GROUND–WATER FLOW MODEL OF THE CORNING AREA, NEW YORK

SUSQUEHANNA RIVER BASIN COMMISSION

RESOURCE QUALITY MANAGEMENT & PROTECTION DIVISION

MARCH 1988

The Susquehanna River Basin Commission was created as an independent agency by a Federal-Interstate Compact* among the States of Maryland, New York, Commonwealth of Pennsylvania and the Federal Government. In creating the Commission, the Congress and State Legislatures formally recognized the water resources of the Susquehanna River basin as a regional asset vested with local, State and National interests for which all the parties share responsibility. As the single Federal-Interstate water resources agency with basinwide authority, the Commission's goal is to effect coordinated planning, conservation, management, utilization, development and control of basin water resources among the government and private sectors.

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Conversion Factors and Abbreviations

Length

inch (in or in.)
foot (ft)
mile (mi)

Area

square foot (ft^2)
square mile (mi^2)

Flow	Multiply by	To Obtain
cubic foot per second (ft^3/s)	86400	cubic foot per day (ft^3/d)
ft^3/s	448.8	gallon per minute (gal/min)
cubic foot per day (ft^3/d)	0.00519	gallon per minute (gal/min)
ft^3/d	7.48	gallon per day (gal/d)
ft^3/d	0.00000748	million gallons per day (Mgal/d)
gallon per minute (gal/min)	192.5	cubic foot per day (ft^3/d)
million gallons per day (Mgal/d)	133700	cubic foot per day (ft^3/d)

Hydraulic Units

Transmissivity, cubic foot per day per foot of aquifer thickness, in reduced form becomes foot squared per day (ft^2/d).

Hydraulic conductivity, cubic foot per square foot per day, in reduced form becomes foot per day (ft/d).

ABSTRACT

A quasi-three-dimensional finite-difference model of ground-water flow has been developed for stratified drift aquifers in the area around Corning, New York. The aquifer system consists of a surficial outwash aquifer that is permeable, areally extensive and hydraulically connected to surface streams but has only a small saturated thickness over most of the valley. The outwash is underlain by extensive beds of silt and clay of variable thickness. A deep aquifer buried beneath the outwash and fine-grained deposits is commonly siltier than the shallow aquifer but provides large yields to wells. Ground-water withdrawals in the area around Corning totaled an estimated 10.2 Mgal/d in 1980.

The model is used to simulate horizontal flow in two layers; the upper layer represents the surficial aquifer and is unconfined, and the lower layer generally represents the buried aquifer and is confined. Vertical flow is simulated between these layers through beds of silt and clay where present or through sand and gravel. Horizontal hydraulic conductivities of the sand and gravel range from 100 to 800 ft/d in the calibrated model; transmissivities in the confined aquifer range from 42,300 ft^2/d to 27,000 ft^2/d in areas tapped by production wells.

The steady-state model was used to simulate average conditions with current levels of ground-water withdrawals, "natural" non-pumping conditions, and a hypothetical drought similar to the extended dry period in the 1960's. The transient simulation demonstrates the sensitivity of the ground-water

system to small changes in river stages. If more detailed transient simulations are desired, then further adjustments to storage coefficients are recommended.

INTRODUCTION

Sand and gravel aquifer systems within the Chemung River basin have been used extensively for industrial and municipal supply. Ground-water withdrawals from the aquifer underlying the metropolitan Corning area totaled an estimated 10.2 Mgal/d in 1980. Although these aquifers are very productive, this heavy reliance on ground water has created depressed ground-water levels in the aquifers underlying the City of Corning and raises concern for the availability of the resource during an extreme drought.

In addition, ground-water contamination has limited the supply of water that can be used without treatment. The City of Corning stopped using production well no. 6 in 1983 because volatile organic compounds were detected in the ground water (Ground Water Associates, 1984). Contamination incidents have heightened public concern over the chemical quality of the ground water in the aquifer and have drawn attention to the need for a plan to manage the resource.

In the fall of 1985, the SRBC began a study of the aquifer system underlying Gang Mills, Painted Post, Riverside, and Corning. The object of this study was to prepare a numerical computer model of the aquifers in the metropolitan Corning area to provide insight into the nature of the system and to assist in formulating management alternatives. Existing models (Reisenauer, 1977; Ballaron, 1985) were judged to be inadequate because they had been developed from limited data. Therefore, substantial effort was devoted to the collection of additional data to quantify hydraulic properties of the aquifer, to identify the lithologic character of the subsurface materials, and to measure ground-water levels necessary for model calibration.

PURPOSE AND SCOPE

This report describes how a numerical computer model was used to integrate the various aspects of the ground-water flow system. The model accounts for the interaction between and interdependence of aquifer geometry, aquifer properties, recharge, discharge, boundary conditions, ground-water withdrawals, and ground-water--surface-water exchange. The report includes: (1) generalized geologic sections and maps showing the various unconsolidated deposits in the area, (2) a discussion of the hydrology of the river and aquifer system and a description of sources of recharge to the aquifer; and (3) a summary of model design, calibration, and application.

Method of Investigation

Previous reports by Randall (1972), Reisenauer (1977), and Miller and others (1982) provided basic hydrogeologic data. In addition, the Commission recently investigated possible downstream impacts of releases of water from Cowanesque Lake on shallow ground water in the Tioga and Chemung River valleys (Senko and Ballaron, 1984; Ballaron 1985), providing a record of shallow water levels in the Painted Post-Riverside-Corning area from December 1983 to December 1984. The present study commenced in October 1985 and field work (described below) was conducted through August 1987.

Wells and Borings

Geologic logs from 62 wells and 28 test borings were available from prior investigations of the geology and ground water. SRBC contracted to drill eleven 6-inch diameter wells to bedrock. Analysis of well cuttings retrieved during drilling helped to further define the lithologic character of the glacial sediments and the aquifer geometry as well as establish the thickness of the valley fill. An additional fifteen 2-inch diameter wells were installed in test holes bored with a hollow-stem auger. Logs for selected wells are located in Appendix 1.

Aquifer Tests

Pumping tests were performed in six of the 6-inch diameter wells drilled by SRBC to estimate the hydraulic characteristics of the aquifer. Results of aquifer tests, mostly estimates of specific capacity, performed by other investigators were available for 33 wells. At five locations along the Chemung River and one along the Cohocton River, drive points with 2-foot screens were installed in the sediments and slug-injection tests conducted to determine conductance of the riverbed.

Ground-Water Levels and Temperatures

Ground-water levels were measured monthly in 47 observation wells and 12 municipal and industrial production wells (well locations are shown on Figure 1 at the end of this report). Nine wells were equipped with continuous water level recorders. Water level data were used to prepare water table and potentiometric surface maps, to define hydraulic characteristics of the aquifer through pumping tests, and to document the aquifer's response to seasonal variations in recharge and discharge. Ground-water temperatures were monitored periodically in wells near the Chemung River to evaluate induced infiltration of river water. Vertical temperature profiles were measured in selected wells to within 0.1^{o}C.

Seepage Measurements

Where upland tributary streams flow across the valley fill deposits, some water seeps to the surficial aquifer. Seepage was calculated from streamflow measurements on various dates during 1985 and 1986. Streambed profiles were surveyed for Post and Cutler Creeks and staff gages installed during summer 1986 to better define infiltration along stream reaches.

Aquifer Simulation Model

A three-dimensional finite-difference ground-water flow model documented by McDonald and Harbaugh (1984) was selected for this study. All available hydrogeologic data were incorporated into the model. It was used in quasi three-dimensional mode and was calibrated under steady-state conditions for calendar year 1986. Following steady-state calibration, the model was used to simulate transient conditions resulting from a two-foot rise in stage of the Chemung River.

ACKNOWLEDGMENTS

The Susquehanna River Basin Commission gratefully acknowledges those persons and organizations who provided useful information and whose cooperation made this study possible: Corning Glass Works, Ingersoll-Rand, Inc., and the Departments of Public Works of the City of Corning and the Village of Riverside. Engineering geologists from the New York Department of Environmental Conservation, Bureau of Water Research, assisted Commission staff by installing a number of monitoring wells with their hollow-stem auger.

Special thanks is given to those persons, organizations, and municipalities who granted access to wells on their properties or allowed the installation of monitoring wells on their properties: Corning Glass Works, Ingersoll-Rand, Inc., Hunt Engineering, the City of Corning, Villages of Painted Post and Riverside, the Corning City School District, the New York Department of Environmental Conservation, and several private landowners.

DESCRIPTION OF THE STUDY AREA

The Painted Post-Riverside-Corning area (Figure 2) is in the Appalachian Plateaus province of south-central New York State, a glaciated plateau of moderate relief. Elevations range from about 1,700 ft in the uplands to 930 ft on the valley floor. The study area covers approximately 5.5 square miles along the Chemung River, from about one mile west of the confluence of the Cohocton and Tioga Rivers to South Corning.

Geologic Setting

Consolidated rocks underlying this region are comprised of marine sediments of Paleozoic age, and include interbedded shale, siltstone, and sandstone of the Upper Devonian West Falls Groups. The strata are nearly horizontal.

During the Pleistocene Epoch, continental glaciers flowed southward from north-central Canada and covered this region (and the rest of the Susquehanna Basin in New York) at least once, perhaps several times. The glaciers deepened and widened most bedrock valleys and deposited rock debris of various textures called "drift." With final melting of the ice a little more than 10,000 years ago, the landscape assumed its present configuration. Maps of surficial geology in the Corning area have been prepared by the U.S. Geological Survey (Miller and others, 1982).

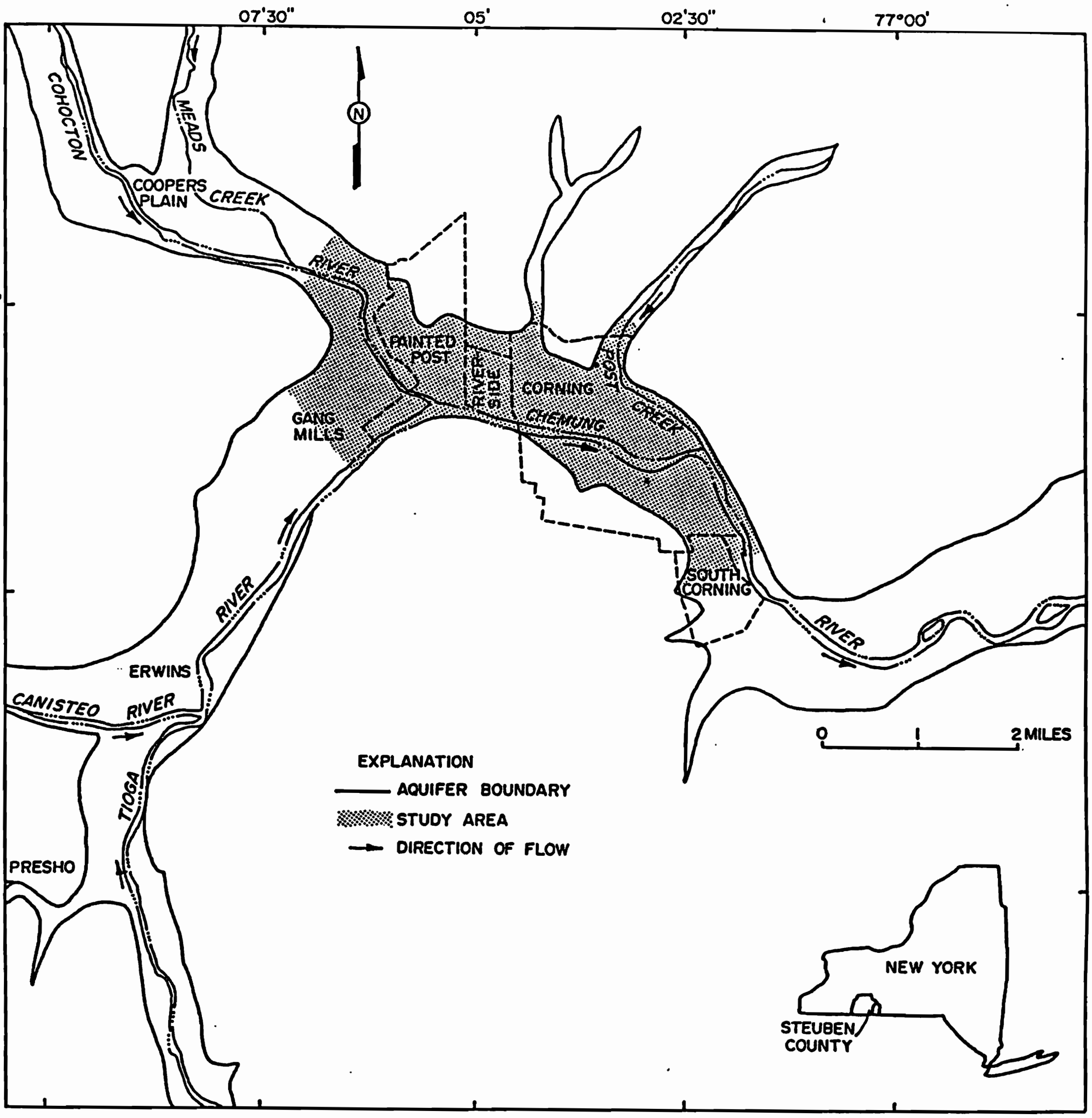

FIGURE 2. MAP SHOWING LOCATION OF THE SAND AND GRAVEL AQUIFER IN THE CHEMUNG RIVER VALLEY NEAR CORNING, NEW YORK.

Nonstratified sediment deposited directly by ice is called till. Till is not sorted by water according to the size and weight of its component fragments, and deposits may consist of a variable mixture of grain sizes, ranging from clay to boulders. Since till is commonly rich in clay and silt it has a very low permeability. In the greater Corning area, a blanket of till is spread across the bedrock uplands. Older dug wells completed in till have yields of about 0.5 gal/min or less, inadequate with respect to modern requirements. These deposits are not important sources of ground water today.

Stratified drift is rock debris of glacial origin that has been sorted, transported and deposited by water. It is generally confined to major valleys, and was deposited during the glacial recession when the climate warmed and melted the ice faster than it was being replaced from the north. Uplands became ice-free first. In the valleys, meltwater flowing from decaying ice tongues deposited layers of sand, gravel, silt and clay upon or adjacent to glacier ice (ice contact) or beyond the glacier itself in streams or lakes (proglacial). These sediments partly filled the deep bedrock valleys to form valley-fill deposits.

Sand and gravel aquifers within the stratified drift are the only aquifers in the Susquehanna River Basin in New York and the northern tier counties of Pennsylvania that consistently yield more than a few gallons per minute to individual wells. Therefore, the principal subject of this report is the stratified drift aquifer in the Corning area, its physical and hydrologic characteristics, including the relationship of the aquifer to the Chemung River.

Valley-Fill Deposits

The valley-fill deposits in the study area range in the thickness from approximately 100 ft in Corning to 135 ft at the mouth of the Tioga River valley in Gang Mills. Geologic cross-sections constructed from logs of wells and test borings show the distribution of sediments at several locations along the Chemung valley (Figure 3, p. 14); traces of these sections are shown on Figure 4 (p. 18).

The arrangement and type of sediments found in the study area generally conform to a depositional pattern described by MacNish and Randall (1982) for many of the broad, relatively shallow and east-west oriented valleys in the Susquehanna River Basin. They suggest (p. 9) that during the waning stages of glaciation, the ends of the ice tongues in these valleys became too thin to flow. Sediments were deposited in smaller lakes and streambeds that formed atop and against stagnant ice, resulting in "a heterogeneous but predominantly coarse and permeable deposit" (Figure 5, p. 19). However, near the mouth of the Tioga River valley a relatively thin cap of sand and gravel overlies a thick section of fine-grained sediments, material more typical of a rapid retreat of the ice margin.

The stratified drift in the valley is chiefly silty to clean sand and gravel. Highly permeable sand and gravel (presumably outwash[1]) are commonly present at the land surface or underlying thin layers of alluvial silt and fine sand. The outwash forms a near surface aquifer, generally in direct hydraulic contact with streams. Thickness ranges from 10 ft to 70 ft but is typically about 25 ft. Over large areas the unit is only thinly saturated but several large-capacity wells tap outwash in Painted Post.

Outwash is underlain by lacustrine deposits of clay, silt and fine sand in much of the valley. Extensive deposits over 90 ft thick were penetrated by well SRB 34 near the mouth of the Tioga River valley. In Painted Post, lacustrine sediments vary in thickness from about 50 ft to less than 10 ft. Logs of closely spaced wells show abrupt thickening or downwarping of these sediments as well as the overlying outwash (Figures 3A and 3C); this is believed to result from a loss of support as buried ice melted. Fine-grained sediments also underlie outwash in Riverside and Corning, but these deposits are typically 10 to 15 ft thick and discontinuous laterally. Where present, lacustrine sediments impede downward (or upward) ground-water flow.

