed release despite the bias in the reported concentrations. This condition depends on the direction of bias: low bias data may be used for release samples, and high bias data may be used for background samples. Low bias release samples are underestimates of true concentration. Underestimated release concentrations that still meet the HRS criteria (e.g., they are still three times background level) clearly establish an observed release. High bias background samples are overestimates of background level. If the concentration of unbiased release samples still significantly exceeds an overestimated background level according to HRS criteria, an observed release is clearly established. Similarly, an observed release is established when low bias release concentrations significantly exceed high bias background concentrations according to the HRS criteria.

These scenarios show that low bias "J-"qualified data may be used for release samples at their reported concentrations, and that high bias "J-"qualified data may be used for background samples at their reported concentrations.

High bias release samples may not be used at their reported concentrations because they are an overestimate of true concentration; the true concentration might be less than the HRS criteria for an observed release. The reported concentration for low bias background concentrations may not be *compared to release samples because it is most likely* an underestimate of background level; the release sample concentration might not significantly exceed the background concentration. However, high bias release data and low bias background data may be used with factors which compensate for the variability in the data. The factors will enable these types of biased data to meet HRS criteria for determining an observed release.

Factors for Biased Data: Tables 1 through 4 (pages 6-13) present analyte-specific factors to address the uncertainty when determining an observed release using high bias release data and low bias background data. The factors are derived from percent recoveries of matrix spikes, surrogates, and laboratory control samples in the CLP Analytical Results Database (CARD) from January 1993 to March 1994.

The range of CARD data for each analyte includes 95 percent of all percent recoveries. Discarding outliers left 95 percent of the CARD data available for calculating factors. The factors are ratios of percent recovery values at the 97.5 and 2.5 percentiles. The ratios generally show a consistent pattern.

An attempt to "convert" a biased value to its true concentration is not recommended because the CARD data do not differentiate and quantify individual sources of *variation*. The *factors are* applied as "safety factors" to ensure that biased data can be used to meet HRS criteria for determining an observed release. Dividing a high bias value by a factor effectively deflates it from the high end of the range to the low end (low bias value). Multiplying a low bias value by the factor effectively inflates it to a high bias value. Use of the ratio of percentiles is a "worst-case" assumption that the data are biased by the extent of the range of CARD data considered. The factors either inflate the values to the high end of the range, or deflate the data to the low end, and thus compensate for the apparent variability when comparing a high bias value to a low bias value (see Exhibit 1).

Factors have been selected for all analytes in the CLP Target Compound List (organic analytes) and Target Analyte List (inorganic analytes). Some organic factors were derived from matrix spike percent recoveries, and some from surrogate percent recoveries, depending on availability of data. When both matrix spike and surrogate data were available for the same compound, the larger value (representing more extreme high and low percent recoveries) was used. Laboratory control samples were used to calculate some of the inorganic factors. A default factor of 10 was used for analytes when percent recovery data were unavailable.

Application of the Factors: Exhibit 1 shows how to apply the factors to "J" qualified data. High bias background data, low bias release data, and unbiased data may be used at their reported concentrations. Multiply low bias background sample data by the analyte-specific factor to bring them to their new value. The new background value effectively becomes a high bias value that may be used to determine an observed release. Divide high bias release sample data by the analyte-specific factor to bring them to their new value. The new release sample value effectively becomes a low bias result that may be used

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Exhibit 1: Use of Factors for "J"-Qualified Data		
Type of Sample	Type of Bias	Action Required
Background Sample	No Bias	None: Use concentration without factor
	Low Bias	Multiply concentration by factor
	High Bias	None: Use concentration without factor
	Unknown Bias	Multiply concentration by factor
Release Sample	No Bias	None: Use concentration without factor
	Low Bias	None: Use concentration without factor
	High Bias	Divide concentration by factor
	Unknown Bias	Divide concentration by factor

to determine an observed release. *Note: Adjusted release and background values must still meet HRS criteria (e.g., release concentration must be at least three times background level) to determine an observed release.*

Examples Using Trichloroethene in Soil:

1. *Release sample data biased low, background sample data biased high.*

Release sample value: 30 μg/kg (J) *low bias*
Background sample value: 10 μg/kg (J) *high bias*

In this instance, the direction of the bias indicates that the release sample concentration exceeds background by more than three times, so an observed release is established (provided all other HRS criteria are met). Use of the factors is not needed.

2. *Release sample data unbiased, background sample data biased low.*

Release sample value: 30 μg/kg *no bias*
Background sample value: 10 μg/kg (J) *low bias*

To use the data to establish an observed release, multiply the background sample value by factor given for trichloroethene (1.8). No factor is needed for the release sample.

New background sample value:
(10 μg/kg) x (1.8) = 18 μg/kg (J) *high bias*

The release sample concentration does not exceed the new background level by a factor of three, so an observed release is not established.

3. *Release sample data biased high, background sample data unbiased.*

Release sample value: 75 μg/kg (J) *high bias*
Background sample value: 15 μg/kg *no bias*

To use the data to establish an observed release, divide the release sample value by the factor for trichloroethene (1.8). No factor is needed for the background sample.

New release sample value:
(75 μg/kg) ÷ (1.8) = 42 μg/kg (J) *low bias*

The new release sample concentration does not exceed background concentration by a factor of three, so an observed release is not established.

4. *Release sample data biased high, background sample data biased low.*

Release sample value: 100 μg/kg (J) *high bias*
Background sample value: 10 μg/kg (J) *low bias*

To use the data to establish an observed release, divide the release sample value and multiply the background sample value by the factor given for trichloroethene in soil (1.8).

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New release sample value:
(100 μg/kg) ÷ (1.8) = 56 μg/kg (J) *low bias*

New background sample value:
(10 μg/kg) x (1.8) = 18 μg/kg (J) *high bias*

The new release sample concentration is three times the new background concentration, so an observed release is established, provided all other HRS criteria are met.

Documentation Requirements for Use of Qualified Data: When using "J"-qualified data to determine an observed release, include the "J"-qualifier commentary from the data validation report in the HRS package. This step will ensure that the direction of bias is documented.

Use of Other Factors: EPA Regions may substitute higher factor values other than the ones in this fact sheet on a case-by-case basis when technically justified. For example, other factors may be applied to conform with site-specific Data Quality Objectives (DQOs) or with Regional Standard Operating Procedures (SOPs).[10]

Detection Limit Restrictions: Factors may only be applied to "J" data with concentrations above the CLP Contract Required Quantitation Limit (CRQL) or Contract Required Detection Limit (CRDL). "J"-qualified data with concentrations below CLP detection limits cannot be used to document an observed release.

Use of "UJ"-Qualified Data

A combination of the "U" and "J" qualifiers indicates that the reported value may not accurately represent the concentration necessary to detect the analyte in the sample. Under limited conditions, "UJ" data can be used to represent background when determining an observed release. These conditions include instances when there is confidence that the background concentration has not been detected and the sample measurement that establishes the observed release equals or exceeds the SQL or other appropriate detection limit. This reasoning is based on the presence of a high bias in the background sample. Thus, UJ data can be used only when all of the following conditions apply:

- The "UJ" value applies to the background sample and represents the detection limit,
- The "UJ" value is biased high, and
- The release sample concentration exceeds the SQL (or applicable detection limit) and is unbiased or biased low.

Summary

Data validation checks the usability of analytical data and identifies certain errors (bias). "J"-qualified data identify that analytes are present, but the reported values represent estimated concentrations associated with bias. Low bias release data and high bias background data may be used at the reported values. High bias release data and low bias background data may not be used at their reported concentrations because they do not establish an observed release with certainty. Application of factors introduced in this fact sheet compensate for this uncertainty, and enable "J" data to be used to determine an observed release.

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Table 1: Factors for Volatile Organic Analytes				
VOLATILE ORGANIC ANALYTES	SOIL MATRIX		WATER MATRIX	
	Number of CARD Samples Reviewed	Factor	Number of CARD Samples Reviewed	Factor
1,1,1-TRICHLOROETHANE	--	10.0	--	10.0
1,1,2,2-TETRACHLOROETHANE	11144	1.5	9180	1.2
1,1,2-TRICHLOROETHANE	--	10.0	--	10.0
1,1-DICHLOROETHANE	11144	1.4	9179	1.3
1,1-DICHLOROETHENE	2064	2.4	1484	2.0
1,2-DICHLOROETHANE	11144	1.4	9179	1.3
1,2-DICHLOROETHENE (TOTAL)	11144	1.4	9179	1.3
1,2-DICHLOROPROPANE	--	10.0	--	10.0
2-BUTANONE	11144	1.4	9179	1.3
2-HEXANONE	11144	1.5	9180	1.2
4-METHYL-2-PENTANONE	11144	1.5	9180	1.2
ACETONE	11144	1.4	9179	1.3
BENZENE	2060	1.7	1482	1.5
BROMODICHLOROMETHANE	--	10.0	--	10.0
BROMOFORM	--	10.0	--	10.0
BROMOMETHANE	11144	1.4	9179	1.3
CARBON DISULFIDE	11144	1.4	9179	1.3