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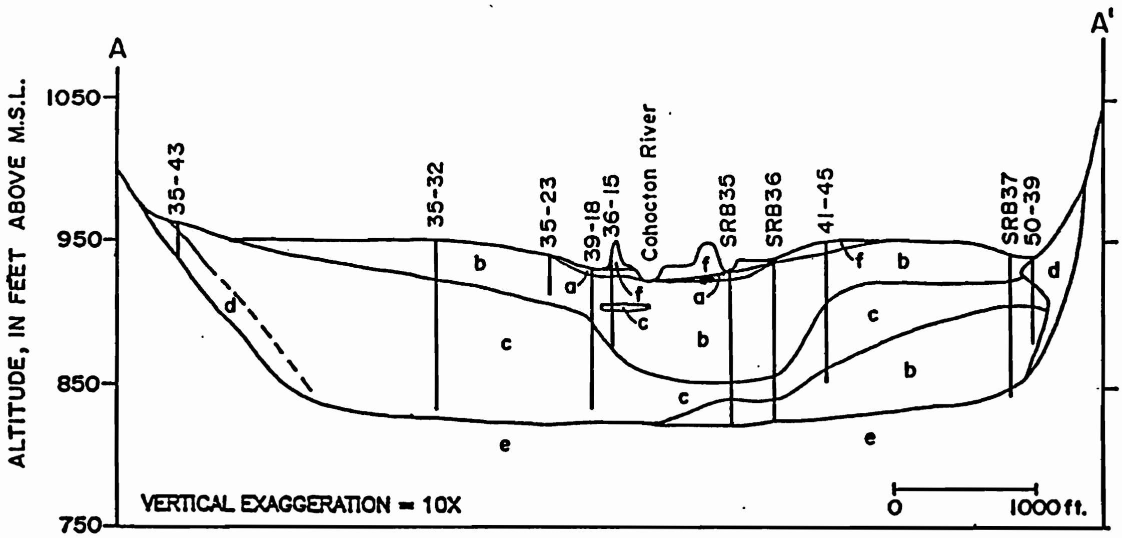
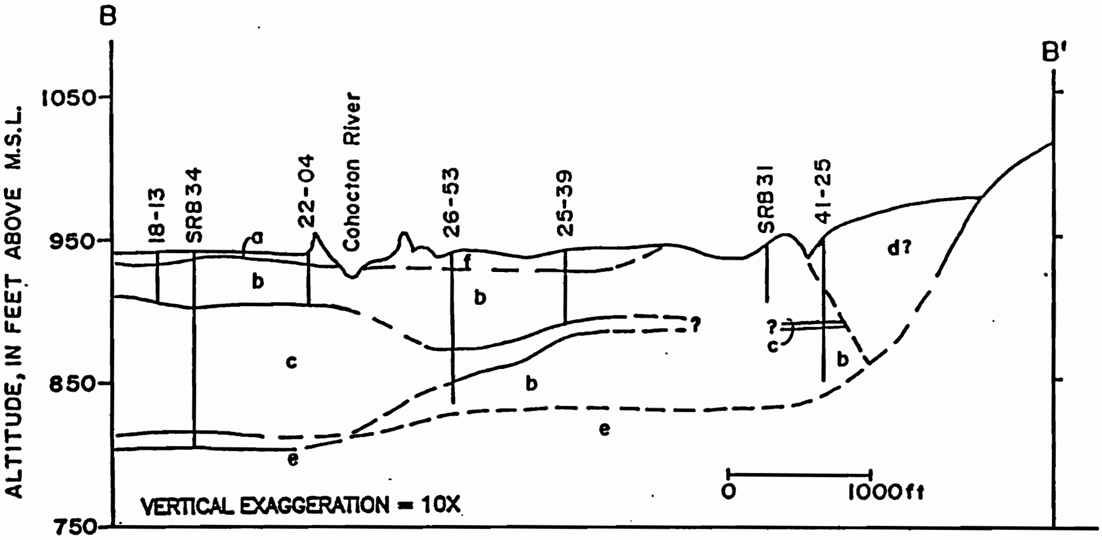
[1] Outwash and ice-contact sand and gravel are distinguished in this report primarily by their stratigraphic position. Careful examination of drill cuttings and detailed descriptions of pebble types (the "bright" and "drab" of Randall, 1977, 1986) might modify this interpretation of the valley-fill.



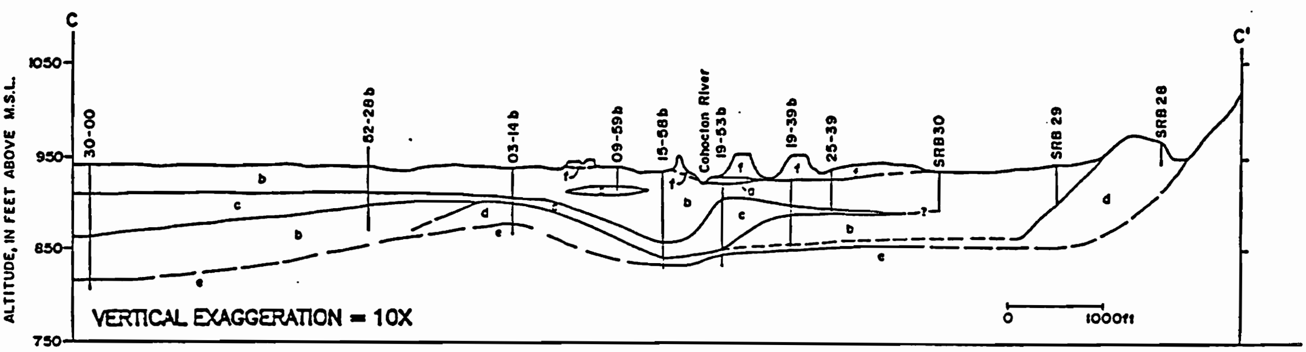
EXPLANATION

- a FLOOD—PLAIN SILT AND SAND
- b OUTWASH AND ICE—CONTACT SAND AND GRAVEL
- c LACUSTRINE SILT AND SAND
- d TILL
- e BEDROCK
- f FILL
- 40-20 WELL OR TEST BORING AND IDENTIFICATION NUMBER

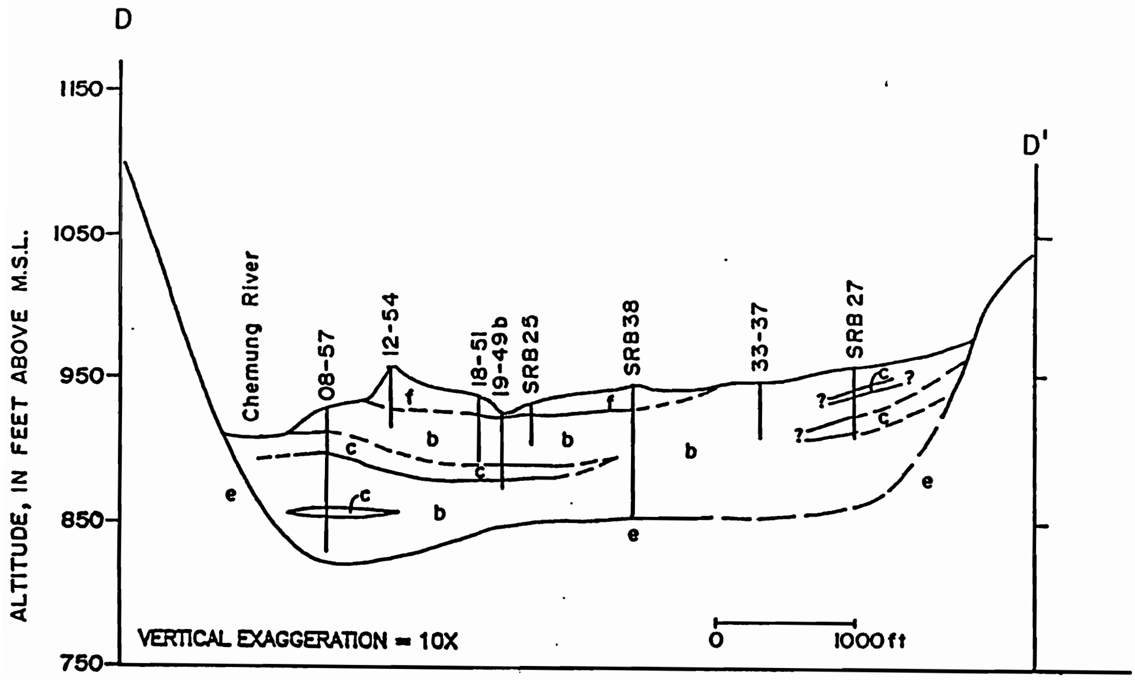
FIGURE 3. GEOLOGIC CROSS SECTIONS OF THE VALLEY—FILL DEPOSITS; A THROUGH G.

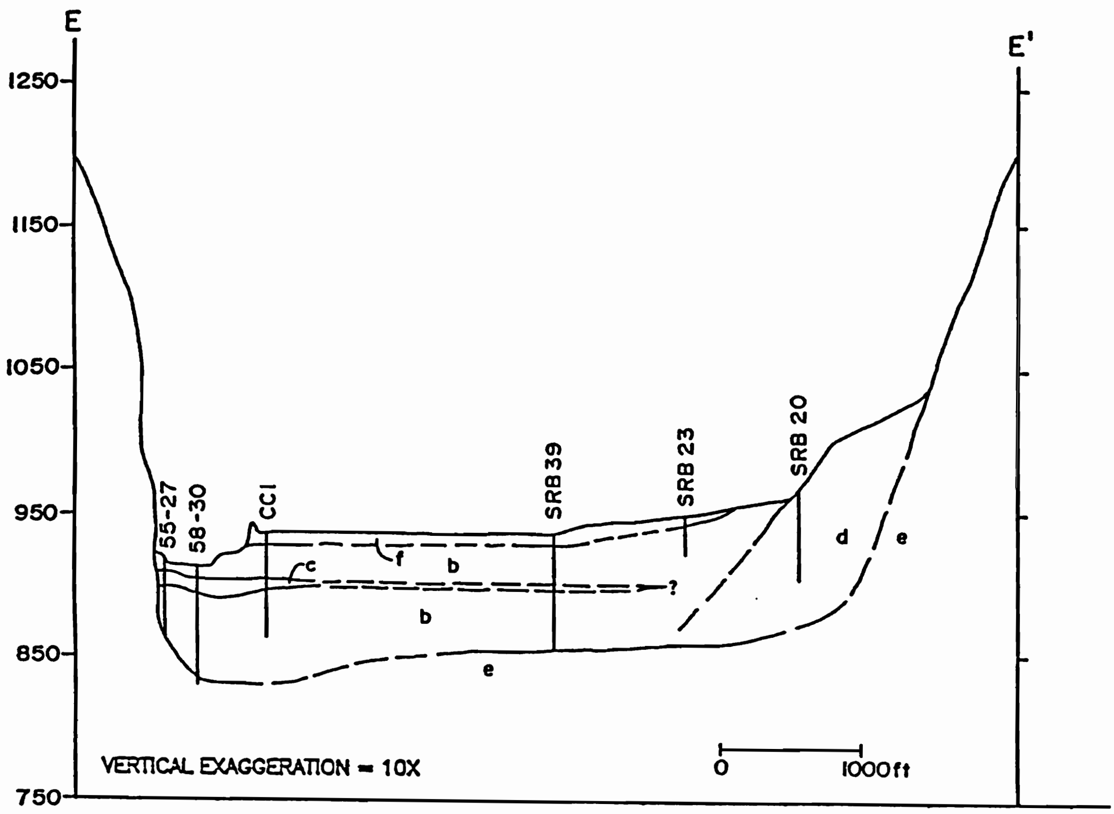


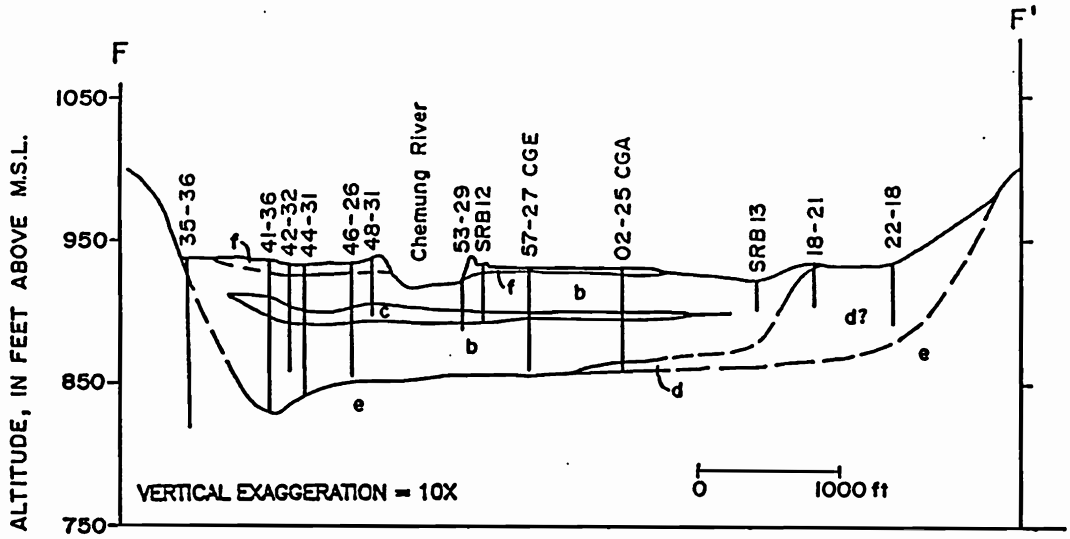
B
B'
ALTITUDE, IN FEET ABOVE M.S.L.
1050
950
850
750
18-13
SRB34
22-04
Cohocton River
26-53
25-39
SRB31
41-25
a
b
c
f
d?
e
?
VERTICAL EXAGGERATION = 10X
0
1000ft

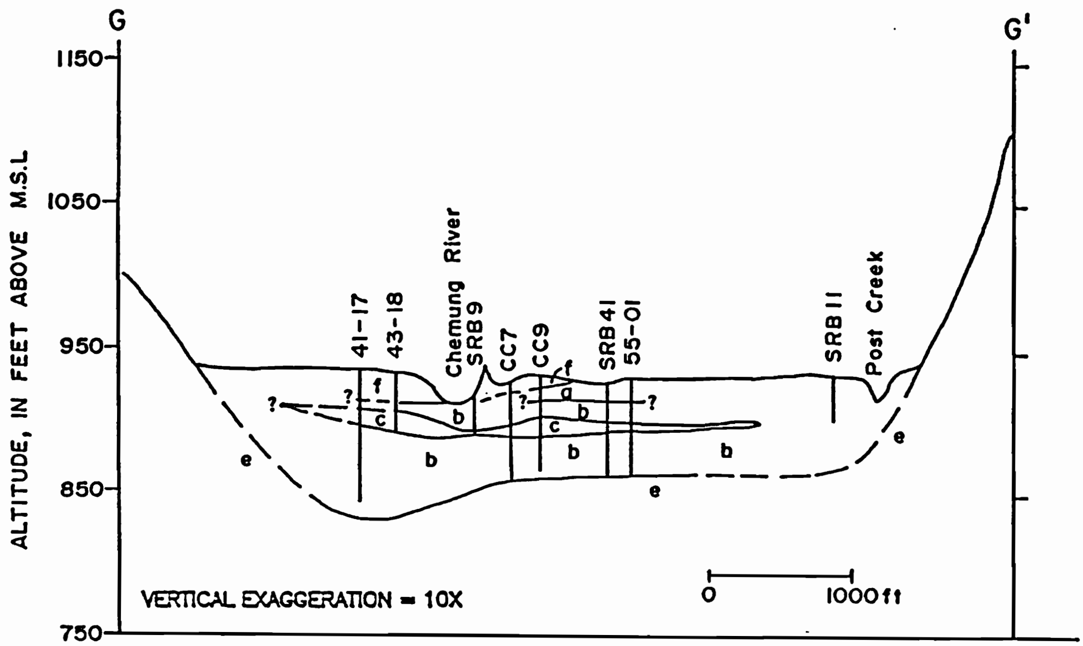


C
C'
ALTITUDE, IN FEET ABOVE M.S.L.
1050
950
850
750
30-00
82-28b
03-14b
09-59b
15-58b
Cohocton River
19-53b
19-39b
25-39
SRB30
SRB 29
SRB 28
VERTICAL EXAGGERATION = 10X
0
1000ft


D
D'
ALTITUDE, IN FEET ABOVE M.S.L.
1150
1050
950
850
750
Chemung River
08-57
12-54
18-51
19-49b
SRB25
SRB38
33-37
SRB 27
b
c
e
f
?
VERTICAL EXAGGERATION = 10X
0
1000 ft


E
E'
1250
1150
1050
950
850
750
55-27
58-30
CC1
SRB39
SRB 23
SRB 20
b
c
d
e
f
?
VERTICAL EXAGGERATION = 10X
0
1000 ft


F
F'
ALTITUDE, IN FEET ABOVE M.S.L.
1050
950
850
750
35-36
41-36
42-32
44-31
46-26
48-31
Chemung River
53-29
SRB12
57-27 CGE
02-25 CGA
SRB 13
18-21
22-18
f
c
b
d
d?
e
VERTICAL EXAGGERATION = 10X
0
1000 ft


G
G'
ALTITUDE, IN FEET ABOVE M.S.L
1150
1050
950
850
750
41-17
43-18
Chemung River
SRB9
CC7
CC9
SRB41
55-01
SRB11
Post Creek
f
c
b
d
e
?
VERTICAL EXAGGERATION = 10X
0
1000 ft

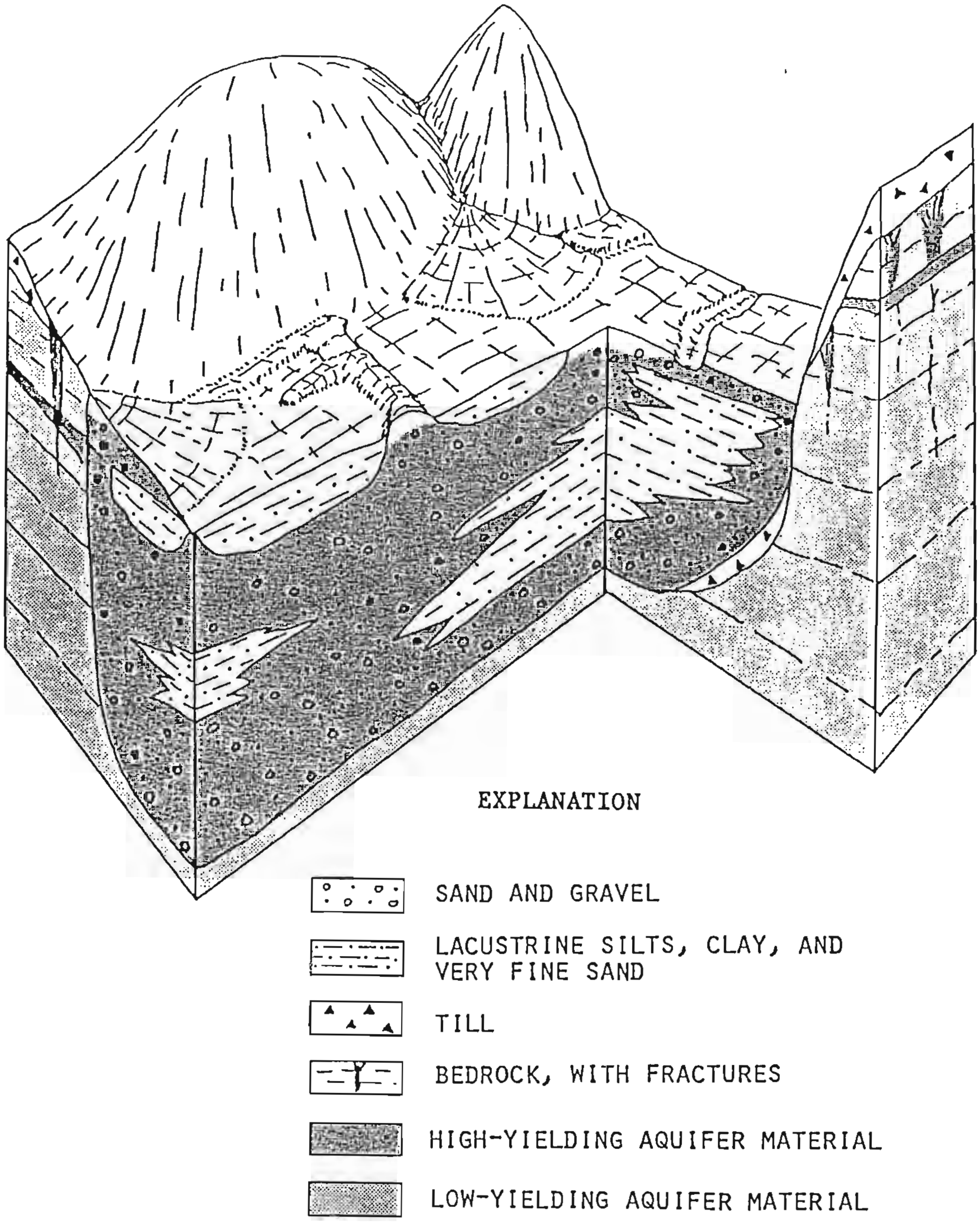


FIGURE 5. GEOLOGY AND HYDROLOGY TYPICAL OF VALLEYS WHERE ICE STAGNATED AND WASTED (MacNISH AND RANDALL 1982.)

Deposits of sand and gravel (presumably ice-contact) underlie lacustrine silts in the central part of the valley and in some areas may comprise the entire thickness of stratified drift (commonly along the sides of valley). These sediments consist of sandy, pebble- to cobble-gravel and pebbly sand, with variable amounts of silt. Thickness ranges from 0 to 70 ft. This unit serves as the principal aquifer for municipal and industrial supply wells in the greater Corning area.

Till sometimes overlies bedrock at the base of the stratified drift and overlies bedrock in most upland areas. Till also forms rounded hills low on both sides of the valley in Corning and small mounds near the center of the valley (as shown in Figure 3C where test boring 03-14b penetrates a mound of till).

Ground-Water Recharge

The source of all ground water in the study area is precipitation within the Chemung River drainage area. Annual precipitation averages about 34 inches. Using water budget analyses, Taylor (1988) estimated 60 percent of precipitation is lost to the atmosphere through evapotranspiration. Streamflow averages about 14 inches per year, of which 8 inches is contributed from ground-water discharge. Since ground-water discharge is approximately equal to ground-water recharge, about 8 inches of precipitation (or about 0.4 $Mgal/d/mi^2$) recharges the ground-water system annually.

A regional water-budget analysis of this type is useful for obtaining a conservative estimate of ground-water recharge for the study area. There are, however, several factors that may result in the underestimation of ground-water recharge locally. First, this type of analysis does not account for ground-water underflow that may be significant in the broad, permeable valley fill deposits at Corning. Second, from a basinwide perspective, the areal extent of sand and gravel aquifers is small. Even subbasins with high proportions of sand and gravel have nearly 80 percent of their area directly underlain by till and bedrock (Taylor, 1988). Thus, a uniform value of recharge per unit area is more representative of bedrock aquifers than the sand and gravel underlying Corning and Painted Post. When average recharge was weighted by aquifer type within two basins, sand and gravel aquifers were calculated to receive about 0.62 $Mgal/d/mi^2$ recharge (Taylor, 1988). Several components of recharge are discussed in the following paragraphs.

Recharge Directly from Precipitation

Where deposits of sand and gravel occur at the surface, nearly all rain and melting snow infiltrates the sediments. The water that is not returned to the atmosphere through evapotranspiration reaches the water table. In the Chemung River valley, if evapotranspiration claims 60 percent of precipitation, 13 to 15 inches may recharge the ground-water system. Recharge from precipitation may be substantially reduced in developed areas where roofs and pavement direct precipitation to storm drains. The amount of recharge depends, to a great extent, on the amount and timing of precipitation and the extent of permeable deposits at the surface.

Runoff from Hillsides

Some additional recharge comes from precipitation on till-covered hills bordering the aquifer and not drained by streams (MacNish and Randall, 1982). Because till in this area contains a large percentage of silt and clay, there is little infiltration from heavy rain or snow melt. Excess storm runoff flows across the land surface or as shallow underflow, moving downslope to recharge aquifers underlying the valley floor.

Recharge from Till and Bedrock Uplands

Some ground water moves through the bedrock from the upland toward the valley. The amount of ground water that seeps into the stratified drift from the till and bedrock upland should be about equal to the natural recharge to these till and bedrock areas. Recent study of a basin underlain primarily by shale bedrock, similar to that in the study area, estimated recharge to average about 0.34 $Mgal/d/mi^2$ (data from Corey Creek, Taylor, 1988).

Infiltration from Tributary Streams

Stream water will infiltrate into an aquifer when the ground-water level in a surficial aquifer is lower than the water surface in a stream crossing it. In parts of the Susquehanna River Basin in New York and northern Pennsylvania, recharge occurs under natural conditions where small tributary streams, originating in the adjacent till-mantled bedrock uplands, lose water by seepage through streambeds as they flow across broad valleys floored with permeable stratified drift. The lower reaches of such streams may be dry for long periods during late summer and fall (Ku and others, 1975). Streams in the Susquehanna River Basin lose an average of at least 1 ft^3/s per 1,000 ft of channel by natural infiltration (Randall, 1978). Infiltration rates have been found to vary with position along the channel (Ballaron, 1985), which is probably related to changes in flow rate, ground-water level, and streambed conditions.

During the summer of 1986 elevations were measured along Post and Cutler Creeks to establish streambed profiles. Staff gages were set at five locations along each stream (Figure 1) using natural channel features such as stable reaches of channel and gravel riffles as the gage controls. Stream stages were observed weekly from June through November (Tables 1 and 2). Periodic discharge measurements were made at the gage sites (Tables 3 and 4) by current-meter methods. Stage-discharge relationships were developed from this limited data. No discharge measurements of high flows are available to define the upper portion of the stage-discharge relation. In addition, man-made changes to the stream channel of Cutler Creek near Gage #3

TABLE 1. Stages Observed at Staff Gages Along Cutler Creek. Elevations are in feet above Mean Sea Level.

Date	#1	#2	#3	#4	#5
6/19/86	1031.66	977.27	955.19	938.03	931.69
6/26/87	1031.46	976.93	955.05	937.87	931.49
7/2/86	1031.58	977.07	955.17	937.91	931.57
7/4/86	1031.46	976.93	955.07	937.87	931.49
7/8/86	1031.58	--	--	--	--
7/11/86	1031.48	976.93	955.13	937.87	931.49
7/17/86	1031.64	977.25	955.23	938.03	931.71
7/24/86	--	--	--	--	932.29
7/29/86	--	977.09	--	937.92	931.72
7/31/86	1031.59	977.07	953.21	937.87	931.67
8/7/86	1031.54	977.01	953.14	937.87	931.55
8/9/86	1031.56	--	--	--	--
8/14/86	1031.52	976.97	953.09	937.83	931.45
8/21/86	1031.45	976.93	953.05	937.78	931.41
8/28/86	1031.39	976.88	952.84	937.76	931.40
9/4/86	1031.43	976.85	--	937.75	931.36
9/11/86	1031.35	976.81	--	937.75	931.35
9/19/86	1031.37	976.82	--	937.73	931.36
9/21/86	1031.56	977.07	953.15	937.90	931.55
9/25/86	1031.48	976.95	953.03	937.80	931.43
10/2/86	1031.56	976.99	Chan. Mod.*	937.87	931.49
10/4/86	1031.79	977.20	Chan. Mod.*	938.01	931.80
10/9/86	1031.53	976.98	953.72	937.84	931.49
10/16/86	1031.51	976.99	952.43	937.86	931.49
10/23/86	1031.50	976.93	952.41	937.84	931.45
10/30/86	1031.51	976.96	952.42	937.85	931.47
11/4/86	1032.08	977.41	952.81	938.31	932.16
11/7/86	1032.05	977.33	952.71	938.23	932.07
11/8/86	1032.28	977.51	952.93	938.37	932.19
11/15/86	1031.79	977.17	952.61	937.98	931.66
11/22/86	1031.77	977.19	952.67	938.07	931.72
11/25/86	1032.66	977.51	953.11	939.12	932.91
11/29/86	1032.20	977.19	952.89	938.40	932.19

*Man-made changes altered the stream channel and required that the staff gage be re-surveyed.

TABLE 2. Stages Observed at Staff Gages Along Post Creek. Elevations are in feet above Mean Sea Level.

Date	#1	#2	#3	#4	#5
6/19/86	967.67	927.66	924.09	915.95	910.36
6/26/86	967.49	927.48	923.79	915.29	910.30
7/2/86	967.63	--	--	--	--
7/4/86	967.45	927.46	923.73	915.23	910.28
7/8/86	967.57	--	--	--	--
7/11/86	967.47	927.44	--	915.27	910.28
7/17/86	967.69	927.68	924.05	915.55	910.54
7/24/86	967.99	--	924.33	--	--
7/29/86	967.64	--	923.85	--	--
7/31/86	967.61	928.58	923.85	915.61	910.39
8/8/86	967.59	927.54	923.81	915.55	910.33
8/9/86	968.02	927.95	924.31	916.20	910.99
8/14/86	967.52	927.54	923.76	915.53	910.25
8/21/86	967.51	927.50	923.79	915.49	910.22
8/28/86	967.46	927.43	923.63	915.41	910.13
9/4/86	967.29	927.35	923.49	915.09	909.99
9/11/86	967.29	927.30	923.25	915.09	909.98
9/19/86	967.37	927.39	923.42	915.18	910.02
9/21/86	967.51	927.56	923.58	915.30	910.03
9/25/86	967.39	927.42	923.47	915.22	910.15
10/2/86	967.46	927.49	923.59	915.33	910.18
10/4/86	967.75	927.74	923.88	915.71	911.66
10/9/86	967.44	927.47	923.56	915.31	910.17
10/16/86	967.43	927.50	923.63	915.34	910.19
10/23/86	967.41	927.47	923.60	915.30	910.11
10/30/86	967.40	927.48	923.59	915.33	910.09
11/4/86	967.90	928.14	924.21	915.82	911.09
11/7/86	967.78	928.00	924.02	915.55	910.97
11/8/86	968.20	928.38	924.53	916.00	911.20
11/15/86	967.70	927.68	924.13	915.54	910.51
11/22/86	967.77	927.76	924.15	915.75	910.86
11/25/86	968.29	928.32	925.32	916.78	Over Top*
11/29/86	968.17	928.20	924.59	916.09	Over Top*

*Staff gage was submerged.