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Table 1: Factors for Volatile Organic Analytes (continued)				
VOLATILE ORGANIC ANALYTES	SOIL MATRIX		WATER MATRIX	
	Number of CARD Samples Reviewed	Factor	Number of CARD Samples Reviewed	Factor
CARBON TETRACHLORIDE	--	10.0	--	10.0
CHLOROBENZENE	2058	1.6	1480	1.4
CHLOROETHANE	11144	1.4	9179	1.3
CHLOROFORM	11144	1.4	9179	1.3
CHLOROMETHANE	11144	1.4	9179	1.3
CIS-1,3-DICHLOROPROPENE	--	10.0	--	10.0
DIBROMOCHLOROMETHANE	--	10.0	--	10.0
ETHYLBENZENE	11144	1.5	9180	1.2
METHYLENE CHLORIDE	11144	1.4	9179	1.3
STYRENE	11144	1.5	9180	1.3
TETRACHLOROETHENE	11144	1.5	9180	1.2
TOLUENE	2029	2.0	1468	1.4
TRANS-1,3-DICHLOROPROPENE	--	10.0	--	10.0
TRICHLOROETHENE	2046	1.8	1452	1.5
VINYL CHLORIDE	11144	1.4	9179	1.3
XYLENE (TOTAL)	11144	1.5	9180	1.2

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Table 2: Factors for Semivolatile Organic Analytes				
SEMIVOLATILE ORGANIC ANALYTES	SOIL MATRIX		WATER MATRIX	
	Number of CARD Samples Reviewed	Factor	Number of CARD Samples Reviewed	Factor
1,2,4-TRICHLOROBENZENE	1978	3.5	1375	2.9
1,2-DICHLOROBENZENE	11899	3.8	7951	4.0
1,3-DICHLOROBENZENE	11899	3.8	7951	4.0
1,4-DICHLOROBENZENE	1980	3.8	1373	3.0
2,2'-OXYBIS(1-CHLOROPROPANE)	11899	3.8	7951	4.0
2,4,5-TRICHLOROPHENOL	11889	8.9	7952	3.6
2,4,6-TRICHLOROPHENOL	11889	8.9	7952	3.6
2,4-DICHLOROPHENOL	11896	4.0	7949	2.5
2,4-DIMETHYLPHENOL	11896	4.0	7949	2.5
2,4-DINITROPHENOL	11889	8.9	7952	3.6
2,4-DINITROTOLUENE	1979	3.4	1375	2.6
2,6-DINITROTOLUENE	11889	8.9	7952	3.6
2-CHLORONAPHTHALENE	11889	8.9	7952	3.6
2-CHLOROPHENOL	1930	3.2	1376	2.9
2-METHYLNAPHTHALENE	11896	4.0	7949	2.5
2-METHYLPHENOL	11899	3.8	7951	4.0
2-NITROANILINE	11889	8.9	7952	3.6
2-NITROPHENOL	11896	4.0	7949	2.5
3,3'-DICHLOROBENZIDINE	11898	4.3	7951	6.0
3-NITROANILINE	--	10.0	--	10.0
4,6-DINITRO-2-METHYLPHENOL	--	10.0	--	10.0
4-BROMOPHENYL-PHENYL ETHER	--	10.0	--	10.0
4-CHLORO-3-METHYLPHENOL	1927	3.6	1375	3.5
4-CHLOROANILINE	11896	4.0	7949	2.5
4-CHLOROPHENYL-PHENYL ETHER	11899	8.9	7952	3.6
4-METHYLPHENOL	11899	3.8	7951	4.0

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Table 2: Factors for Semivolatile Organic Analytes (continued)				
SEMIVOLATILE ORGANIC ANALYTES	SOIL MATRIX		WATER MATRIX	
	Number of CARD Samples Reviewed	Factor	Number of CARD Samples Reviewed	Factor
4-NITROANILINE	11889	8.9	7952	3.6
4-NITROPHENOL	1905	4.8	1368	4.5
ACENAPHTHENE	1965	3.1	1361	3.0
ACENAPHTHYLENE	11889	8.9	7952	3.6
ANTHRACENE	–	10.0	–	10.0
BENZO(A)ANTHRACENE	11898	4.3	7951	6.0
BENZO(A)PYRENE	–	10.0	–	10.0
BENZO(B)FLUORANTHENE	–	10.0	–	10.0
BENZO(G,H,I)PERYLENE	–	10.0	–	10.0
BENZO(K)FLUORANTHENE	–	10.0	–	10.0
BIS(2-CHLOROETHOXY)METHANE	11896	4.0	7949	2.5
BIS(2-CHLOROETHYL)ETHER	11899	3.8	7951	4.0
BIS(2-ETHYLHEXYL)PHTHALATE	11898	4.3	7951	6.0
BUTYLBENZYLPHTHALATE	11898	4.3	7951	6.0
CARBAZOLE	–	10.0	–	10.0
CHRYSENE	11898	4.3	7951	6.0
DI-N-BUTYLPHTHALATE	–	10.0	–	10.0
DI-N-OCTYLPHTHALATE	–	10.0	–	10.0
DIBENZ(A,H)ANTHRACENE	11889	8.9	7952	3.6
DIBENZOFURAN	11889	8.9	7952	3.6
DIETHYLPHTHALATE	11889	8.9	7952	3.6
DIMETHYLPHTHALATE	11889	8.9	7952	3.6
FLUORANTHENE	–	10.0	–	10.0
FLUORENE	11889	8.9	7952	3.6
HEXACHLOROBENZENE	–	10.0	–	10.0
HEXACHLOROBUTADIENE	11896	4.0	7949	2.5
HEXACHLOROCYCLOPENTADIENE	11889	8.9	7952	3.6

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Table 2: Factors for Semivolatile Organic Analytes (continued)				
SEMIVOLATILE ORGANIC ANALYTES	SOIL MATRIX		WATER MATRIX	
	Number of CARD Samples Reviewed	Factor	Number of CARD Samples Reviewed	Factor
HEXACHLOROETHANE	11899	3.8	7951	4.0
4-NITROPHENOLINDENO(1,2,3-CD)PYRENE	--	10.0	--	10.0
ISOPHORONE	11896	4.0	7949	2.5
N-NITROSO-DI-N-PROPYLAMINE	1966	3.7	1345	3.7
N-NITROSODIPHENYLAMINE (1)	--	10.0	--	10.0
NAPHTHALENE	11896	4.0	7949	2.5
NITROBENZENE	11896	4.0	7949	2.5
PENTACHLOROPHENOL	1895	18.8	1359	3.7
PHENANTHRENE	--	10.0	--	10.0
PHENOL	1924	3.2	1368	3.5
PYRENE	1901	8.3	1369	4.9

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Table 3: Factors for Pesticide/PCB Analytes				
PESTICIDE/PCB ANALYTES	SOIL MATRIX		WATER MATRIX	
	Number of CARD Samples Reviewed	Factor	Number of CARD Samples Reviewed	Factor
4,4'-DDD	–	10.0	–	10.0
4,4'-DDE	–	10.0	–	10.0
4,4'-DDT	1801	7.4	1353	4.6
ALDRIN	1870	7.9	1350	4.8
ALPHA-BHC	–	10.0	–	10.0
ALPHA-CHLORDANE	–	10.0	–	10.0
AROCLOR-1016	–	10.0	23305	8.7
AROCLOR-1221	–	10.0	23305	8.7
AROCLOR-1232	–	10.0	23305	8.7
AROCLOR-1242	–	10.0	23305	8.7
AROCLOR-1248	–	10.0	23305	8.7
AROCLOR-1254	–	10.0	23305	8.7
AROCLOR-1260	–	10.0	23305	8.7
BETA-BHC	–	10.0	–	10.0
DELTA-BHC	–	10.0	–	10.0
DIELDRIN	1886	6.2	1350	2.8

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Table 3: Factors for Pesticide/PCB Analytes (continued)				
PESTICIDE/PCB ANALYTES	SOIL MATRIX		WATER MATRIX	
	Number of CARD Samples Reviewed	Factor	Number of CARD Samples Reviewed	Factor
ENDOSULFAN I	–	10.0	–	10.0
ENDOSULFAN II	–	10.0	–	10.0
ENDOSULFAN SULFATE	–	10.0	–	10.0
ENDRIN	1866	8.5	1348	3.4
ENDRIN ALDEHYDE	–	10.0	–	10.0
ENDRIN KETONE	–	10.0	–	10.0
GAMMA-BHC (LINDANE)	1872	4.5	1350	3.1
GAMMA-CHLORDANE	–	10.0	–	10.0
HEPTACHLOR	1877	4.5	1351	3.6
HEPTACHLOR EPOXIDE	–	10.0	–	10.0
METHOXYCHLOR	–	10.0	–	10.0
TOXAPHENE	–	10.0	–	10.0

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Table 4: Factors for Inorganic Analytes				
INORGANIC ANALYTES	SOIL MATRIX		WATER MATRIX	
	Number of CARD Samples Reviewed	Factor	Number of CARD Samples Reviewed	Factor
ALUMINUM	1147	1.5	1686	1.2
ANTIMONY	1153	1.8	1688	1.2
ARSENIC	1208	1.6	1701	1.2
BARIUM	1149	3.3	1686	1.1
BERYLLIUM	1150	1.2	1686	1.2
CADMIUM	1148	1.3	1685	1.2
CALCIUM	1163	1.2	1685	1.1
CHROMIUM	1148	1.2	1686	1.2
COBALT	1153	1.2	1685	1.2
COPPER	1154	1.1	1683	1.2
CYANIDE	884	1.4	–	10.0
IRON	1149	1.2	1687	1.2
LEAD	1331	1.3	1727	1.2
MAGNESIUM	1143	1.2	1686	1.1
MANGANESE	1151	1.2	1685	1.2
MERCURY	1563	1.7	–	10.0
NICKEL	1150	1.2	1685	1.2
POTASSIUM	–	10.0	–	10.0
SELENIUM	1190	2.3	1695	1.3
SILVER	1152	1.6	1684	1.3
SODIUM	–	10.0	–	10.0
THALLIUM	1197	1.7	1691	1.2
VANADIUM	1152	1.2	1685	1.1
ZINC	1154	1.3	1689	1.2

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References

1. U.S. Environmental Protection Agency, 1994. *CLP National Functional Guidelines for Inorganic Data Review.* Office of Solid Waste and Emergency Response. Publication 9240.1-05-01.