TABLE 3. Seepage Runs Along Cutler Creek

	Date			
	6/18/86	7/17/86	8/7/86	9/15/86
Cutler Creek #1				
Gage Height (ft)	0.61	0.54	0.44	0.25
Elevation (ft above MSL)	1031.71	1031.64	1031.54	1031.35
Discharge (ft^3/s)	7.09	5.51	1.76	0.105
Cutler Creek #2				
Gage Height (ft)	1.16	1.02	0.78	0.58
Elevation (ft above MSL)	977.39	977.25	977.01	976.81
Discharge (ft^3/s)	7.89	5.56	1.88	0.045
Cutler Creek #3				
Gage Height (ft)	0.65	0.63	0.81	
Elevation (ft above MSL)	955.22	955.20	953.14	
Discharge (ft^3/s)	8.27	5.67	1.71	
Cutler Creek #4				
Gage Height (ft)	0.58	0.53		
Elevation (ft above MSL)	938.07	938.02		
Discharge (ft^3/s)	7.69	5.03		
Cutler Creek #5				
Gage Height (ft)		0.72		
Elevation (ft above MSL)		931.71		
Discharge (ft^3/s)		4.78		

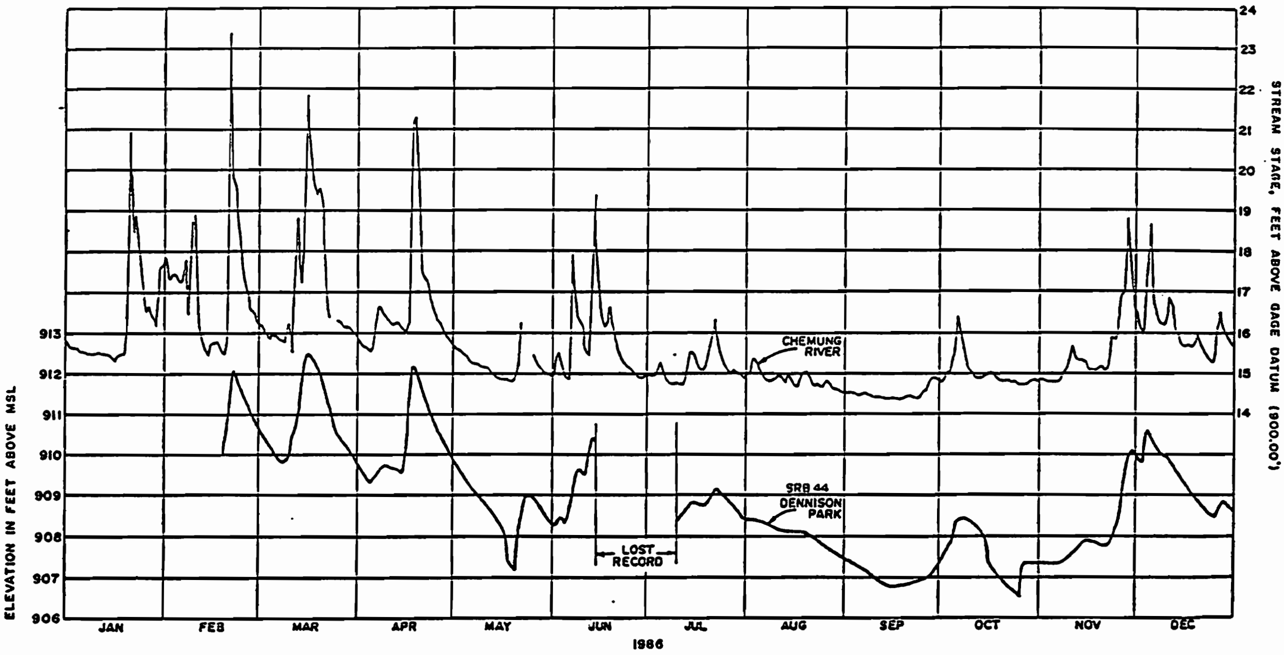
TABLE 4. Seepage Runs Along Post Creek

	Date					
	6/17/86	7/18/86	8/9/86	8/14/86	9/18/86	9/25/86
Post Creek #1						
Gage Height (ft)	1.02	.945	1.20	0.70	0.50	
Elevation (ft above MSL)	967.83	967.76	968.01	967.51	967.31	
Discharge (ft^3/s)	22.62	16.00	38.27	5.97	1.22	
Post Creek #2						
Gage Height (ft)	0.71			0.40	0.19	
Elevation (ft above MSL)	927.83			927.52	927.31	
Discharge (ft^3/s)	24.47			5.29	1.28	
Post Creek #3						
Gage Height (ft)	2.02			1.38		1.17
Elevation (ft above MSL)	924.35			923.71		923.50
Discharge (ft^3/s)	23.95			4.82		2.61
Post Creek #4						
Gage Height (ft)	0.92			0.69	0.38	0.42
Elevation (ft above MSL)	915.73			915.50	915.19	915.23
Discharge (ft^3/s)	22.43			6.64	2.24	3.43
Post Creek #5						
Gage Height (ft)			10.63	10.85	10.42	10.43
Elevation (ft above MSL)			910.28	910.45	910.02	910.03
Discharge (ft^3/s)			7.22	12.63	1.92	2.93

modified the rating at this gage. High flows in late July resulted in the shift of bed materials along both streams and likely altered the stage-discharge relation at most gages.

River-Aquifer Relationship

Under natural, long-term average conditions, ground-water discharges from the unconsolidated aquifer to the Tioga River, the Cohocton River, and the Chemung River. However, infiltration from the rivers to the aquifer can occur in several ways. First, because much of the shallow unconfined aquifer is directly connected to the rivers in the study area, river water enters the aquifer when river stage rises above the water table. Continuous water-level records show that ground-water levels of not only the shallow but also the deep aquifers respond rapidly to rises in river stage (Figures 6 and 7). These rises in water level in the deep aquifer as a result of rising stream stage may be caused by recharge to the aquifer from the stream. However, where confining beds are thick and areally continuous, it is unlikely that surface water could reach the deep aquifer as rapidly as the records show and the rise is likely a pressure response. Second, river water infiltrates into the aquifer when the cone of depression of a pumping well intersects the river. Many of the production wells in the study area are located close to the rivers and it is likely that much of the water they pump from the aquifer is derived from induced recharge. Unfortunately, the loss of water from the river could not be measured directly from



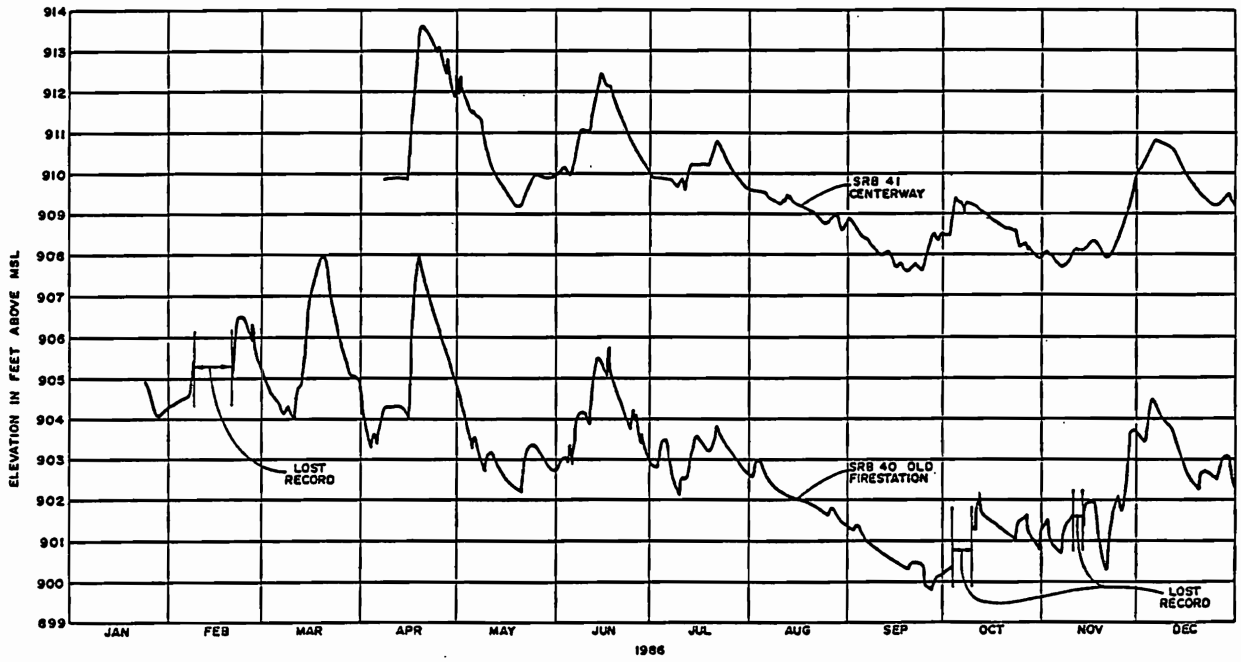


FIGURE 6. GROUND—WATER LEVELS IN OBSERVATION WELLS SRB 44, SRB 41, AND SRB 40 AND THE STAGE OF THE CHEMUNG RIVER AT CORNING, JANUARY THROUGH DECEMBER, 1986. (WELL LOCATIONS ARE SHOWN ON FIGURE 1)

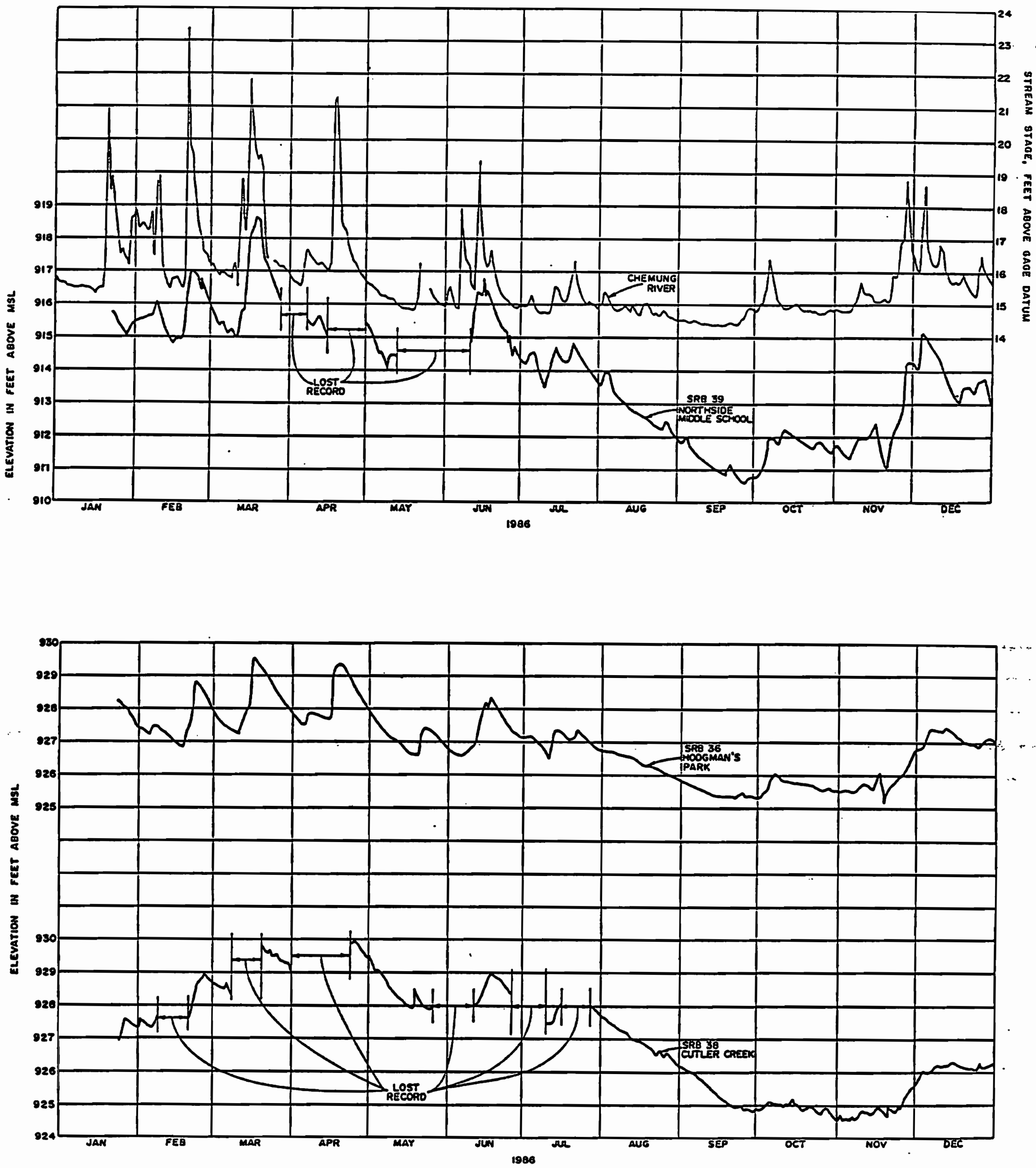


FIGURE 7. GROUND–WATER LEVELS IN OBSERVATION WELLS SRB 36, SRB 38, AND SRB 39 AND THE STAGE OF THE CHEMUNG RIVER AT CORNING, JANUARY THROUGH DECEMBER, 1986. (WELL LOCATIONS ARE SHOWN ON FIGURE 1)

discharge measurements.[2] Induced infiltration was investigated indirectly and its volume estimated during model simulations.

Hydraulic Conductivity of the Riverbed

The amount of induced recharge is partly governed by characteristics of the riverbed materials, such as the vertical hydraulic conductivity and the riverbed thickness. The riverbed of the Chemung River is commonly composed of sand and gravel, and varies in permeability and thickness along the channel according to natural patterns of scour and sedimentation, and in some instances the intervention by man. To investigate riverbed characteristics, drive points were installed at water's edge at four sites along the Chemung River and one site along the Cohocton River. These were located generally near major production wells. The riverbed was about 2 ft thick in the Cohocton River and ranged from about 3 to 7 ft thick at points driven in the Chemung River. Slug-injection tests performed on these wells, and analyzed according to methods described in Ferris and Knowles (1962) and Cooper and others (1967), indicate horizontal hydraulic conductivity ranges from 0.55 to 3.7 ft/d for the riverbed; vertical hydraulic conductivity would be expected to be less. Some well points were apparently driven completely through the streambed to the shallow aquifer and hydraulic conductivities were several orders of magnitude higher.

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2 The stream reach in Corning where induced infiltration is likely to occur is complicated by a number of industrial discharges and storm sewers. In addition, a measurement error of 5 percent of the minimum discharge recorded during the summer of 1986, 176 ft^3/s, exceeds the expected loss due to induced infiltration.

Ground-Water Temperature

Temperature of ground water is near 10° or $11^{\circ}C$ at depths tapped by most production wells in the study area. Vertical temperature profiles show temperature in most wells changes little with depth (no more than $1^{\circ}C$) except within about 20 feet of the land surface where some fluctuations occur in response to seasonal variations in air temperature.

Previous studies of ground water in the Susquehanna River Basin have shown anomalies in ground-water temperature result from induced infiltration of river water. Induced infiltration causes the water in the aquifer to be warmer than normal during the late summer and fall and cooler during winter and spring (Randall 1977, 1986; Yeager, 1986). The largest annual fluctuations are close to the riverbank and in the most permeable layers, whereas farther from the river temperatures fluctuate less.

Vertical temperature profiles in riverbank wells should detect areas where there is a good connection between the river and aquifer and induced infiltration is occurring. The wide seasonal fluctuation in temperature at well SRB 8 is a clear indication of large-scale induced infiltration (Figure 8). Temperature varied from near 6° in March, 1987 to $21^{\circ}C$ in August, 1987 at a depth of 30 ft below land surface. This well is located within the levee, between the Chemung River and

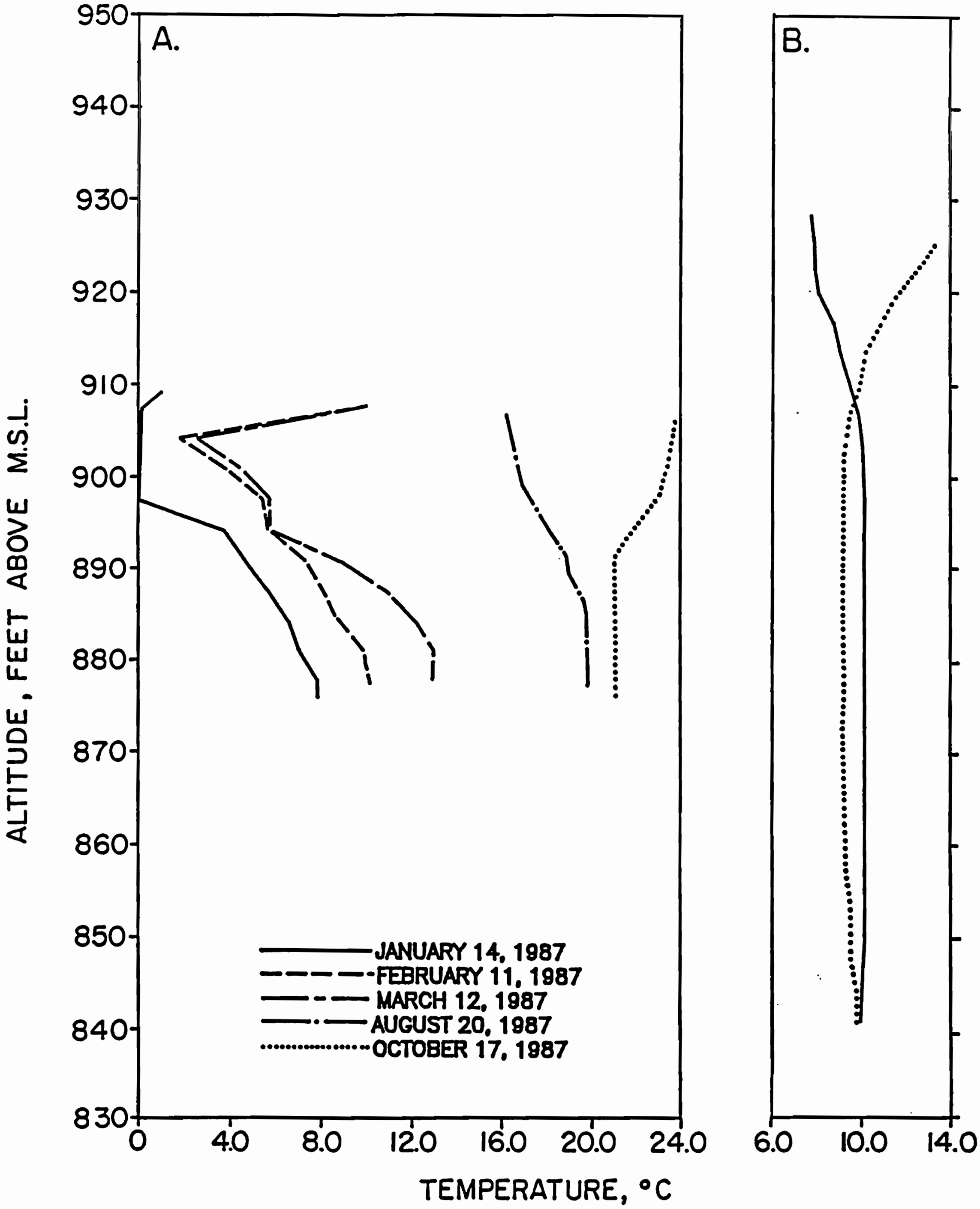


FIGURE 8. WATER—TEMPERATURE PROFILES OF WELLS (A) SRB 8 NEAR THE CHEMUNG RIVER IN CORNING (DOWNSTREAM FROM CENTERWAY BRIDGE); (B) SRB 35 NEAR THE COHOCTON RIVER IN PAINTED POST.

production wells of Corning City (CC 7 and CC 9) and Corning Glass Works. The only other well located near the river and accessible for measuring temperature profiles is located in Hodgman's Park in Painted Post (SRB 35). This well shows no evidence of induced infiltration, possibly because, with the closure of the Ingersoll-Rand facility, there are no production wells nearby.