2. U.S. Environmental Protection Agency, 1993. *CLP National Functional Guidelines for Organic Data Review.* Office of Solid Waste and Emergency Response. Publication 9240.1-05.

3. U.S. Environmental Protection Agency, 1991. *Contract Laboratory Program Statement of Work for Inorganics Analysis.* Document No. ILM02.0

4. U.S. Environmental Protection Agency, 1991. *Contract Laboratory Program Statement of Work for Organics Analysis.* Office of Solid Waste and Emergency Response. Document No. OLM1.8

5. U.S. Environmental Protection Agency, 1992. *Hazard Ranking System Guidance Manual.* Office of Solid Waste and Emergency Response. Directive 9345.1-07.

6. U.S. Environmental Protection Agency, 1991. *Guidance for Performing Preliminary Assessments Under CERCLA.* Office of Solid Waste and Emergency Response. Publication 9345.0-01A.

7. U.S. Environmental Protection Agency, 1992. *Guidance for Performing Site Inspections under CERCLA.* Office of Solid Waste and Emergency Response. Directive 9345.1-05.

8. U.S. Environmental Protection Agency, 1992. *Quality Assurance/Quality Control Samples.* Environmental Response Team Quality Assurance Technical Information Bulletin.

9. U.S. Environmental Protection Agency, 1986. *Test Methods for Evaluating Solid Waste (SW-846): Physical and Chemical Methods.* Office of Solid Waste and Emergency Response. Document No. SW-846.

10. U.S. Environmental Protection Agency, 1993. *Data Quality Objectives Process for Superfund.* Office of Emergency and Remedial Response. Directive 9355.9-01.

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(Red)

REFERENCE NO. 50

1941.28

BACKGROUND DOCUMENT

RESOURCE CONSERVATION AND RECOVERY ACT

SUBTITLE C - IDENTIFICATION AND LISTING OF HAZARDOUS WASTE

§§261.31 and 261.32 - Listing of Hazardous Wastes (Finalization of May 19, 1980 Hazardous Waste List)

U.S. ENVIRONMENTAL PROTECTION AGENCY

OFFICE OF SOLID WASTE

November 14, 1980

Hazardous Waste Listing Background Document

INTRODUCTION

Subtitle C of the Solid Waste Disposal Act, as amended by the Resource Conservation and Recovery Act of 1976 creates a comprehensive "cradle-to-grave" management control system for the disposal of hazardous wastes designed to protect the public health and the environment from the improper disposal of such waste. Section 3001 of that Subtitle requires EPA to identify the characteristics of and list hazardous wastes. Wastes identified or listed as hazardous will be included in the management control system created by Sections 3002-3006 and 3010. Wastes not identified or listed will be subject to the requirements for non-hazardous waste imposed by the States under Subtitle D.

Hazardous Waste List

The purpose of the hazardous waste list as required by Section 3001 of RCRA is to identify those wastes which may present a potential hazard to human health or the environment. The waste so identified is considered hazardous (unless it has been excluded from the list under §§260.20 and 260.22) and subject to the Subtitle C regulations. A solid waste, or class of solid wastes is listed if the waste:

(1) exhibits any of the characteristics identified in Subpart C of the final regulations; or

(2) meets the definition of §261.11(a)(2) of the regulations (i.e., may cause or significantly contribute to, an increase in mortality or an increase in serious irreversible, or incapacitating reversible, illness) and thus, presents an acute hazard to humans; or

(3) contains any of the toxic constituents listed in Appendix VIII of Part 261 unless, after considering any of a number of factors, the Administrator concludes that the waste will not meet the criterion of §261.11(a)(3) (i.e., may pose a substantial present or potential hazard to human health or the environment when it is improperly treated, stored, transported, disposed of or otherwise managed).

The Agency considered several approaches for formulating the list. The approaches can be broken down into three main types:

- <u>Hazardous Waste from Non-Specific Sources</u> - these are wastes which are generated from a number of different sources (i.e., electroplating, etc.)
- <u>Hazardous Waste from Specific Sources</u> - these are wastes which would be generated from a very specific source (i.e., distillation bottoms from the production of acetaldehyde from ethylene, etc.)

- Commercial Chemical Products - these are a list of commercial chemical products or manufacturing chemical intermediates which if discarded either as the commercial chemical or manufacturing chemical intermediate itself; off-specification commercial chemical products or manufacturing chemical intermediates; any container or inner liner removed from a container that has been used to hold these commercial chemical products or manufacturing chemical intermediate unless decontaminated; or any residue or contaminated soil, water or other debris resulting from the clean-up of a spill into or on any land or water, of these commercial chemical products or manufacturing chemical intermediates are hazardous wastes.

(This listing background document will cover the first two categories; the third category of hazardous waste is discussed in the background document entitled, "Hazardous Waste from Discarding of Commercial Chemical Products and the Containers and Spill Residues Thereof."

HAZARDOUS WASTE FROM NON-SPECIFIC AND SPECIFIC SOURCES

On May 19, 1980, as part of its final and interim final regulations implementing Sections 3001 of RCRA, EPA published

a list of hazardous wastes which included 85 wastes from manufacturing processes (§§261.31 and 261.32, 45 FR 33123-33124). These lists were published in interim final form to allow the public an opportunity to comment on additional data the Agency had collected on these wastes since the close of the initial public comment period on the proposed Subtitle C regulations (43 FR 58957-58959, December 18, 1978).

At the same time, the Agency also proposed for comment eleven additional hazardous waste listings (45 FR 33136-33137, May 19, 1980). All of these wastes were identified by the Agency in the course of developing the necessary technical data to support the May 19, 1980, interim final hazardous waste list.

The background data used to support these listings came primarily from two sources. The majority of this data or information comes from studies undertaken by the Agency or data available to the Agency (i.e., industry assessment studies conducted by the Office of Solid Waste, effluent guidelines studies conducted by the Office of Water Planning and Standards, health effects and fate and transport data compiled by the Office of Research and Development and Office of Water Planning and Standards, damage assessments and incidents compiled by the Office of Solid Waste, etc.)*.

*It should be noted that a number of these documents (e.g., pesticide waste background documents) contain confidential information. This data has been removed from the document and will not be made available to the public. This data, however, is part of the Administrative record and is included in the Agency's case to support the listing.

The second source of data came from information collected from State Agencies (i.e., manifest data, etc.).

The Agency received a large number of comments on both the interim final and proposed hazardous waste listings. We have evaluated these comments carefully and responsed in detail in the listing background documents. The respective listing background documents have also been revised as appropriate and are now "final-final" documents.

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- Distillation bottoms from the production of phthalic anhydride from ortho-xylene (T)

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36. Secondary Lead Smelting 832

- Emission control dust/sludge from secondary lead smelting (T)

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LISTING BACKGROUND DOCUMENT

Wastes from Usage of Halogenated Hydrocarbon Solvents in Degreasing Operations

The following spent halogenated solvents used in degreasing: tetrachloroethylene, methylene chloride, trichloroethylene, 1,1,1-trichloroethane, carbon tetrachloride and the chlorinated fluorocarbons; and sludges from the recovery of these solvents in degreasing operations.(T)*,**,***

I. SUMMARY OF BASIS FOR LISTING

Solvent degreasing operations remove grease, wax, dirt, oil, and other undesirable substances from various materials. All degreasing facilities which use the halogenated hydrocarbon solvents listed above generate spent solvent solutions which are either discarded or processed to recover the solvent from the spent solution. Spent solvents include those which are no longer useful without further processing, either because they have outlasted their shelf life or because they have been contaminated, or so changed chemically or physically that they are no longer useful as solvents. The recovery operations invariably generate solvent sludges.

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* In December, 1978, the Agency proposed a generic listing for this class of wastes.

** These solvents are often marketed under various trade marks; the listing obviously includes all trade mark solvents which have the generic chemical name listed above. Another point of consideration is that different names may be used to refer to the same solvent:

tetrachloroethylene = perchloroethylene
1,1,1-trichloroethane = methyl chloroform
carbon tetrachloride = tetrachloromethane
methylene chloride = dichloromethane
trichloroethylene = 1,1,2-trichloroethylene

*** In response to industry comments, it should be noted that the Agency is no longer listing these wastes on the basis of ignitability or EP toxicity. However, these solvents may be contaminated with metals (i.e., lead and chromium) in the degreasing operations; therefore, the generator will be responsible for determining whether the waste would also meet the EP toxicity characteristic.

ORIGINAL
(Red)

REFERENCE NO. 51

Hawley's

Condensed Chemical

Dictionary

TWELFTH EDITION

Revised by

Richard J. Lewis, Sr.

VNR VAN NOSTRAND REINHOLD COMPANY
New York

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braces the study of plant hormones or growth regulators (auxin, gibberellin, synthetic types).

phytol. CAS: 150-86-7. $C_{20}H_{40}O$. An alcohol obtained by the decomposition of chlorophyll.
Properties: Odorless liquid; bp 202–204C (10 mm Hg); d 0.8478 (25/4C); soluble in the common organic solvents; insoluble in water. Combustible.
Use: Synthesis of vitamins E and K.

phytonadione. (2-methyl-3-phytyl-1,4-naphthoquinone; vitamin K_1). $CH_3C_{10}H_4O_2C_{20}H_{39}$.
Properties: Clear, yellow, viscous, odorless liquid. D 0.967 (25/25C), refr index 1.5230–1.5252 (25C), stable in air. Protect from sunlight!! Insoluble in water; soluble in benzene, chloroform, and vegetable oils; slightly soluble in alcohol.
Derivation: Synthetically from 2-methyl-1,4-naphthoquinone and phytol.
Grade: USP.
Use: Food supplement.

phytosterol. Sterol alcohols from plants. See sterol.

pi bond. A covalent bond formed between atoms by electrons moving in orbitals that extend above and below the plane of an organic molecule containing double bonds. A double bond consists of one pi and one sigma bond and a triple bond consists of one sigma and two pi bonds.
See also metallocene, orbital theory.

pickle alum. See aluminum sulfate.

pickle liquor. A waste solution of metal salts resulting from the cleaning of metals with acids.

pickling. (1) Removal of scale, oxides, and other impurities from metal surfaces by immersion in an inorganic acid, usually sulfuric, hydrochloric, or phosphoric. Rate of scale removal varies inversely with concentration and temperature; the usual concentration is 15% at or above 100C. The rate is also increased by electrolysis. (2) A method of food preservation involving use of salt, sugar, spices, and organic acids (acetic). (3) Preserving or preparing hides for tanning by immersion in a 6–12% salt solution, together with enough acid to maintain pH at 2.5 or less.

picloram. (4-amino-3,5,6-trichloropicolinic acid). CAS: 1918-02-1. $C_6H_3Cl_3N_2O_2$.
Properties: Crystalline solid, mp 218C.
Hazard: Toxic by ingestion and inhalation. Use has been restricted. TLV: 10 mg/m^3 of air.
Use: Herbicide and defoliant.

pico-. Prefix meaning 10^{-12} unit (symbol = p); e.g., 1 pg = 1 picogram = 10^{-12} gram.

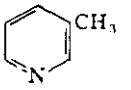
picocurie. One trillionth (10^{-12}) of a curie. A standard measure of the intensity of radiation.

α-picoline. (2-methylpyridine; 2-picoline). CAS: 109-06-8.

$C_5H_4N(CH_3)$ or $\overline{NC(CH_3)CHCHCH}$

Properties: Colorless liquid, strong unpleasant odor, d 0.952, bp 129C, fp −69.9C, refr index 1.4957 (20C), miscible with water and alcohol, flash p (OC) 102F (39C), autoign temp 1000F (537C). Combustible.
Derivation: From cyclohexylamine plus ammonia and zinc chloride, also from coal tar and bone oil.
Hazard: Moderate fire risk, irritant.
Use: Organic intermediate for pharmaceuticals, dyes, rubber chemicals, solvent, source for vinyl pyridine, laboratory reagent.

β-picoline. (3-methylpyridine; 3-picoline). CAS: 108-99-6.



Properties: Colorless liquid, unpleasant odor, bp 143.5C, fp −18.3C, d 0.9613 (15/4C), refr index 1.5060 (20C). Soluble in water, alcohol, and ether. Combustible.
Derivation: From cyclohexylamine plus ammonia and zinc chloride, also from coal tar and bone oil.
Hazard: Moderate fire risk, irritant.
Use: Solvent in synthesis of pharmaceuticals, resins, dyestuffs, rubber accelerators, insecticides; preparation of nicotinic acid and nicotinic acid amide, waterproofing agents; laboratory reagent.

γ-picoline. (4-methylpyridine; 4-picoline). CAS: 108-89-4.

$\overline{NCHCHC(CH_3)CHCH}$.

Properties: Colorless, moderately volatile liquid. D 0.957 (15/4C), bp 144.9C, refr index 1.5050 (20C), mp 3.8C. Soluble in water, alcohol, and ether. Flash p (OC) 134F (56.6C). Combustible.
Derivation: From cyclohexylamine plus ammonia and zinc chloride, also from coal tar and bone oil.
Hazard: Moderate fire risk, irritant.
Use: Solvent in synthesis of pharmaceuticals, resins, dyestuffs, rubber accelerators, pesticides and waterproofing agents; laboratory reagent; making isoniazid; catalyst; curing agent.

ORIGINAL
(Red)

REFERENCE NO. 52

0772318

COMMONWEALTH OF PENNSYLVANIA
PENNSYLVANIA FISH COMMISSION
Bureau of Fisheries and Engineering
Robinson Lane
Bellefonte, PA 16823
814-359-2754

March 11, 1982

RECEIVED
MAR 16 1982
ENVIRONMENT
WATER QUALITY
NORRISTOWN REGIONAL OFFICE

Mr. Charles Rehm
Planning Engineer
Regional Environmental Protection Office
Department of Environmental Resources
1875 New Hope Street
Norristown, PA 19401

Dear Mr. Rehm:

We have a question relating to industrial waste discharge application PA-0013641, SIC 3317, for the Bishop Tube Company, Frazer, Pa., as published in the Pennsylvania Bulletin. Would you please clarify the justification for the discharge limitation of 110°F for the design flow of 0.102 MGD to Little Valley Creek, Chester County, which has a low flow equal to 0.04 CFS.

Our concern in this matter stems from the fact that Area Fisheries Manager Michael Kaufmann has recently found wild brown trout young of the year in this stream and was preparing to recommend its reclassification from trout stocked water to coldwater fishery.

Whatever the case, the temperature limitation seems extremely high to our staff.

Thank you for your help.

Sincerely,

Robert B. Hesser
Fishery Resources Biologist

RBH:dk
cc: E. Miller
R. Snyder
J. Miller
M. Kaufmann
N. Sickles
R. Bednarczyk

JOHN ORWAY

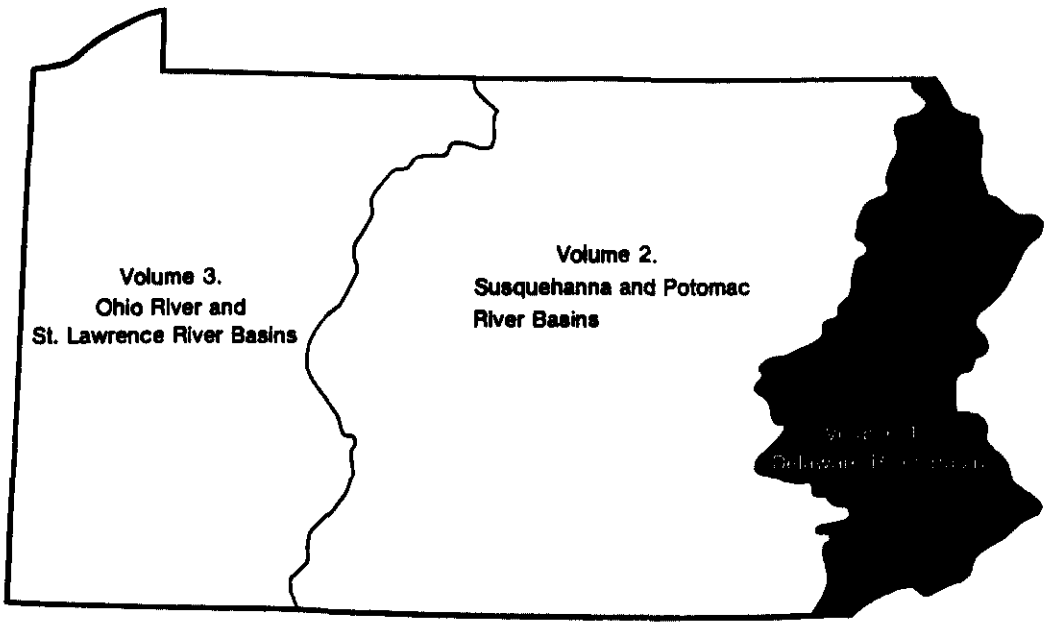
REFERENCE NO. 53

Environmental Laboratory
Wayne, PA 19087-1710

Water Resources Data Pennsylvania Water Year 1992

Volume 1. Delaware River Basin

by K.E. White, T.E. White, R.L. Druther, and P. Moleski



U.S. GEOLOGICAL SURVEY WATER-DATA REPORT PA-92-1
Prepared in cooperation with the Pennsylvania Department of Environmental Resources, the Philadelphia Water Department and with other State, municipal, and Federal agencies

U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY
Robert M Hirsch, Acting Director