Wells SRB 44 and SRB 3, located south of the Chemung River in Corning, show some subtle temperature anomalies (Figure 9). Corning City water supply wells in this area were not operating during the course of this study and are not responsible for the fluctuation in temperature. Temperature profiles were also measured in wells SRB 12, 39, 40 and 41 several times during 1986 and 1987; these wells show no temperature anomalies.

Well SRB 26, located about 50 ft west of Cutler Creek, shows a wide seasonal fluctuation of ground-water temperature, from 7°C in March to 14°C in August, about 27 feet below land surface (Figure 10). This may result from natural infiltration from the tributary stream as it flows across the stratified drift. Deeper wells near Cutler Creek (SRB 27 and 38) show a nearly constant temperature of 9.5° to 10°C with depth.

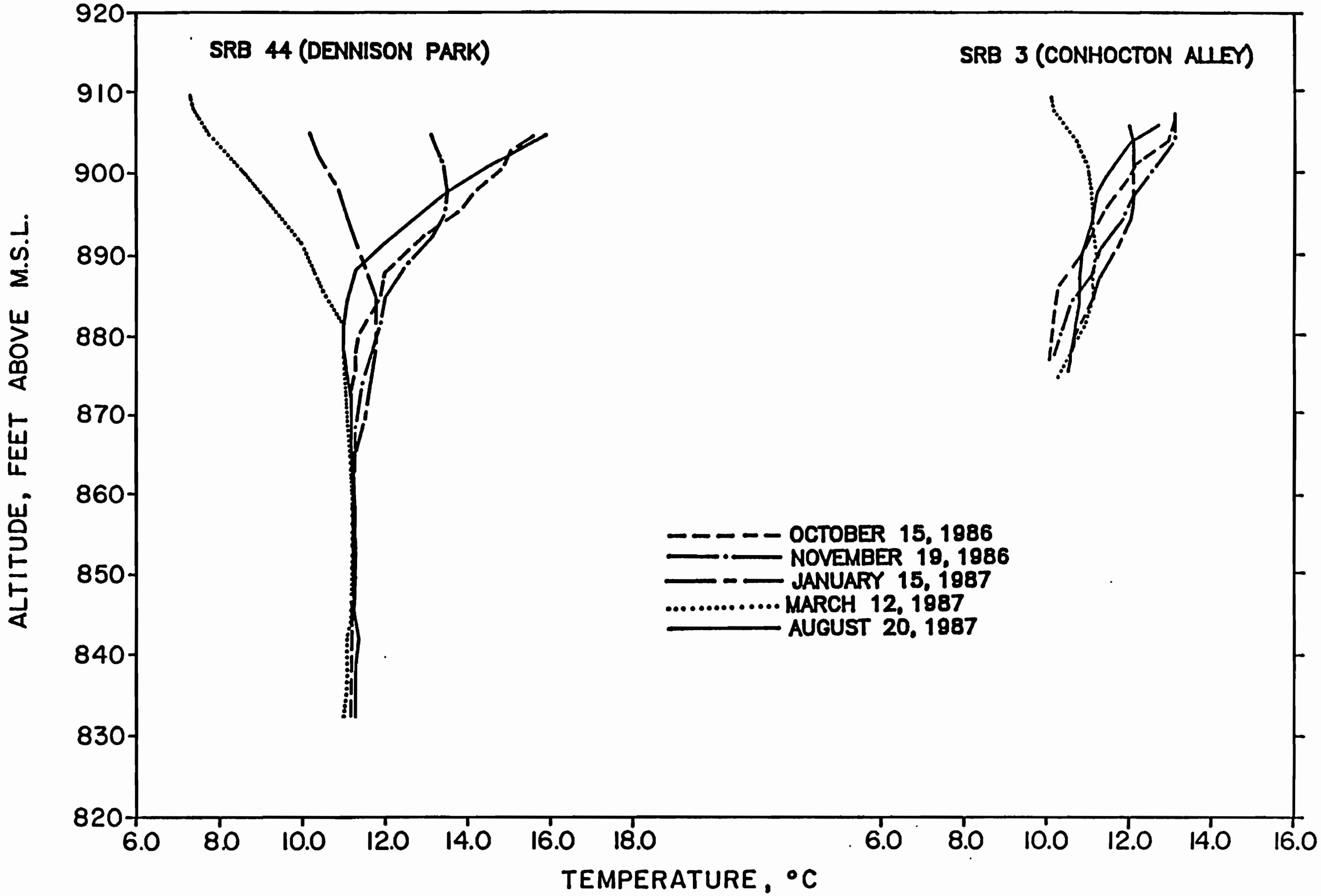


FIGURE 9. WATER-TEMPERATURE PROFILES OF WELLS SOUTH OF THE CHEMUNG RIVER IN CORNING.

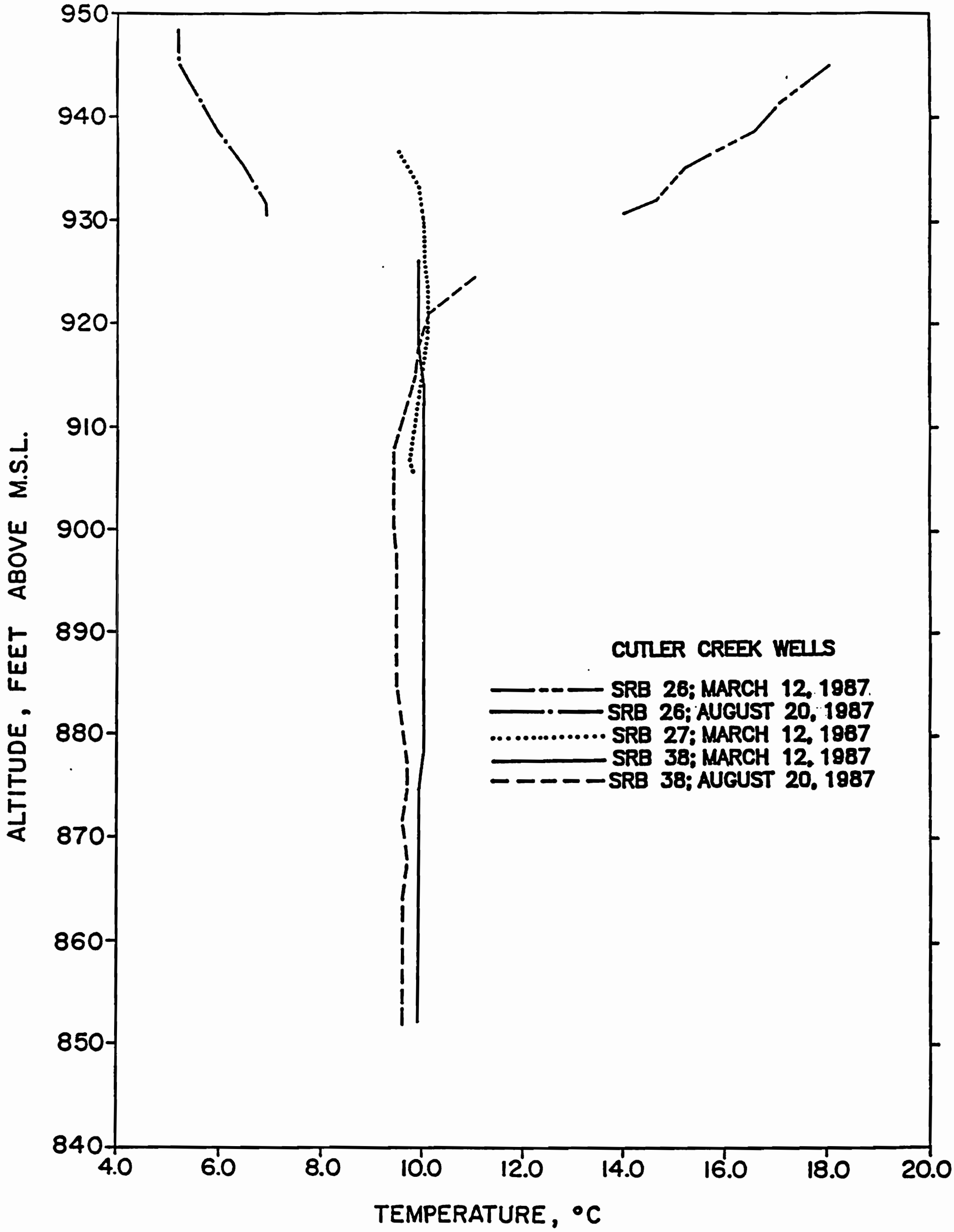


FIGURE 10. WATER–TEMPERATURE PROFILES OF WELLS NEAR CUTLER CREEK.

AQUIFER SIMULATION AND ANALYSES BY NUMERICAL MODEL

Conceptual Model

The various aspects of the geologic framework and hydrology described in preceding sections can be conceptualized as a ground-water flow system made up of two aquifers--a surficial aquifer of highly permeable outwash that is areally extensive, and a deep aquifer of siltier ice-contact sand and gravel (Figure 11). The surficial aquifer is unconfined, bounded above by the water table and below by layers of lacustrine silts that commonly separate the aquifers. The deep aquifer is artesian or confined, and generally extends from the base of the silt to bedrock. Thicknesses of both aquifer layers vary throughout the valley with the thickness of confining beds and the shape of the valley carved into bedrock. Although ground water also occurs in secondary openings in the bedrock, permeability is several orders of magnitude less than in the unconsolidated deposits.

Ground water flows from areas of recharge toward the major rivers, which have a direct hydraulic connection with the unconfined aquifer. Some recharge enters the shallow aquifer and flows within the outwash to rivers and streams. Ground water in a recharge area may also flow from the surficial aquifer to the deep aquifer and within that layer to a well, or follow a deep flow path until it reaches a discharge area and flows back into the shallow aquifer. By representing the aquifer system with two layers, each layer can have different potentials at the same location and both shallow and deep ground-water flow can occur.

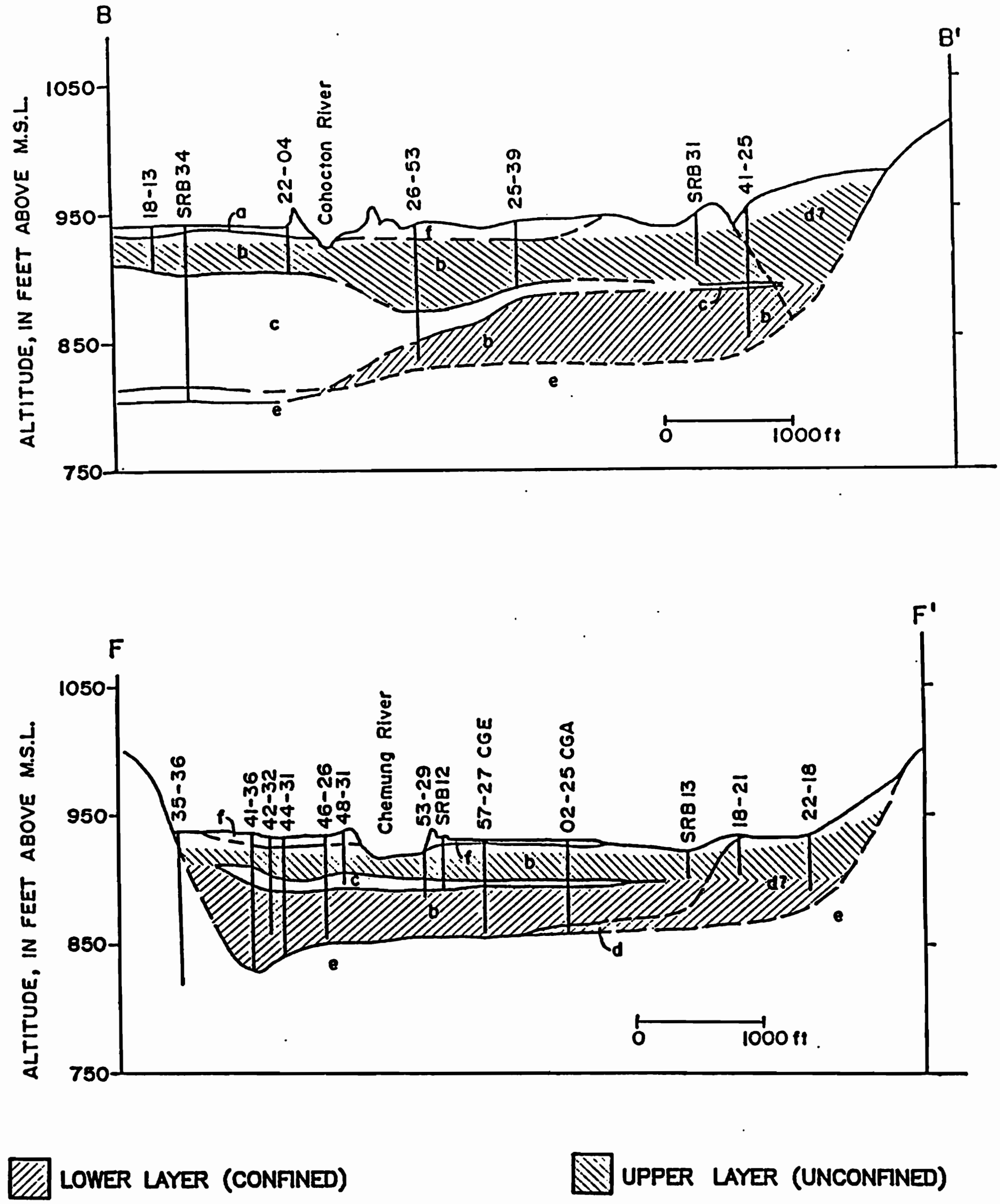


FIGURE 11. SCHEMATIC PROFILES OF THE VALLEY FILL ALONG SECTIONS B–B' AND F–F' SHOWING VERTICAL DISCRETIZATION FOR THE CONCEPTUAL MODEL.

Horizontal flow in the confining beds can be ignored because transmissivity in this layer is much lower than in either aquifer layer. However, confining beds of silt are a primary control on vertical flow in the aquifer system. Vertical flow between the two aquifers can be expected to vary areally because of variation in the distribution and thickness of lacustrine deposits.

Numerical Model

A three-dimensional finite-difference ground-water flow model documented by McDonald and Harbaugh (1984) was selected to represent the aquifer system of the conceptual model. It was used in quasi-three-dimensional mode that permitted simulation of horizontal flow in two dimensions, storage within both and upper and lower layer, and vertical flow between the two layers.