For additional information write to
Disctrict Chief, Water Resources Division
U.S. Geological Survey, WRD
840 Market Street
Lemoyne, PA 17043
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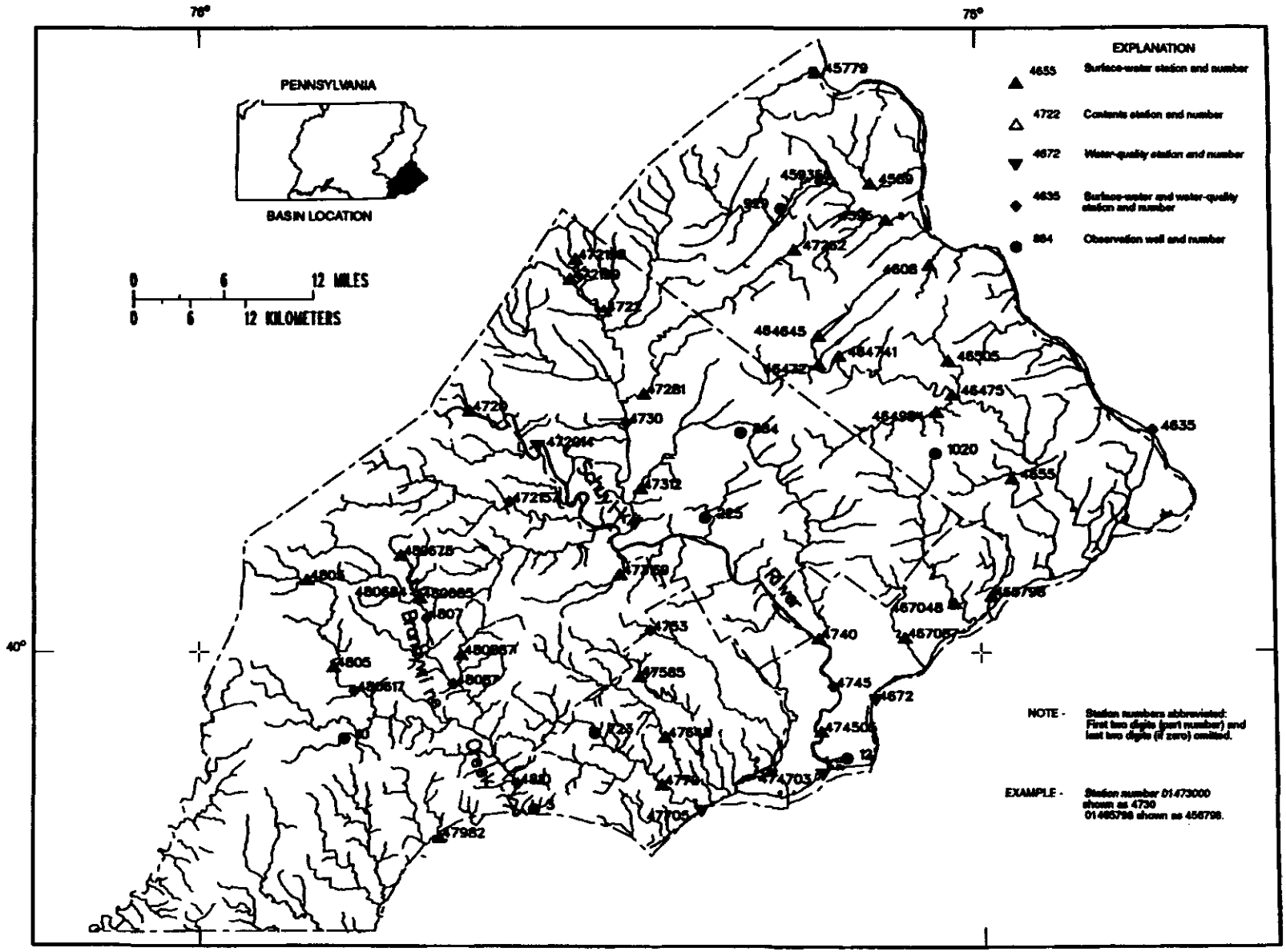

Figure 7.--Location of data-collection stations in the lower Delaware Basin.

SCHUYLKILL RIVER BASIN

01472000 SCHUYLKILL RIVER AT POTTSTOWN, PA

LOCATION.--Lat 40°14'30", long 75°39'07", Montgomery County, Hydrologic Unit 02040203, on right bank 75 ft upstream from bridge on Hanover Street in Pottstown and 0.4 mi downstream from Manatawny Creek.

DRAINAGE AREA.--1,147 mi^2.

PERIOD OF RECORD.--October 1927 to current year. Monthly discharges only for some periods, published in WSP 1302.

GAGE.--Water-stage recorder. Datum of gage is 117.86 ft above sea level. October 1926 to Nov. 22, 1928, nonrecording gage and Nov. 23, 1928, to Dec. 26, 1972, recording gage, at site 100 ft downstream at same datum. Dec. 27, 1972, to May 10, 1974, nonrecording gage 1.0 mi downstream at datum 2.83 ft lower.

REMARKS.--Records good except those for estimated daily discharges, which are poor. Flow regulated by Blue Marsh Lake (station 01470870) since April 1979 and to some extent by Still Creek Reservoir (station 01469200) since February 1933, and by Lake Ontelaunee. Satellite telemetry at station. Several measurements of water temperature were made during the year.

DISCHARGE, CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1991 TO SEPTEMBER 1992
DAILY MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	383	436	791	1070	951	1600	3290	1490	5380	793	959	529
2	380	432	868	955	863	1480	2830	1390	4230	669	846	482
3	376	425	2600	907	836	1340	2170	1310	2800	644	901	493
4	372	422	3970	1070	780	1220	1970	1270	2270	762	816	506
5	370	407	2680	1140	747	1130	1770	1140	3250	763	840	549
6	476	428	2100	1020	705	1050	1600	1150	5490	1140	753	500
7	658	456	1830	834	689	1420	1480	1080	4540	1380	623	587
8	512	402	1650	874	704	1760	1420	1910	3770	768	562	583
9	469	366	1580	827	676	1550	1330	4460	3210	794	628	592
10	415	367	2360	898	616	1480	1260	3300	2530	1120	669	666
11	e465	435	2220	876	602	1990	1310	2520	2180	891	1020	906
12	e600	458	1900	850	631	2930	1250	2150	1870	801	976	1040
13	e530	482	1730	836	595	2560	1150	1900	1670	806	833	694
14	e480	465	1870	1230	622	2170	1080	1880	1500	947	923	627
15	e460	426	1760	1610	821	1930	1030	1760	1390	1100	772	538
16	450	403	1620	1340	1420	1740	1010	1990	1290	1430	661	491
17	847	393	1370	1130	1330	1590	1050	2370	1150	1440	721	480
18	1520	381	1190	1040	1170	1490	1090	1980	1100	1620	826	509
19	1460	385	1030	e990	1100	1630	1130	1850	1380	1320	1290	461
20	1010	381	914	e880	1100	1740	1060	1630	1430	1110	856	438
21	872	429	996	e990	1040	1620	1110	1500	1090	1040	726	434
22	645	818	941	1160	978	1540	1600	1360	1030	979	569	462
23	542	3740	918	991	939	1550	2100	1270	1340	1150	531	624
24	539	3410	1020	1790	957	1550	1830	1200	1030	1240	523	701
25	550	2360	884	1530	962	1410	2140	1140	1210	1090	664	556
26	486	1430	836	1320	1560	2010	2070	1090	991	1090	575	2200
27	471	1010	733	1180	2120	9410	1920	1550	838	994	500	2240
28	461	886	696	999	1960	10300	1790	1200	816	1260	538	1740
29	450	847	895	918	1780	6640	1640	1030	756	1280	762	1470
30	517	738	1260	907	---	5000	1530	1010	997	1160	761	1310
31	480	---	1350	963	---	3750	---	3020	---	1140	589	---
TOTAL	18246	24018	46562	33125	29254	78580	48010	53900	62528	32721	23213	23408
MEAN	589	801	1502	1069	1009	2535	1600	1739	2084	1056	749	780
MAX	1520	3740	3970	1790	2120	10300	3290	4460	5490	1620	1290	2240
MIN	370	366	696	827	595	1050	1010	1010	756	644	500	434

e Estimated.

STATISTICS OF MONTHLY MEAN DATA FOR WATER YEARS 1928 - 1992, BY WATER YEAR (WY)

MEAN	1101	1632	2110	2132	2465	3076	2880	2320	1574	1269	1048	1068
MAX	3870	3897	6805	7383	5117	8948	7820	7220	7634	3940	5290	3732
(WY)	1977	1951	1984	1979	1971	1936	1983	1989	1972	1984	1933	1987
MIN	258	309	419	316	540	1101	875	729	461	302	301	256
(WY)	1931	1931	1931	1981	1934	1981	1985	1965	1965	1966	1966	1932

SUMMARY STATISTICS	FOR 1991 CALENDAR YEAR		FOR 1992 WATER YEAR		WATER YEARS 1928 - 1992	
ANNUAL TOTAL	510276		473565			
ANNUAL MEAN	1398		1294		1886	
HIGHEST ANNUAL MEAN					3211	1984
LOWEST ANNUAL MEAN					843	1965
HIGHEST DAILY MEAN	6000	Jan 17	10300	Mar 28	71200	Jun 23 1972
LOWEST DAILY MEAN	314	Sep 16	366	Nov 9	175	Sep 19 1932
ANNUAL SEVEN-DAY MINIMUM	338	Sep 12	400	Nov 15	210	Sep 19 1932
INSTANTANEOUS PEAK FLOW			13600	Mar 27	95900	Jun 23 1972
INSTANTANEOUS PEAK STAGE			9.33	Mar 27	a29.97	Jun 23 1972
10 PERCENT EXCEEDS	2770		2170		3810	
50 PERCENT EXCEEDS	1030		1030		1290	
90 PERCENT EXCEEDS	416		470		468	

a From floodmark.