The upper model layer is treated as an unconfined or water-table aquifer. Transmissivity in this layer is proportional to saturated thickness. The lower model layer, representing ice-contact deposits, is treated as a confined or artesian aquifer. The confining beds are not directly simulated in the numerical model; there are no active nodes representing lacustrine silt and storage within these deposits is not considered. Vertical flow within the confining beds is represented as leakage between the two model layers. Other simplifying assumptions that allow the system to be simulated mathematically include:

1. Ground-water flow in the upper and lower aquifers is horizontal, and the aquifers are isotropic.
2. The aquifer system can be divided into a finite number of rectangular cells; the hydraulic properties of each cell are homogeneous. The center of each cell is termed a "node." Water levels calculated for each node represent the average water level in that cell. Aquifer properties may vary from cell to cell.
3. The vertical layers in the model were specified according to the general aquifer geometry, and include some distortion in the grid in the vertical direction. That is, the vertical dimension can vary at each cell within a layer rather than being a constant. While this departure from rectilinear cells introduces an error in calculated heads, the error is believed to be acceptably small.
4. Recharge to the aquifer is from precipitation, inflow across boundaries, and infiltration from rivers and streams. Recharge is constant during a steady-state simulation.
5. Ground water is discharged by pumping from wells, leakage to rivers and streams, and underflow out of the model area at the southeastern boundary. Evapotranspiration is accounted for in the calculation of recharge.

Model Grid

The modeled area is shown in Figure 12. As the figure indicates, the grid network consists of two layers of 27 rows and 48 columns. Only cells lying within the valley were included in model computations; there are 546 active nodes in each layer, outlined by a heavy line on Figure 12.

The grid is oriented parallel to the general trend of the Chemung River. Nodes are uniformly spaced; each cell is 500 ft long by 500 ft wide. Grid size and orientation were selected to most accurately represent the geometry of the Chemung River because of its important influence on the ground-water flow system. The present model is designed as a general purpose model to investigate how the aquifer system functions and to help formulate management alternatives. Data was collected accordingly. If the process of model calibration were to include simulation of individual cones of depression around production wells, smaller cells or variable spacing would be essential.

Boundary Conditions

For purposes of the model, the base of the stratified drift was assumed to be a no-flow boundary. Although some water probably flows up into the aquifer from underlying bedrock, the amount of inflow is probably small enough to be ignored. Lateral no-flow boundaries were placed along most of the perimeter of the active part of the model grid to coincide with till-and-bedrock along the valley sides. Along the valleys of the Tioga River, Cohocton River, and Chemung River, stratified drift continues beyond the modeled area. Specified head boundaries were used across these valleys (except at river nodes) to simulate the movement of ground water as underflow to and from parts of the aquifer beyond the model boundary.

Leakage through the specified head boundary varies at a rate proportional to the difference between head in the aquifer outside the simulated area and head at the boundary (Figure 13) and is given by the expression:

$$Q_{i,j,k,m} = C_m(HB_m - h_{i,j,k})$$

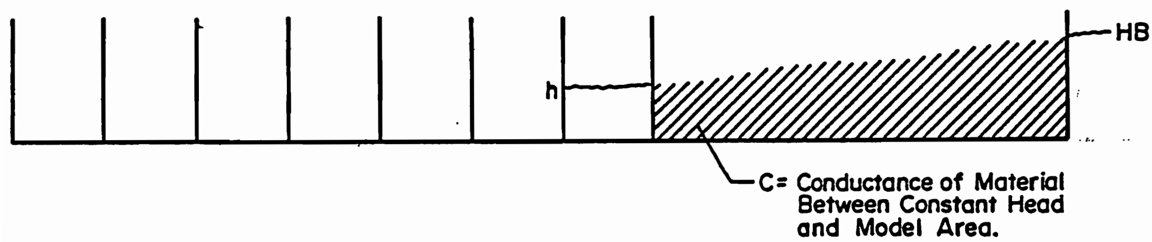
where

$Q_{i,j,k,m,}$ is the rate at which water enters or discharges to the cell from boundary m (L^3t^{-1});

C_m is the hydraulic conductance of the material between the known head and the boundary of the simulated area (L^2t^{-1});

HB_m is the head at the boundary m (L); and

$h_{i,j,k}$ is the head in the cell (L) (p.343, McDonald and Harbaugh, 1984).



$$Q = C(HB - h)$$

FIGURE 13. HORIZONTAL LEAKAGE SIMULATED USING A SPECIFIED HEAD BOUNDARY (AFTER McDONALD AND HARBAUGH, 1984, p344).

The conductance term, C_m, for each cell along the boundary is given by:

$$C_m = \frac{KA}{L}$$

where

K is the hydraulic conductivity of the cell (Lt^{-1});

A is the cross-sectional flow area (L^2); and

L is the length of the flow path (L).

Head along the specified head boundary was extrapolated from the hydraulic gradient near the boundary. Hydraulic conductivity at the boundary was estimated from well logs and drilling data and was adjusted during calibration. Change in storage in the aquifer material between the boundary head and the simulated area is not accounted for in the boundary specification.

Boundaries were selected to best represent the rate at which water is believed to enter or leave the active part of the model grid. Nevertheless, because the boundaries do not exactly represent the system, model-determined ground-water levels and/or flow directions may not be reliable near the edges of the model area. The modeled area is large enough so that errors in boundary conditions should have little effect on heads in the area of interest in the interior portion of the grid.

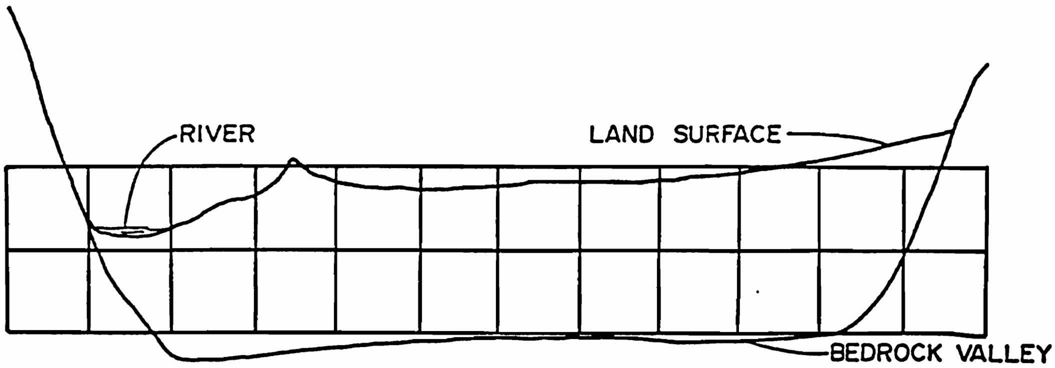
Recharge

Sources of ground-water recharge have been described previously. In 1986, recharge from precipitation directly on the aquifer was estimated to be 13 inches. This represents 36 percent of the estimated precipitation. The likely range of recharge varies from a low of about 7 inches, the base runoff at the Corning gage during 1986, to a high of about 14.4 inches, the quantity of recharge expected if all precipitation not lost to evapotranspiration infiltrated to the water table. Thirteen inches per year converts to a rate of 0.00297 ft/d used for model input during steady-state calibration.

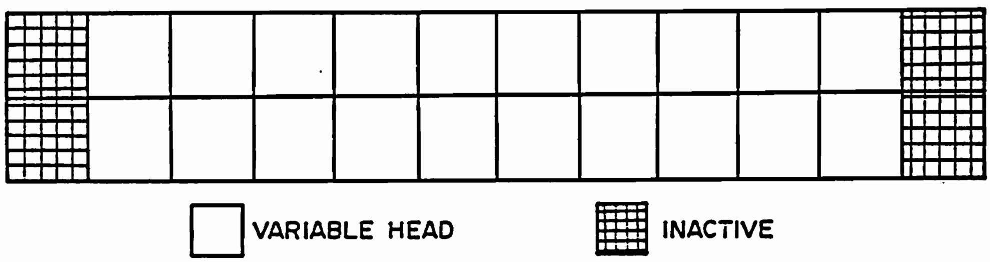
Recharge from upland hillsides was accounted for in the model after a method developed by Randall (1986) in his modeling study of the Susquehanna River Valley in southwestern Broome County, New York. Till-covered hillsides that slope toward stratified drift aquifers in valleys are presumed to contribute storm runoff, in proportion to precipitation, to the valley aquifers by flow across land surface or through openings in the upper foot or so of soil. To incorporate this additional recharge, drainage divides were drawn up the hillside from the corners of each active model block along the perimeter. The area between these mini-divides was compared by inspection to the area of a block. Additional recharge was added to the active block to reflect the area of slope draining to that block. Runoff from hillsides was ignored as a source of recharge where the Tioga River, Post Creek, or the Chemung River flows next to hillside with no intervening aquifer, and where runoff drains towards Post or Cutler Creek and contributes directly to streamflow.

Recharge from tributary streams occurs as loss of water by seepage where they cross the surficial aquifer. This was simulated by variable fluxes in cells along the course of the streams and is discussed under "Rivers and Streams."

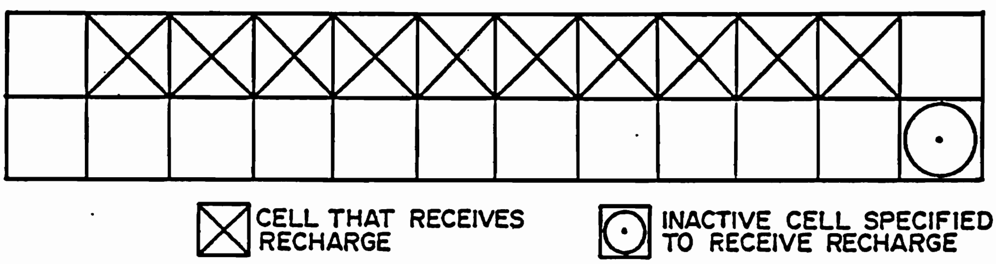
Recharge directly from precipitation on the aquifer, runoff from adjacent hillsides, and seepage from tributary streams affects active cells in the upper model layer. Initially, the model was unstable at some areas of the northern margin, where stratified drift is poorly permeable and thin. The base of the upper layer in these areas is higher than the water table in nearby locations. Some cells in the upper layer along the perimeter would go dry when the simulated water level fell below the base of the upper layer during early iterations. To overcome this problem and so that cells would remain active until the model converged to a solution, hydraulic conductivity of the sediments was adjusted, vertical conductance lowered, and recharge was distributed between the upper and lower layers. The upper layer received recharge from precipitation and most of the runoff from hillsides; that part of the runoff from hillsides believed to represent recharge from bedrock of the valley walls (about 7 inches per year) was diverted to the lower layer. This amount of recharge is roughly equivalent to that calculated for a bedrock basin and is applied uniformly throughout the year. Since the model code permits recharge in only one cell for each horizontal cell location, recharge was added to specified inactive cells in the lower layer (Figure 14) using Option 2 of McDonald and Harbaugh (p. 241, 242, 1984).



CROSS SECTION SHOWING STRATIFIED DRIFT PARTLY FILLING A BEDROCK VALLEY WITH FINITE DIFFERENCE GRID SUPERIMPOSED.



STATUS OF CELLS AT END OF SIMULATION.



CELLS THAT RECEIVE RECHARGE UNDER OPTION 2.

FIGURE 14. SCHEMATIC SHOWING CELLS THAT RECEIVE RECHARGE UNDER OPTION 2 IN THE RECHARGE PACKAGE.

Rivers and Streams

Rivers and streams may contribute water to the aquifer or drain water from the aquifer depending on the head gradient between the river and the aquifer. In Figure 15A, the river is gaining. The head in the aquifer beneath the river is above the river stage and upward leakage across the riverbed thickness takes place. Figure 16 shows how this situation is simplified in the model. In Figure 15B the head in the aquifer beneath the river is lower than the river stage. This situation occurs in naturally losing reaches of a river or in areas where nearby pumping produces a downward hydraulic gradient across the riverbed.

Rivers and streams were modeled using the river package described by McDonald and Harbaugh (1984, p. 209-240). To simulate the effect of leakage through the riverbed, the river is divided into reaches each of which is completely contained in a single cell. River/aquifer leakage is defined between each river reach and the model cell that contains the reach. In calculating river leakage, the model uses the head difference between the aquifer and the river as long as the porous material adjacent to the riverbed is fully saturated. However, if the head in the aquifer is below the riverbed and the material adjacent to the riverbed is not saturated, the model will calculate leakage across the riverbed to the aquifer using the head difference between the river stage and riverbed base. This is a reasonable approximation of the river-aquifer relationship if the vertical

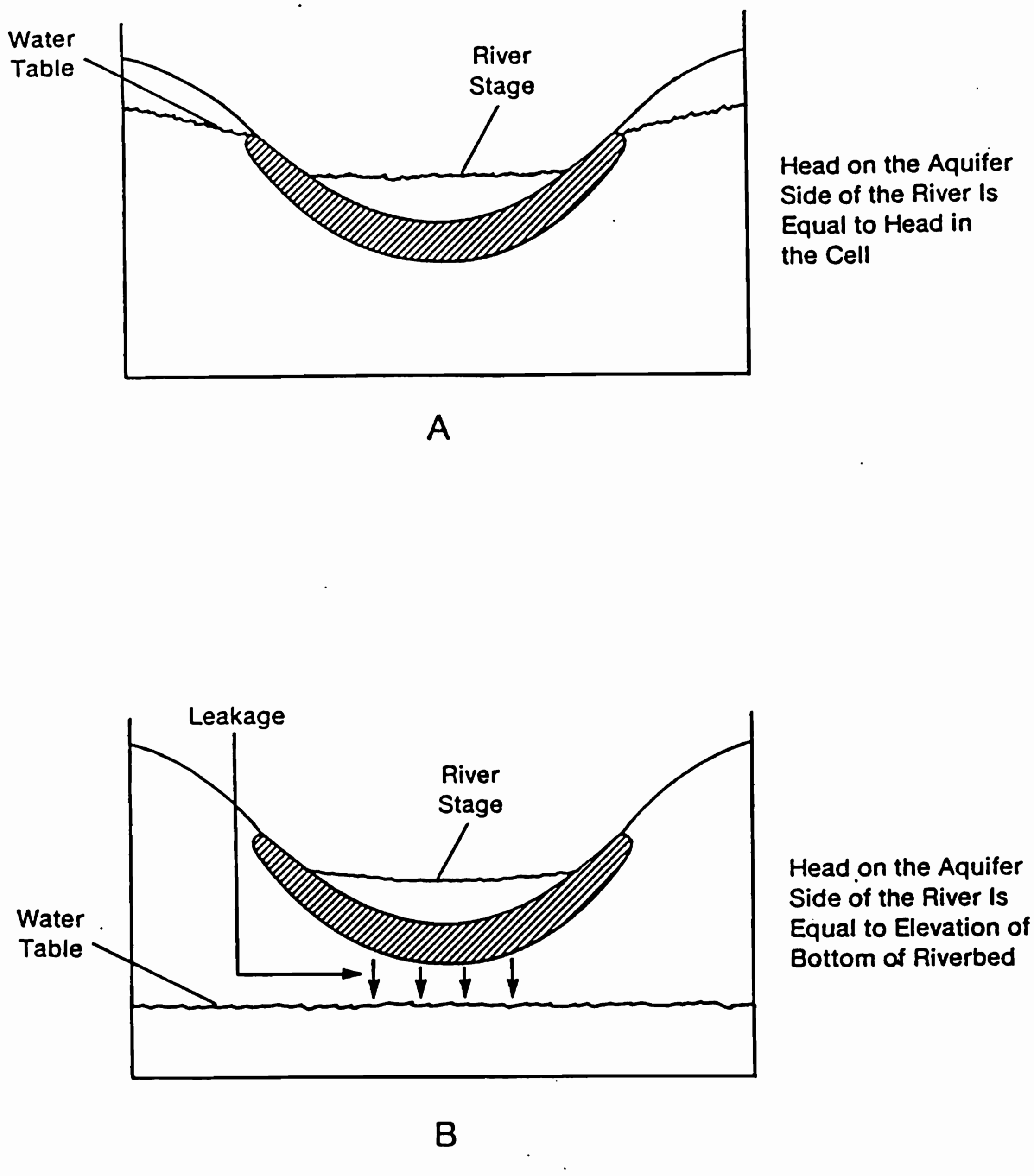


FIGURE 15. CROSS SECTION SHOWING THE RELATION BETWEEN HEAD ON THE AQUIFER SIDE OF THE RIVERBED AND HEAD IN THE CELL. HEAD IN THE CELL IS EQUAL TO THE WATER-TABLE ELEVATION. (FROM McDONALD AND HARBAUGH, 1984)

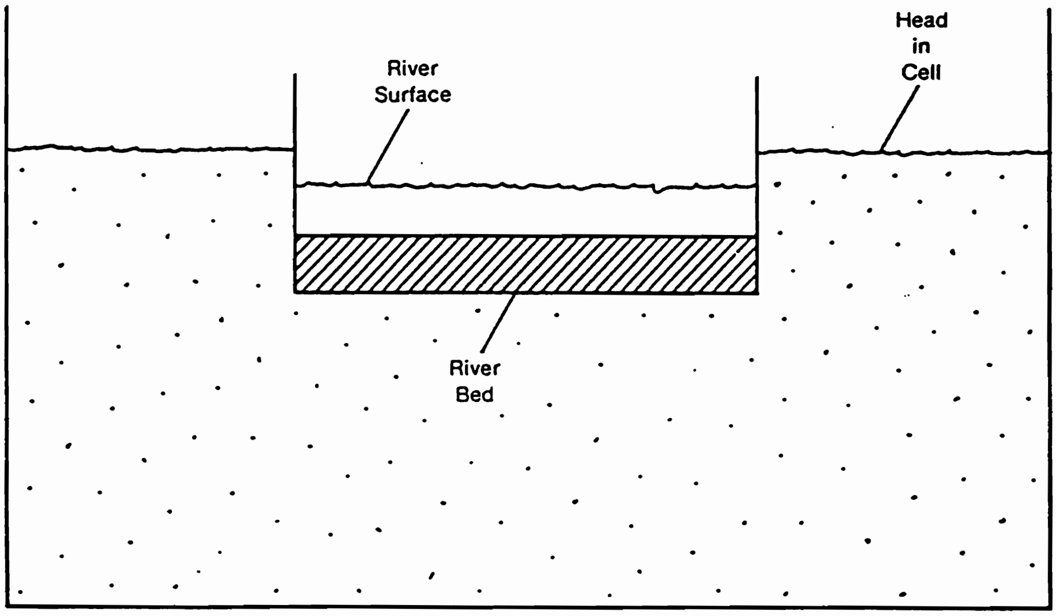


FIGURE 16. BLOCK DIAGRAM OF A CROSS SECTION OF AN AQUIFER CONTAINING A RIVER (FROM McDONALD AND HARBAUGH, 1984).

hydraulic conductivity of the riverbed is smaller than the vertical hydraulic conductivity of the underlying outwash aquifer, and the riverbed is the principal factor controlling leakage.

A modification of the river package that not only computes leakage to or from the streams to the aquifer system but also routes flow through one or more streams, channels, or ditches has been developed and is undergoing testing within the U.S. Geological Survey (D.E. Prudic, 1986, "Stream package": Carson City, NV, U.S. Geological Survey, written communication). This new package allows streams to go dry (and leakage to cease) during a given period of a simulation and will provide for a more sophisticated representation of Post and Cutler Creeks.

Model input for the river package consists of one record for each river reach that specifies the cell containing the reach and the parameters needed to calculate seepage--river stage, riverbed conductance, and riverbed bottom. Input parameters used in seepage calculations were estimated by methods described below.

Stage. River reaches were assigned stages corresponding to the average river stage for the time period simulated. Altitude of the river surface at six sites along the Chemung River, two on the Cohocton River and one on the Tioga River was determined on one or more dates in 1983-1985 by measuring from reference points on bridges or exposed well casing. These measurements were used to construct a water surface profile of altitude at each site versus river length. Because these profiles also included the stage at the U.S. Geological Survey gaging station on the Chemung River at Corning, river altitude could be estimated at each site for any date of interest. (Because field measurements were made on average to low flows, estimates for high flows probably would not be reliable.) For cells between these sites along the Chemung, Cohocton and Tioga Rivers, river altitude was estimated by interpolation.

Average stages for stream reaches of Post and Cutler Creeks were estimated from topographic maps and from observations made at staff gages installed at five locations along each creek. Data were collected weekly during summer and fall, 1986; and, with the exception of several incidents of storm runoff, most depict average to low streamflows.

Conductance. Conductance of a reach of the riverbed (or streambed) is approximated using Darcy's Law as:

$$CRIV = KLW/M$$

where:

CRIV is the conductance of the reach of the riverbed, (L^2t^{-1});

K is the hydraulic conductivity of the riverbed (Lt^{-1});

L is the length of the reach (L);

W is the width of the reach (L);

M is the thickness of the riverbed (L).

For river reaches, average dimensions of the river were assumed to be represented on 7 1/2-minute quadrangle maps. An enlargement (1:1000 scale) was used to estimate length and width for each river reach. For Post and Cutler Creeks, total stream length was taped during streambed surveys and later subdivided into reaches. Average stream width was estimated from measurements made during seepage runs. A value of 0.55 ft/d was used for the vertical hydraulic conductivity of the riverbed for the Chemung, Tioga, and Cohocton Rivers. This is an initial estimate, based on the results of the slug tests described in the section describing the river-aquifer relationship. These tests provide estimates of the horizontal hydraulic conductivity, which were assumed to be higher than the vertical hydraulic conductivity. Thus, the lowest value estimated from these tests was used. A vertical hydraulic conductivity of 42.6 ft/d was used for most reaches along Post and Cutler Creeks. This value represents a conservative average value for silty gravel alluvium in the Susquehanna River basin (Randall, 1978). Conductivity values were reduced appropriately where Cutler Creek flows in concrete-lined channels. River and streambed thicknesses were assumed to be a uniform 1.0 ft in initial model runs to simplify computation.

Conductance was adjusted during calibration. For rivers and streams, the model assumes that there is always enough water in a river to supply the aquifer. Leakage rates of major rivers were compared with river discharge rates to assure that the flow rate was greater than the leakage rate. For smaller streams, leakage calculated by the model was compared with the results of seepage runs. In general, cell by cell adjustments were not made. Initial estimates were reduced for some reaches of the Chemung by a factor of 6.25, for the Tioga by a factor of 3, for Post Creek by a factor of 35, and for Cutler Creek by a factor of 10. Original estimates of conductance were retained for all reaches of the Cohocton River and for the Chemung River downstream from the gage location. Much of the reduction in conductance for the major rivers can be accounted for by refining estimates of riverbed thickness: about 5 ft for the Chemung, 3 ft for the Tioga, 1 ft for the Cohocton. Further adjustments in conductance probably reflect inaccurate estimates of a combination of factors: uniform values of hydraulic conductivity may be inappropriate, river dimensions represented on maps may have been too large, and riverbed thickness, which varies along a channel, may be too small in some reaches. Larger reductions of conductance for Post and Cutler Creeks are most likely related to overestimating the vertical conductivity of streambed sediments. In addition, most of the reaches of Post Creek downstream of staff gage #3 have been rechannelized and affected by nearby road construction activities.

Riverbed Bottom. Riverbed bottom, or the depth at which the aquifer becomes hydraulically detached from the river or stream, was estimated from the field data. Below this cutoff elevation, the rate of flow from river to aquifer will not increase due to decreasing head in the aquifer.

Ground-Water Withdrawals

Wells were simulated for each grid block containing significant ground-water withdrawals; that is, pumpage from wells that is not returned to the ground-water system. Pumping was simulated in 15 cells (Table 5). Pumping rates were based on information provided by well owners. Records of pumpage were available for municipal wells, however, most large industrial wells are unmetered and production was estimated from typical hours of operation and presumed withdrawal rates. The largest withdrawals occur at Ingersoll-Rand, Corning Glass facilities and at Corning City wells #2, #8, and #9.

Aquifer Properties

The hydraulic properties that determine the capacity of an aquifer to transmit, store, and yield water must be characterized for each active cell and input into the model. In the upper model layer, these properties are hydraulic conductivity and saturated thickness, which are calculated in the model from the elevation of the aquifer bottom and initial estimates of the water-table elevation. Specific yield must be entered for each cell for transient simulation. In the lower layer, transmissivity, an initial estimate of head, and coefficient of storage (for transient simulations only) are required for model input. Horizontal water-transmitting capacity was assumed equal along both horizontal axes; that is, each cell was assumed to be isotropic. Vertical water-transmitting capacity between the layers was estimated and entered into the model where the upper layer is underlain an active cell of layer 2.

TABLE 5. Ground-Water Withdrawals Used in Average Annual Steady-State Simulations. Stress rate is in ft^3/d.

Layer	Row	Column	Stress Rate	Well No.	Well Owners
2	6	7	53994.	1	Painted Post Village
2	6	8	30371.	2	Painted Post Village
1	9	3	79418.	3	Corning Glass-Sullivan Park
1	11	10	80220.	4	Ingersoll-Rand
1	11	11	80220.	5	Ingersoll-Rand
2	15	30	30082.	6	Corning Glass (Powerhouse)
2	12	29	99846.	7	Corning Glass
2	12	30	67384.	8	Corning Glass
2	12	31	67385.	9	Corning Glass
2	13	21	126880.	10	Corning City
2	13	28	67652.	11	Corning City
2	13	33	150410.	12	Corning City
2	15	26	145870.	13	Corning City
2	15	38	173810.	14	Corning Glass
2	16	37	100270.	15	Corning Glass

Hydraulic Conductivity

Hydraulic conductivity of the upper model layer[3] and transmissivity of the lower model layer were estimated using several methods. SRBC staff conducted aquifer tests of 24 hours or more on six wells; values of transmissivity were calculated from these tests. In addition, previously published estimates of transmissivity (principally derived from specific capacity data) were available for 37 large-capacity municipal or industrial wells (Ballaron, 1985; Reisenauer, 1977; Ground-Water Associates, 1984). These data are shown in Table 6. A third source of transmissivity data was from an analysis of geologic logs of about 105 wells and test borings (Randall, 1972). At each test hole or well site, values of hydraulic conductivity were assigned to each saturated unit described in the log by use of the relationship between grain-size parameters of stratified drift and hydraulic conductivity in the horizontal direction (Randall, 1977, p. 40). Transmissivity was computed by multiplying the thickness of each unit by its hydraulic conductivity and summing the products. Values of transmissivity estimated by this third method are much less accurate than values obtained from pumping tests or estimated from specific capacity.

Individual values of transmissivity (for the lower layer) or hydraulic conductivity (for the upper layer) were plotted, and

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[3] Hydraulic conductivity was calculated at each well location by dividing the estimated transmissivity by the median saturated thickness of sand and gravel.

TABLE 6. Transmissivity Values for the Corning and Nearby Areas

Well Number (Lat-Long)	Owner	Specific Capacity Yield (gal/min) Drawdown (ft)	Estimated Transmissivity[1] (gal/d/ft)	Transmissivity from Pumping Test (gal/d/ft)
420825-770209	USGS	16/1	32,000	
420831-770213	USGS	16/1	32,000	
420827-770217	Corning City #4	744/2	745,000	
		744/2.5	429,000*	
		872/2	628,000*	
420818-770222	Corning City #5	720/9	160,000	
		728/6.3	166,000*	
		743/7	153,000*	
		720/9	115,000*	
420823-770222	Corning City #6	708/8	180,000	
		708/8	127,000*	
		703/7	145,000*	
420836-770243	Corning Glass #2	1012/5	405,000	
420851-770244	Corning School Board	120/3.1		100,000[2]
420828-770252	Corning Hospital	515/3	340,000	290,000
		517/3	247,000*	
420827-770253	Corning Hospital	520/4	260,000	230,000
420847-770305	Corning City #9	1865/1.4	1,918,000*	
420856-770307	SRB 41 Centerway	250/10.7	28,000[2]	
420857-770327	Corning Glass Bldg. D	584/4	292,000	
		554/3.5	228,000*	
420844-770331	Corning Glass #6	770/5	300,000	
		1012/5	291,000*	
420847-770305	Corning City #7	708/8	127,000*	
		703/6	169,000*	
420857-770321	Corning Glass Bldg. B	608/29.4	30,000*	
420858-770314	Corning Glass Museum	1100/10.3	153,000*	
420856-770336	Corning City #3	955/11	173,000	
		1000/7	206,000*	
		744/4.5	238,000*	
		955/11.2	123,000*	
420841-770339	Air Reduction Co.	220/2	220,000	
420848-770349	Corning City #8	1893/10.6	257,000*	
420847-770353	Corning City #8R	331/11		215,000[3]
420837-770716	Erwin	503/3	335,000	

[1] Estimated Transmissivity from Reisenauer, 1977; except for values noted (*), which are from Ground Water Associates, 1984.

[2] SRBC pumping test.

[3] Pumping test performed by Hydro Group, Inc.

[4] Pumping test performed by Stearns & Wheler.

TABLE 6. (Continued)

Well Number (Lat-Long)	Owner	Specific Capacity Yield (gal/min) Drawdown (ft)	Estimated Transmissivity[1] (gal/d/ft)	Transmissivity from Pumping Test (gal/d/ft)
420828-770746	Erwin	70/18	7,800	
420902-770325	Corning Glass	578/7	165,000	
420908-770338	SRB 40 Old Firestation	87/28.3	6,000[2]	
420941-770320	SRB 42 RR Yards	45/16.3	5,000[2]	
420901-770421	Corning City #2	960/26	74,000	
		708/5	204,000*	
		960/26	53,000*	
420901-770426	Corning City #1	1000/22	90,000	
		1000/22	65,000*	
420916-770401	SRB 39 Northside Sch.	193/20.5		31,000[2]
420926-770444	SRB 38 Cutler Cr.	236/15		24,300[2]
420944-770525	Painted Post Vil.	850/20	85,000	
420919-770527	Ingersoll-Rand	1016/6	340,000	
420920-770530	Ingersoll-Rand	1200/6	400,000	
420922-770536	Ingersoll-Rand	1005/4	500,000	
420925-770539	Ingersoll-Rand	1520/13	235,000	
420950-770539	Painted Post Vil.	726/14	103,000	
420941-770545	Ingersoll-Rand	191/1	380,000	
420909-770559	Erwin	85/2	85,000	100,000
420951-770550	Painted Post #4			212,300[4]
420922-770604	Lodge on the Green	457/3	300,000	
420918-770613	Lodge on the Green	292/8	75,000	
420936-770615	Corning Glass	300/1	600,000	
420939-770618	Corning Glass	350/9	78,000	
420939-770600	SRB 36 Hodgman's Pk.	218/65		59,800[2]
420904-770702	Morningside Hts.	130/8	32,500	

then contoured to reflect areal patterns of the plotted data, variations in thickness of the aquifer (lower layer), and geologic interpretations of the stratified drift. Base values of hydraulic conductivity and transmissivity were adjusted during calibration. In the upper model layer, final values for hydraulic conductivity ranged from 800 ft/d for permeable stratified drift to 1 ft/d for fine-grained surficial materials. In the lower layer, transmissivity in the aquifer tapped by production wells varies from about 42,300 ft^2/d to 27,000 ft^2/d. Low values of transmissivity were used at the margins of the valley.

Vertical Conductance

Vertical flow was simulated as leakage between the two aquifer layers, described by McDonald and Harbaugh (1984, p. 138-147). Movement of ground water between vertically adjacent nodes was calculated from:

$$Q_v = C_v \Delta h$$

where

Q_v is the vertical flow (L^3t^{-1}),

Δh is the difference in head between nodes in the upper and lower cells (L), and

C_v is the conductance (L^2t^{-1}).

Conductance is defined as:

$$C_v = \frac{K_v A}{L_v}$$

where

K_v is the average or effective hydraulic conductivity between vertically adjacent nodes (Lt^{-1}),

A is the area of the cell (L^2), and

L_v is the distance between nodes of vertically adjacent cells (L).

Rather than specifying both vertical hydraulic conductivity and vertical grid spacing terms for each cell, a single term "Vcont" represents the effective vertical hydraulic conductivity divided by the vertical grid spacing:

$$\text{Vcont} = \frac{K_v}{L_v}$$

The model code requires that Vcont between nodes be entered as input data rather than calculating it in the program.

Values for Vcont were based on typical vertical hydraulic conductivity values from the literature and were adjusted during calibration. Several methods were used to calculate Vcont, depending on the way the aquifer system was discretized vertically. In areas where the vertical section is uninterrupted sandy gravel broken into two layers, the value of vertical hydraulic conductivity was assumed to be the same in each layer so the value between the nodes is that same constant. However, the distance between the nodes of the vertically adjacent cells (L) may vary at each cell to account for vertical distortion of the model grid, so Vcont may vary between cells with similar geology. Vcont values for these cells are large, leakage between layers is pronounced, and modeled heads will be equal or nearly so in the upper and lower layers.

Where the two aquifer layers are separated by a thick confining bed of silt and clay, a low value for the vertical hydraulic conductivity of the silt and clay dominates the calculation of conductance. Vcont was approximated by the estimated vertical hydraulic conductivity of the confining bed, divided by its thickness. Values of Vcont in these areas are low and there is little or no leakage between the two layers.

In some areas modeled, the confining bed is thin or discontinuous. Values of vertical hydraulic conductivity in the silty and sandy gravels of the upper and lower layers are probably not the same. Presumably Vcont is intermediate between either of the situations discussed previously. The equivalent or average conductance was calculated from the conductance of each layer in series, according to equations provided in the model documentation.