01473169 VALLEY CREEK AT PENNSYLVANIA TURNPIKE BRIDGE NEAR VALLEY FORGE, PA.

LOCATION.--Lat 40°04'45", long 75°27'40", Chester County, Hydrologic Unit 02040202, on right bank, 100 ft upstream from Pennsylvania turnpike bridge, 0.9 mi downstream from confluence with Little Valley Creek, near Valley Forge.

DRAINAGE AREA.--20.8 mi^2.

PERIOD OF RECORD.--October 1982 to current year.

GAGE.--Water-stage recorder. Datum of gage is 108.62 ft above sea level.

REMARKS.--Records good except those for estimated daily discharges, which are poor. Several measurements of water temperature were made during the year.

DISCHARGE, CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1991 TO SEPTEMBER 1992
DAILY MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	15	18	18	18	18	18	24	19	24	18	18	11
2	13	21	34	18	17	17	23	19	19	16	13	11
3	17	21	99	18	17	17	22	19	19	26	12	14
4	17	21	36	23	17	16	22	18	19	23	13	14
5	15	18	24	20	16	17	22	18	77	16	12	11
6	17	20	23	19	17	16	21	18	27	15	12	20
7	15	21	22	18	17	36	21	18	22	15	12	24
8	15	20	21	18	17	21	21	92	21	14	12	16
9	15	21	24	21	e16	18	21	35	20	16	12	14
10	15	21	44	19	15	26	21	24	19	15	11	14
11	16	25	23	18	16	55	22	22	19	16	18	19
12	15	18	22	18	17	24	21	20	18	14	13	13
13	16	19	22	18	17	21	19	20	17	14	12	13
14	15	17	22	41	17	20	19	20	17	17	15	13
15	19	17	19	19	35	20	19	20	17	19	16	12
16	17	16	18	17	32	19	20	36	16	15	15	12
17	57	18	18	16	20	19	31	22	16	16	73	12
18	20	16	18	16	20	19	25	20	16	20	20	12
19	16	15	18	e15	19	47	21	20	68	14	14	13
20	12	15	18	15	19	26	18	19	22	13	12	12
21	11	17	18	15	17	23	18	19	18	13	12	12
22	11	86	18	15	16	22	30	18	17	12	11	15
23	10	39	18	30	19	24	20	18	18	19	11	20
24	9.8	21	18	32	20	21	20	18	17	14	11	12
25	11	19	18	20	19	20	24	19	19	15	11	26
26	16	18	18	19	29	49	28	19	18	14	11	98
27	15	18	18	19	19	68	21	19	16	14	11	27
28	16	18	16	19	19	27	20	18	16	13	11	19
29	17	16	29	18	18	25	20	17	15	13	13	16
30	18	14	19	18	---	24	19	18	15	12	11	15
31	19	---	19	18	---	28	---	60	---	23	11	---
TOTAL	510.8	644	752	608	555	803	653	742	662	494	459	540
MEAN	16.5	21.5	24.3	19.6	19.1	25.9	21.8	23.9	22.1	15.9	14.8	18.0
MAX	57	86	99	41	35	68	31	92	77	26	73	98
MIN	9.8	14	16	15	15	16	18	17	15	12	11	11
CFSM	.79	1.03	1.17	.94	.92	1.25	1.05	1.15	1.06	.77	.71	.87
IN.	.91	1.15	1.34	1.09	.99	1.44	1.17	1.33	1.18	.88	.82	.97

e estimated.

STATISTICS OF MONTHLY MEAN DATA FOR WATER YEARS 1983 - 1992, BY WATER YEAR (WY)

MEAN	21.2	29.0	29.4	29.1	33.6	37.0	43.0	41.0	30.7	29.1	25.4	25.5
MAX	34.7	48.8	60.8	40.6	53.5	65.5	98.8	77.5	49.9	46.4	36.3	50.7
(WY)	1990	1987	1984	1990	1984	1983	1983	1984	1984	1984	1989	1989
MIN	15.0	19.5	18.9	16.8	19.1	17.9	18.1	23.9	16.9	15.9	14.8	15.4
(WY)	1987	1991	1989	1985	1992	1985	1985	1992	1985	1992	1992	1986

SUMMARY STATISTICS	FOR 1991 CALENDAR YEAR		FOR 1992 WATER YEAR		WATER YEARS 1983 - 1992	
ANNUAL TOTAL	9685.8		7422.8			
ANNUAL MEAN	26.5		20.3		31.1	
HIGHEST ANNUAL MEAN					47.0	1984
LOWEST ANNUAL MEAN					20.3	1992
HIGHEST DAILY MEAN	309	Jul 13	99	Dec 3	684	Sep 27 1985
LOWEST DAILY MEAN	9.8	Oct 24	9.8	Oct 24	9.8	Oct 24 1991
ANNUAL SEVEN-DAY MINIMUM	12	Oct 19	11	Aug 22	11	Aug 22 1992
INSTANTANEOUS PEAK FLOW			464	Jun 19	1580	Sep 20 1989
INSTANTANEOUS PEAK STAGE			6.18	Jun 19	9.02	Sep 20 1989
ANNUAL RUNOFF (CFSM)	1.28		.98		1.50	
ANNUAL RUNOFF (INCHES)	17.32		13.28		20.34	
10 PERCENT EXCEEDS	34		26		52	
50 PERCENT EXCEEDS	21		18		24	
90 PERCENT EXCEEDS	16		12		16	

SCHUYLKILL RIVER BASIN

01474500 SCHUYLKILL RIVER AT PHILADELPHIA, PA
(National stream-quality accounting network station)

LOCATION.--Lat 39°58'00", long 75°11'20", Philadelphia County, Hydrologic Unit 02040203, on right bank 150 ft upstream from Fairmount Dam, 1,500 ft upstream from bridge on Spring Garden Street in Philadelphia, and 8.7 mi upstream from mouth. Water-quality sampling site 1.6 mi upstream.

DRAINAGE AREA.--1,893 mi^2.

WATER-DISCHARGE RECORDS

PERIOD OF RECORD.--September 1931 to current year. Records for January 1898 to December 1912, published in WSP 35, 48, 65, 82, 97, 125, 166, 202, 214, 261, 301, 381 have been found to be unreliable and should not be used.

REVISED RECORDS.--WSP 756: Drainage area. WSP 1302: 1936(M). WSP 1432: 1945. See also PERIOD OF RECORD.

GAGE.--Water-stage recorder and concrete control. Datum of gage is 5.74 ft above sea level. Prior to Nov. 25, 1956, water-stage recorder at site on right bank just upstream from Fairmount Dam at same datum. Nov. 26, 1956, to Oct. 6, 1966, water-stage recorder at site on left bank 40 ft upstream from Fairmount Dam at same datum.

REMARKS.--Records fair except those for estimated daily discharges, which are poor. Flow regulated by Still Creek Reservoir (station 01469200) since February 1933, Blue Marsh Lake (station 01470870) since April 1979, Green Lane Reservoir (station 01472200) since December 1956 and to some extent by Lake Ontelaunee. Records of discharge do not include diversion above station by city of Philadelphia for municipal water supply. Satellite telemetry at station.

EXTREMES OUTSIDE PERIOD OF RECORD.--Flood of Oct. 4, 1869, reached a stage of 17.0 ft, discharge, 135,000 ft^3/s, from rating extended above 46,000 ft^3/s. Flood of Mar. 1, 1902, reached a stage of 14.8 ft, discharge, 98,000 ft^3/s.

DISCHARGE, CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1991 TO SEPTEMBER 1992
DAILY MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	576	621	1100	1580	1260	2270	4740	1880	6900	1230	1580	713
2	559	621	1270	1430	1170	1960	4090	1740	5760	944	1220	643
3	543	622	6390	1210	1140	1760	3360	1630	4260	866	1110	620
4	499	639	8590	1310	1080	1590	2870	1550	3170	1280	1070	668
5	476	607	4970	1600	1010	1440	2590	1490	4720	1060	1020	664
6	559	589	3370	1620	964	1330	2320	1420	10100	1250	998	699
7	670	616	2770	1370	890	1630	2050	1380	7400	1590	882	839
8	809	620	2380	1190	915	2880	1890	2360	5550	1450	692	942
9	695	582	2230	1160	926	2560	1800	8010	4620	1030	711	788
10	655	568	4040	1240	865	2100	1640	5720	3770	1180	803	820
11	600	676	3840	1230	817	4770	1690	4140	3080	1340	965	977
12	596	732	3020	1190	794	4710	1740	3260	2600	1080	1600	1110
13	756	726	2510	1160	812	3880	1620	2780	2220	1040	1340	1160
14	767	696	2800	1440	794	3290	1450	2480	1950	1060	1150	867
15	892	652	2900	2700	977	2810	1360	2370	1790	1310	1150	756
16	873	627	2410	2250	2670	2500	1330	3180	1600	1870	1060	677
17	1640	581	2100	1530	2410	2190	1410	3560	1430	2070	1280	620
18	2700	614	1700	1410	1910	2010	1750	3030	1300	2340	1350	569
19	1990	568	1480	1160	1730	2660	1530	2560	2330	2190	1400	625
20	1530	568	1280	1030	1780	2980	1600	2310	2510	1600	1660	587
21	1250	568	1280	1160	1580	3090	1470	2020	1760	1350	1090	597
22	1060	1210	1320	1200	1390	2730	1630	1710	1370	1240	898	588
23	868	4810	1310	1550	1330	2660	2550	1540	1350	1390	762	802
24	783	5060	1290	2910	1360	2650	2460	1440	1500	1650	748	798
25	743	3590	1240	2840	1360	2390	2380	1490	1420	1540	680	823
26	701	2340	1200	2000	2050	2610	2900	1390	1430	1540	804	2960
27	673	1560	1070	1680	3240	10800	2590	1620	1170	1470	721	3500
28	692	1180	977	1500	2870	13700	2310	1730	1040	1420	642	3060
29	642	1110	1230	1310	2520	9380	2120	1350	e1000	1570	701	2200
30	633	1080	1940	1260	---	7120	1960	1190	1070	1460	904	1730
31	680	---	1960	1230	---	5690	---	2610	---	2070	922	---
TOTAL	27110	35033	75967	47450	42614	114140	65200	74940	90170	44480	31913	32402
MEAN	875	1168	2451	1531	1469	3682	2173	2417	3006	1435	1029	1080
MAX	2700	5060	8590	2910	3240	13700	4740	8010	10100	2340	1660	3500
MIN	476	568	977	1030	794	1330	1330	1190	1000	866	642	569
MED	695	633	1960	1370	1260	2660	1920	1880	2080	1390	998	793
CFSM	.46	.62	1.29	.81	.78	1.95	1.15	1.28	1.59	.76	.54	.57
IN.	.53	.69	1.49	.93	.84	2.24	1.28	1.47	1.77	.87	.63	.64

e Estimated.

01474500 SCHUYLKILL RIVER AT PHILADELPHIA, PA--Continued
(National stream-quality accounting network station)

STATISTICS OF MONTHLY MEAN DATA FOR WATER YEARS 1932 - 1992, BY WATER YEAR (WY)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
MEAN	1316	2265	3054	3254	3641	4671	4169	3160	2136	1641	1389	1397
MAX	4771	6272	9569	11400	8136	13320	11620	9943	11640	6434	7980	4863
(WY)	1956	1973	1984	1979	1939	1936	1983	1989	1972	1984	1933	1960
MIN	89.4	223	444	340	647	1552	1237	693	261	116	140	117
(WY)	1942	1932	1981	1981	1934	1981	1985	1965	1965	1966	1966	1932

SUMMARY STATISTICS	FOR 1991 CALENDAR YEAR		FOR 1992 WATER YEAR		WATER YEARS 1932 - 1992	
ANNUAL TOTAL	775857		681419			
ANNUAL MEAN	2126		1862		2669	
HIGHEST ANNUAL MEAN					4791	1984
LOWEST ANNUAL MEAN					1014	1965
HIGHEST DAILY MEAN	11300	Jan 12	13700	Mar 28	93400	Jun 23 1972
LOWEST DAILY MEAN	294	Sep 14	476	Oct 5	.60	Sep 2 1966
ANNUAL SEVEN-DAY MINIMUM	343	Sep 13	555	Oct 1	24	Sep 28 1941
INSTANTANEOUS PEAK FLOW			15100	Mar 28	103000	Jun 23 1972
INSTANTANEOUS PEAK STAGE			8.36	Mar 28	14.65	Jun 23 1972
ANNUAL RUNOFF (CFSM)	1.12		.98		1.41	
ANNUAL RUNOFF (INCHES)	15.25		13.39		19.16	
10 PERCENT EXCEEDS	4740		3250		5770	
50 PERCENT EXCEEDS	1560		1410		1640	
90 PERCENT EXCEEDS	501		654		407	

REFERENCE NO. 54

NUS CORPORATION AND SUBSIDIARIES — **TELECON NOTE**

CONTROL NO:	DATE: 4/6/89	TIME: 907

DISTRIBUTION:

BETWEEN:	OF: PA American Water Co.	PHONE:
Bob Berillie		(215) 279-8616

AND: Edward [illegible]

DISCUSSION:

There are two intakes that feed the Norristown Treatment Plant.

One is a submerged crib, located between Barbadoes Island and Bridgeport (the primary intake) just upstream of Rt 202 bridge

The second intake is located between Barbadoes Island and Norristown. This intake draws from the surface

ACTION ITEMS:

Edward [illegible] 4/6/89

NUS 067 REVISED 0686

ORIGINAL
(Red)

REFERENCE NO. 55

EPA REGION III
SUPERFUND DOCUMENT MANAGEMENT SYSTEM

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IMAGERY COVER SHEET
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DATE OF DOCUMENT 01-01-01

DESCRIPTION OF IMAGERY Wetland Legend Map.

NUMBER AND TYPE OF IMAGERY ITEM(S) 1 Oversized Map

ORIGINAL (Red)

REFERENCE NO. 56

BR
PA-1

Commonwealth of Pennsylvania

Pennsylvania Code

Title 25. Environmental Resources

Department of Environmental Resources
Chapter 93. Water Quality Standards

Current through 23 Pa.B. 2102 (April 24, 1993)

Department of Environmental Resources
Bureau of Water Quality Management
Division of Assessment and Standards
10th Floor, Market Street State Office Building
400 Market Street
Harrisburg, PA 17101-2301
(717) 787-9637

§ 93.2. Scope.

(a) This chapter sets forth water quality standards for the waters of this Commonwealth. These standards are based upon water uses which are to be protected and will be considered by the Department in its regulation of discharges.

(b) Where interstate or international agencies under an interstate compact or international agreement establish water quality standards regulations applicable to the waters of this Commonwealth more stringent than those in this title the more stringent standards shall apply.

Source

The provisions of this § 93.2 amended through March 8, 1985, effective February 16, 1985, 15 Pa.B. 907. Immediately preceding text appears at serial page (50936).

Notes of Decisions

Denial of an application for a mine drainage permit cannot be based solely on the ground that the watershed has been designated a conservation area as defined in this section. *Doraville Enterprises v. Commonwealth*, 73 Pa. D.&C.2d 635, 644, 645 (1975).

§ 93.3. Protected water uses.

Water uses which shall be protected, and upon which the development of water quality criteria shall be based, are set forth, accompanied by their identifying symbols, in the following Table 1:

Table 1

Symbol	*Protected Use*
	Aquatic Life
CWF	*Cold Water Fishes*—Maintenance and/or propagation of fish species including the family Salmonidae and additional flora and fauna which are indigenous to a cold water habitat.
WWF	*Warm Water Fishes*—Maintenance and propagation of fish species and additional flora and fauna which are indigenous to a warm water habitat.
MF	*Migratory Fishes*—Passage, maintenance and propagation of anadromous and catadromous fishes and other fishes which ascend to flowing waters to complete their life cycle.
TSF	*Trout Stocking*—Maintenance of stocked trout from February 15 to July 31 and maintenance and propagation of fish species and additional flora and fauna which are indigenous to a warm water habitat.

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Symbol	*Protected Use*
	Water Supply
PWS	*Potable Water Supply*—Used by the public as defined by the Federal Safe Drinking Water Act, 42 U.S.C. § 300F, or by other water users that require a permit from the Department under The Pennsylvania Safe Drinking Water Act (35 P. S. §§ 721.1—721.18), or the act of June 24, 1939 (P. L. 842, No. 365) (32 P. S. §§ 631—641), after conventional treatment, for drinking, culinary, and other domestic purposes, such as inclusion into foods, either directly or indirectly.
IWS	*Industrial Water Supply*—Use by industry for inclusion into nonfood products, processing and cooling.
LWS	*Livestock Water Supply*—Use by livestock and poultry for drinking and cleansing.
AWS	*Wildlife Water Supply*—Use for waterfowl habitat and for drinking and cleansing by wildlife.
IRS	*Irrigation*—Used to supplement precipitation for growing crops.
	Recreation
B	*Boating*—Use of the water for power boating, sail boating, canoeing, and rowing for recreational purposes when surface water flow or impoundment conditions allow.
F	*Fishing*—Use of the water for the legal taking of fish.
WC	*Water Contact Sports*—Use of the water for swimming and related activities.
E	*Esthetics*—Use of the water as an esthetic setting to recreational pursuits.
	Special Protection
HQ	*High Quality Waters*—A stream or watershed which has excellent quality waters and environmental or other features that require special water quality protection.
EV	*Exceptional Value Waters*—A stream or watershed which constitutes an outstanding national, State, regional or local resource, such as waters of national, State or county parks or forests, or waters which are used as a source of unfiltered potable water supply, or waters of wildlife refuges or State game lands, or waters which have been characterized by the Fish Commission as "Wilderness Trout Streams," and other waters of substantial recreational or ecological significance.

Symbol	*Protected Use*
	Other
N	*Navigation*—Use of the water for the commercial transfer and transport of persons, animals, and goods.

Source

The provisions of this § 93.3 amended February 15, 1985, effective February 16, 1985, 15 Pa.B. 544. Immediately preceding text appears at serial pages (50936) to (50938).

Cross References

This section cited in 25 Pa. Code § 287.1 (relating to definitions).

§ 93.4. Statewide water uses.

(a) Those uses set forth in the following Table 2 were considered in determining the water quality criteria applicable to the particular waters listed in § 93.9 (relating to designated water uses and water quality criteria) except where otherwise indicated in such section.

TABLE 2

Symbol	*Use*
	Aquatic Life
WWF	Warm Water Fishes
	Water Supply
PWS	Potable Water Supply
IWS	Industrial Water Supply
LWS	Livestock Water Supply
AWS	Wildlife Water Supply
IRS	*Irrigation*
	Recreation
B	Boating
F	Fishing
WC	Water Contact Sports
E	Esthetics

(b) Less restrictive uses than those currently designated for particular waters listed in § 93.9 may be adopted where it is demonstrated that:

(1) The existing designated use is not attainable because of natural background conditions;

(2) The existing designated use is not attainable because of irretrievable man-induced conditions; or

(3) Application of effluent limitations for existing sources more stringent than those required under 33 U.S.C. § 1311, in order to attain the existing designated use, would result in substantial and widespread adverse economic and social impact.

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Cross References

This section cited in 25 Pa. Code § 93.5 (relating to application of water quality criteria to discharge of pollutants).

§ 93.5. Application of water quality criteria to discharge of pollutants.

(a) *Application of effluent limitations.* The water quality criteria prescribed in this chapter for the various designated uses of the waters of this Commonwealth apply to receiving waters and are not to be necessarily deemed to constitute the effluent limit for a particular discharge, but rather one of the major factors to be considered in developing specific limitations on the discharge of pollutants. Where water quality criteria become the controlling factor in developing specific effluent limitations, the procedures in § 95.3 (relating to waste load allocations) will be employed.

(b) *Design conditions.*

(1) Except if otherwise specified in this chapter, the water quality criteria in this chapter shall be achieved at stream flows equal to or exceeding $Q_{7\text{-}10}$. For streams where the $Q_{7\text{-}10}$ flow is estimated to be zero, water quality criteria shall be achieved at the first downstream point where the stream is capable of supporting designated water uses, as defined in § 93.4 (relating to Statewide water uses).

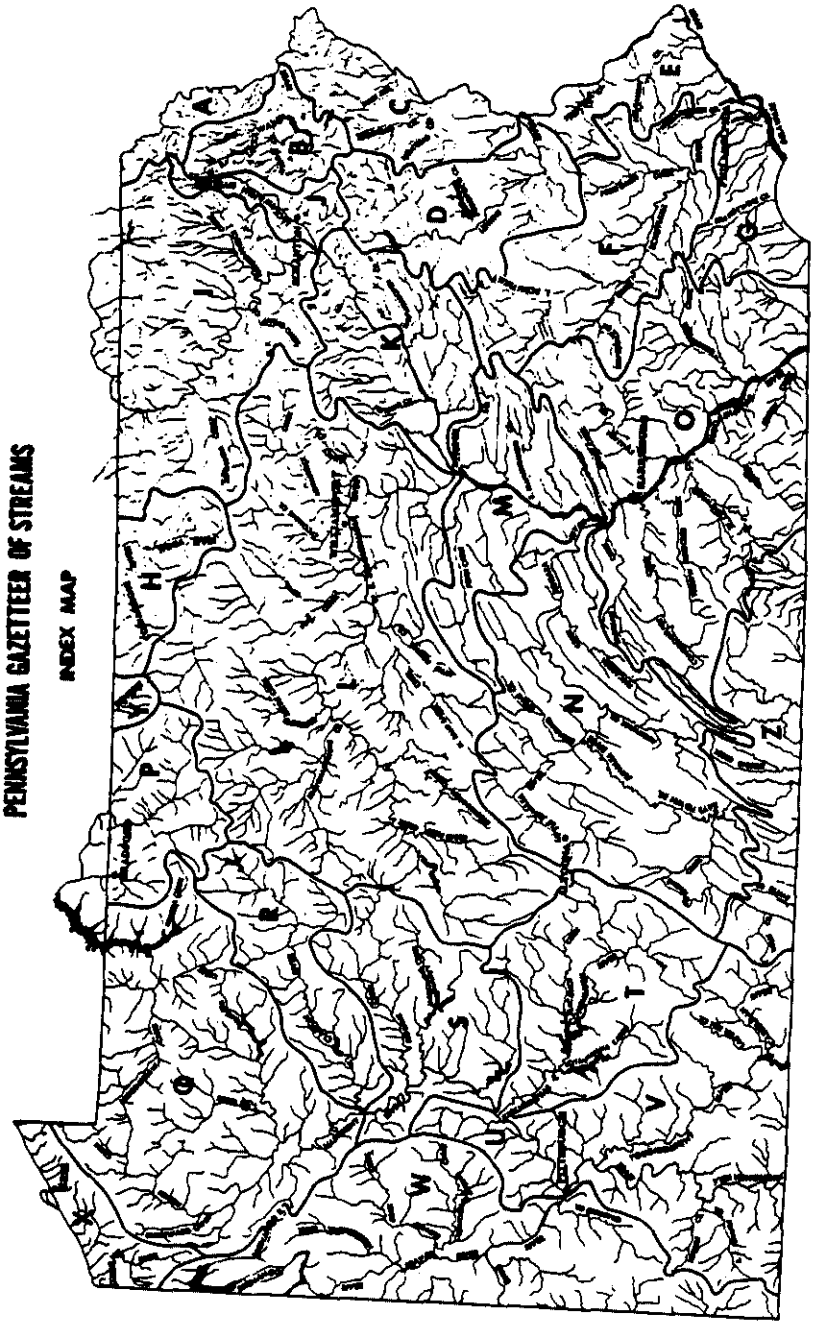
(2) The Department may impose more restrictive design stream flow conditions where, in its judgment, the conditions are necessary for the protection of designated water uses.

(3) In establishing effluent limitations based on water quality criteria in this chapter, the Department may consider design conditions including, but not limited to, temperature, pH and hardness. The combination of design conditions shall provide a minimum 99% level of protection.

(c) *Application of ambient stream concentrations.* Where adopted water quality criteria as set forth in § 93.9 (relating to designated water uses and water quality criteria) are more stringent than ambient stream concentrations of specific water quality indicators, the ambient stream concentrations shall be deemed to be the applicable criteria used to establish specific effluent limits.

(d) *Application of osmotic pressure criterion for protection of aquatic life.* To protect aquatic life and irrigation where it occurs, the amount and composition of total dissolved solids in discharges into the surface waters of this Commonwealth shall be controlled so that the osmotic pressure of the receiving waters does not exceed either the criteria listed in paragraphs (1) or (2):

(1) Fifty milliosmoles per kilogram at any time.


PENNSYLVANIA GAZETTEER OF STREAMS
INDEX MAP

§ 93.9f. Drainage List F.

Delaware River Basin in Pennsylvania
Schuylkill River

Stream	Zone	County	Water Uses Protected	Exceptions To Specific Criteria
1—Delaware Estuary				
2—Schuylkill River	Main Stem, Source to Little Schuylkill River	Schuylkill	CWF	None
3—Unnamed Tributaries to Schuylkill River	Basins, Source to Little Schuylkill River	Schuylkill	CWF	None
3—Big Creek	Basin	Schuylkill	CWF	None
3—Silver Creek	Basin	Schuylkill	CWF	None
3—Mill Creek	Basin, Source to Mud Run	Schuylkill	CWF	None
4—Mud Run	Basin, Source to Schuylkill County Municipal Dam	Schuylkill	HQ-CWF	None
4—Mud Run	Basin, Schuylkill County Municipal Dam to Kaufman Run	Schuylkill	CWF	None
5—Kaufman Run	Basin, Source to Schuylkill County Municipal Dam	Schuylkill	HQ-CWF	None
5—Kaufman Run	Basin, Schuylkill County Municipal Dam to Mouth	Schuylkill	CWF	None
4—Mud Run	Basin, Kaufman Run to Mouth	Schuylkill	CWF	None
3—Mill Creek	Main Stem, Mud Run to Mouth	Schuylkill	CWF	None
4—Unnamed Tributaries to Mill Creek	Basins, Mud Run to Mouth	Schuylkill	CWF	None
4—Tar Run	Basin, Source to Schuylkill County Municipal Dam	Schuylkill	HQ-CWF	None

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Stream	Zone	County	Water Uses Protected	Exceptions To Specific Criteria
4—Tar Run	Basin, Schuylkill County Municipal Dam to Mouth	Schuylkill	CWF	None
4—Wolf Creek	Basin, Source to Schuylkill County Municipal Dam	Schuylkill	HQ-CWF	None
4—Wolf Creek	Basin, Schuylkill County Municipal Dam to Mouth	Schuylkill	CWF	None
3—Tumbling Run	Basin, Source to Schuylkill Haven Dam	Schuylkill	HQ-CWF	None
3—Tumbling Run	Basin, Schuylkill Haven Dam to Mouth	Schuylkill	CWF	None
3—West Branch Schuylkill River	Basin	Schuylkill	CWF	None
3—Mahanhon Creek	Basin	Schuylkill	CWF	None
3—Red Creek	Basin	Schuylkill	CWF	None
3—Plum Creek	Basin	Schuylkill	CWF	None
3—Pine Creek	Basin	Schuylkill	CWF	None
3—Bear Creek	Basin	Schuylkill	CWF	None
3—Stony Creek	Basin	Schuylkill	CWF	None
3—Little Schuylkill River	Basin, Source to Still Creek	Schuylkill	CWF	None
4—Still Creek	Basin, Source to Tamaqua Water Supply Dam	Schuylkill	HQ-CWF	None
4—Still Creek	Basin, Tamaqua Water Supply Dam to Mouth	Schuylkill	CWF	None
3—Little Schuylkill River	Basin, Still Creek to Owl Creek	Schuylkill	CWF	None
4—Owl Creek	Basin, Source to Lower Tamaqua Dam	Schuylkill	HQ-CWF	None
4—Owl Creek	Basin, Lower Tamaqua Dam to Mouth	Schuylkill	CWF	None
3—Little Schuylkill River	Basin, Owl Creek to Mouth	Schuylkill	CWF	None