Coefficient of Storage and Specific Yield

The coefficient of storage of an aquifer represents the volume of water released from or taken into storage, per unit of aquifer storage area per unit change in head (Driscoll, 1986). The coefficient of storage is dimensionless. In unconfined aquifers, the storage coefficient is equivalent to the specific yield, or the quantity of water that can be drained by gravity from a unit volume of aquifer. In confined aquifers, the storage coefficient is the result of compression of the aquifer and expansion of the confined water when head is reduced during pumping. The coefficient of storage and specific yield are included in the analysis of hydrologic problems where water level changes with time are of interest (transient analysis). During steady-state conditions, the storage coefficient and specific yield are not considered.

Values for coefficients of storage from aquifer test analyses in the Corning area are listed in Table 7. Although only limited data are available, they compare favorably with typical values of storage coefficient and specific yield found in other glacial aquifers (Table 8). A storage coefficient of 10^{-3} (intermediate to the range of values reported for Corning) was specified for the confined aquifers represented by layer 2. Layer 1 is generally unconfined, and a specific yield of 0.22 was assigned to all cells in this layer.

Model Calibration

Before any model can be used to predict the effects of imposed stresses it must be capable of simulating observed conditions to an acceptable degree. Calibration means that, given a certain combination of input parameters and boundary conditions, the model will compute heads that approximately match

TABLE 7. Coefficients of Storage for Wells in the Corning Area

Well Number (Lat.-Long.)	Owner	Coefficient of Storage
420847-770353	Corning City #8R	0.22
420916-770401	SRB39 Northside School	0.015
420926-770444	SRB38 Cutler Creek	4.21×10^{-4}
420951-770550	Painted Post #4	6.24×10^{-4}
420939-770600	SRB36 Hodgman's Pk	9.27×10^{-4}

TABLE 8. Coefficients of Storage for Glacial Aquifers Reported in the Literature

Geologic Unit	Coefficient of Storage	Source
Confined sand and gravel	10^{-4} to 10^{-2}	Lyford and others, 1984
Unconfined sand and gravel	0.05 to 0.35	
Confined sand and gravel	10^{-3}	Yeager, 1986
Unconfined sand and gravel	0.25	
Unconfined sand and gravel (valley train deposits)	0.11 to 0.13	Werkheiser, 1987

field-measured values. The model was calibrated to both steady-state conditions and transient conditions. The steady-state calibration procedure consisted of a series of simulations, each of which treated average water levels, recharge and discharge rates as constant and permanent. Steady-state simulations permit adjustments to be made in the arrays of data for various hydrologic parameters without the complications of simulating aquifer storage, changing pumping rates, and fluctuating river stage at the same time. In this study, the magnitude and distribution of hydraulic conductivity values in both layers, vertical hydraulic conductance between these layers and stream leakage coefficients (and to a minor degree, the altitude of the base of layer 1) were adjusted by trial and error within certain ranges defined by field data to produce a consistent and reasonable representation of the ground-water flow system.

The transient calibration is used to test values of storage coefficient and specific yield. Ground-water levels fluctuate in response to numerous stresses, including variations in recharge, fluctuating river stages, and changing pumping rates. If a change in ground-water level is observed, and the cause of the water level changes is known or can be estimated, then values for storage can be tested in a series of transient simulations.

Steady-State Calibration

The model was calibrated under average conditions measured in calendar year 1986. Hydrologic conditions (precipitation and streamflow) during 1986 were fairly close to the long-term average. Additionally, there was little or no net gain or loss of ground water from aquifer storage as indicated by the similarity of water level readings for January, 1986 and January, 1987. Although annual precipitation data were not available from the Weather Service for 1986 due to the relocation of the Corning station mid-year, some data were obtained from Steuben County Emergency Management Office (Sala Halm, personal communication). A county-wide network of observers measures daily precipitation for this agency, primarily to provide an early warning system for floods. Averages of these data from observers in or near the study area indicated 36 inches of precipitation fell in Corning in 1986, only slightly more than the long-term average.

Calibration to average annual conditions was principally performed to maximize the accuracy of recharge estimates. Annual recharge estimated from baseflow data was believed to be more reliable than weekly or monthly estimates based on precipitation data and calculations of potential evaporation. On the other hand, pumpage and river stage varied throughout the year and selecting constant values for model input is difficult. Selection of values for these inputs would have been more straight-forward if calibration were to a period of short-term equilibrium. A river stage of 916.10 ft at the Corning gage, that equates to a discharge of 1996 ft^3/s in 1986[4], was used as

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[4] Values for 1986 are provisional data from the U.S. Geological Survey and may be subject to change.

the basis for model input for river reaches. This compares favorably with the long-term average discharge of 2192 ft^3/s (average of 11 years). Stream stage was taken from topographic maps which are assumed to portray average conditions. Ground-water withdrawals were estimated to varying degrees of accuracy. Since water is metered at municipal wells, annual pumpage was totaled for each well and converted into the equivalent daily withdrawal rate. At the Corning Glass' Sullivan Park complex, hours of pump operation are recorded and reasonable estimates of pumpage can be made for any time period. Water use estimates provided by Ingersoll-Rand and Corning Glass for their unmetered wells were assumed to be valid year-round--when in fact, actual withdrawals likely vary with plant operation. However, selection of any other time period of calibration would not improve estimates of pumpage from these wells. Corning Glass has several wells used for air conditioning; these cycle on and off during the cooling season and are off for several months a year. To estimate a constant pumping rate for steady-state model input, periods of no pumping were factored into the calculation.

Monthly water levels measured in 46 wells were averaged for comparison with model output. These average water levels were used to construct a map of estimated water levels for layer 1. Fewer wells were available to determine the potentiometric surface of the lower aquifer. The few localities where pairs of shallow and deep wells were in close proximity were particularly important to model calibration.

The ground-water flow model was considered to be calibrated under average steady-state conditions when simulated heads matched corresponding observed heads to a reasonable degree. The goodness of the match between simulated and observed heads was judged by two methods. Simulated and estimated head gradients were compared along selected columns (Figure 17) and on water-level contour maps drawn from simulated and averaged heads.

Differences between simulated and estimated heads were considered acceptable if they were within 5 ft of each other. In the Chemung River valley, most departures are about 1 ft or less. Near the valley walls, where data are sparse and gradients are steep, larger discrepancies were considered acceptable. Simulated heads differ from observed heads by as much as 7 ft in these areas. Observed and simulated water levels did not correspond within acceptable limits in the deep aquifer underlying the City of Corning, north of the Chemung River. However, most wells measured in this area are production wells and pumping wells do not reflect the average water level for an entire cell in the model. Water levels measured in SRB 41 and SRB 8, two observation wells in which there was no pumping, differ from simulated water levels by only 0.6 ft and 0.1 ft, respectively. Therefore, further adjustments in transmissivity were not made. Calibration is improved if ground-water withdrawals simulated in Corning are increased by 20 percent in unmetered production wells, suggesting pumping may be

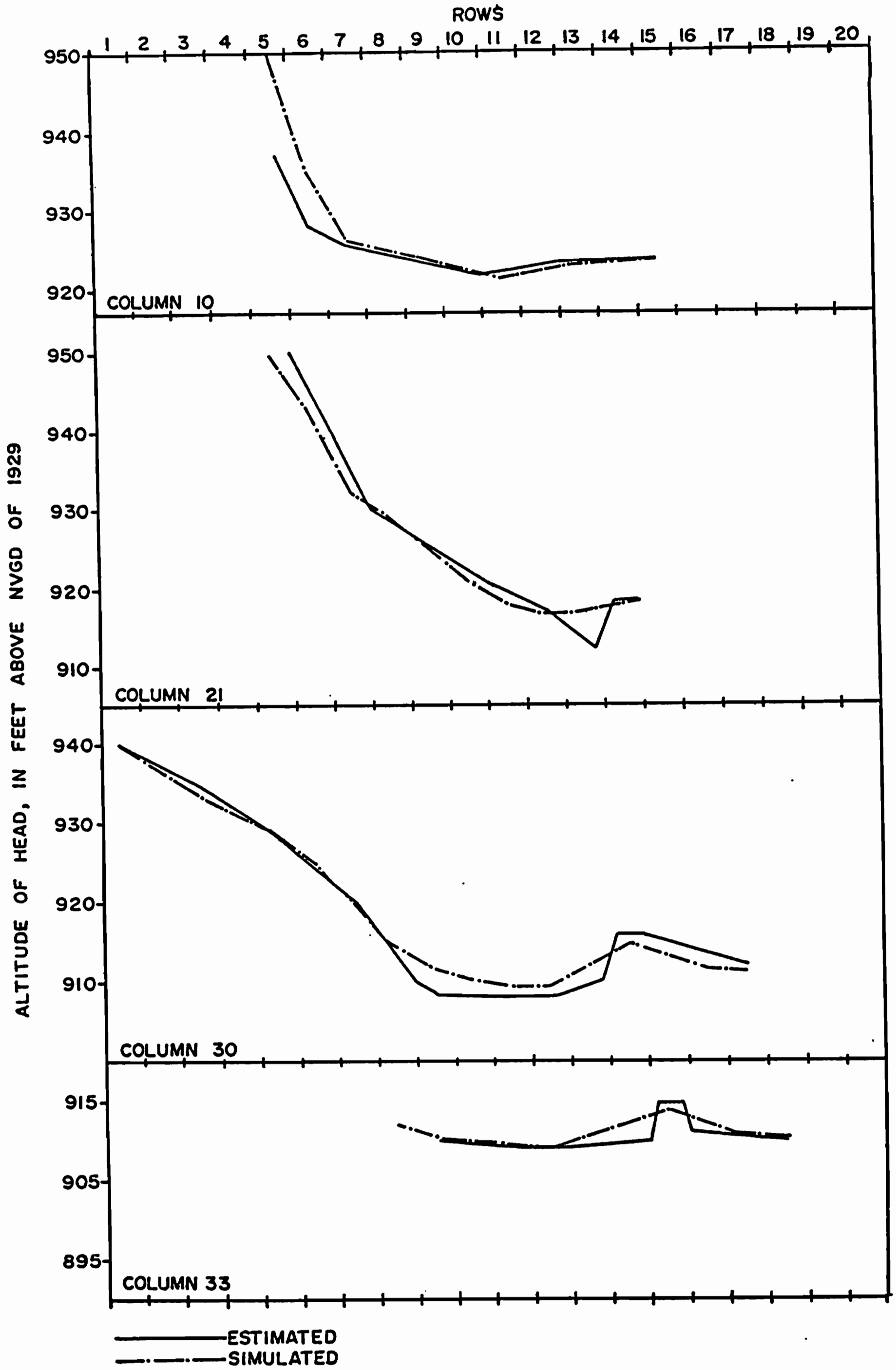


FIGURE 17. COMPARISON OF ESTIMATED AND SIMULATED HEADS ALONG SELECTED GRID COLUMNS FOR AVERAGE STEADY-STATE CONDITIONS.

underestimated. Even without this change, the match between simulated and observed heads for the calibrated steady-state model was judged to be acceptable based on the objectives of the modeling effort.

Table 9 shows a comparison of water-level altitudes for wells in the monitoring network with simulated heads of corresponding cells in the calibrated model. A comparison of this type can assist in interpreting modeling results but is not intended as an absolute measure of model performance. Observation wells are rarely located at the node of a grid block and only partially penetrate an aquifer so measured water levels are inherently different from the average water-levels simulated. The largest discrepancy between an observation well where no pumping occurred and a model cell, about 11 ft, is in a well near Cutler Creek (SRB 27). Overall, 81 percent of the simulated levels are within 5 ft of the observed head, and 92 percent are within 10 ft.

A water-level contour map drawn from model-generated head data representing average, steady-state conditions in the upper layer is shown in Figure 21. Final values for horizontal hydraulic conductivity and transmissivity of the drift are presented in Figures 18 and 19. Values of Vcont are presented in Figure 20. Calibrated hydraulic conductivity of the streambed is 1.2 ft/d for Post Creek, 4.26 ft/d for Cutler Creek, and 0.088 and 0.55 ft/d for the Chemung River, assuming riverbed thickness of one foot.

TABLE 9. Comparison of Measured and Simulated Steady-State Water Levels in the Corning Area, Steuben County, New York

Well Owner and Number or Name	Model Layer[a]	Model cell[b] (row, column)	Water-Level Altitude Calendar Year 1986 (ft above sea level) Observed	Simulated	Difference
(S. of Chemung R. in Corning)					
SRB 1	1	19,42	907.90	908.09	+0.19
SRB 2	1?	18,39-40	909.07	(1)908.59	-0.48
SRB 3	1?	16,39-40	909.03	(1)908.77	-0.26
SRB 4	1	16-17,37	909.18	908.67	-0.51
SRB 5	1	16,32-33	910.91	912.56	+1.65
SRB 44	2	19-20,41-42	est. 909	907.80	-1.20(est)
CC 4	2	16-17,41	907.[c]	908.65	+1.65
CC 5	2	18,40	904.[c]	908.43	+4.43
CC 8	2	15,26-27	907.[c]	910.18	+3.18
42-21	2	13-14,39-40	909.49	909.36	-0.13
31-13	2	15-16,41	909.05	908.83	-0.22
(N of Chemung R. in Corning)					
SRB 6	1	11,38	910.84	910.69	-0.15
SRB 7	1	12,36	909.25	910.55	+1.30
SRB 43	2	12,39		910.07	
SRB 8	2?	14-15,33-34	909.54	909.43	-0.11
SRB 10	1?	12,33	909.32	910.09	+0.77
SRB 11	1	9,33	909.90	911.62	+1.72
SRB 41	2	12,32	909.46	908.82	-0.64
SRB 12	2?	13,29	909.65	909.54	-0.11
CG E	2	12,29-30	903.24[c]	908.79	+5.55
CG B	2	12,30-31	876.0[c]	908.42	+32.42
CG Center	2	12,31	890.0[c]	908.27	+18.27
SRB 13	1	9,29-30	907.94	913.19	+5.25
SRB 14	1	3,29	934.91	934.10	-0.81
SRB 42	2	3-4,29	926.80	931.93	+5.13
SRB 15	1?	5,25	964.04	966.10	+2.06
SRB 16	1	8,27	919.17	919.84	+0.67
SRB 17	1?	11,25-26	911.77	914.39	+2.62
SRB 18	1	13,26	911.47	913.78	+2.31
SRB 19	1	9,25	est. 919	919.71	+0.71(est)
SRB 20	2?	6,23	924.69	927.23	+2.54
SRB 21	1	9-10,24	920.97	920.95	-0.02
SRB 39	2	9,24	914.22	915.27	+1.05
SRB 22	1	13,21-22	912.05	916.94	+4.89

[a] 1, upper; 2, lower.
[b] Cell locations are shown on Figure 12. Hyphenated numbers indicate well is close to boundary between two rows or columns.
[c] Water level measured with an air line in a production well.

TABLE 9 (Continued)

Well Owner and Number or Name	Model Layer[a]	Model cell[b] (row, column)	Water-Level Altitude Calendar Year 1986 (ft above sea level) Observed	Simulated	Difference
SRB 23	1	7,21	932.89	934.28	+1.39
SRB 26	1	6,19	950.26	950.55	+0.29
SRB 27	2?	6,18	935.35	946.47	+11.12
CC 1	2	13,20-21	910.35[c]	915.57	+5.22
CC 2	2	13,21	901.96[c]	914.71	+12.75
CC 7	2	14,33	911[c]	908.86	-2.14
CC 9	2	13,33	903[c]	906.85	+3.85
(Riverside)					
SRB 24	1	12,17-18	919.91	920.94	+1.03
SRB 25	1	9-10,16-17	927.68	923.29	-4.39
SRB 38	2	8,17	927.19	921.80	-5.39
SRB 29	1	6-7,14-15	949.71	941.81	-7.90
(Painted Post)					
SRB 28	1	5,14	--	954.52	+8.01
SRB 30	1	8-9,10-11	925.46	924.72	-0.74
SRB 31	1?	6-7,9	927.06	928.09	+1.03
SRB 32	1	9,5	927.06	927.32	+0.26
SRB 33	1	8-9,6	926.98	927.33	+0.35
SRB 35	2	9,5	927.28	927.66	+0.38
SRB 36	2	8,5-6	926.93	927.86	+0.93
SRB 37	2	6,7	924.67	926.08	+1.41
1R 5	1	11-12,11-12	922.71	921.61	-1.10

[a] 1, upper; 2, lower.
[b] Cell locations are shown on Figure 12. Hyphenated numbers indicate well is close to boundary between two rows or columns.
[c] Water level measured with an air line in a production well.

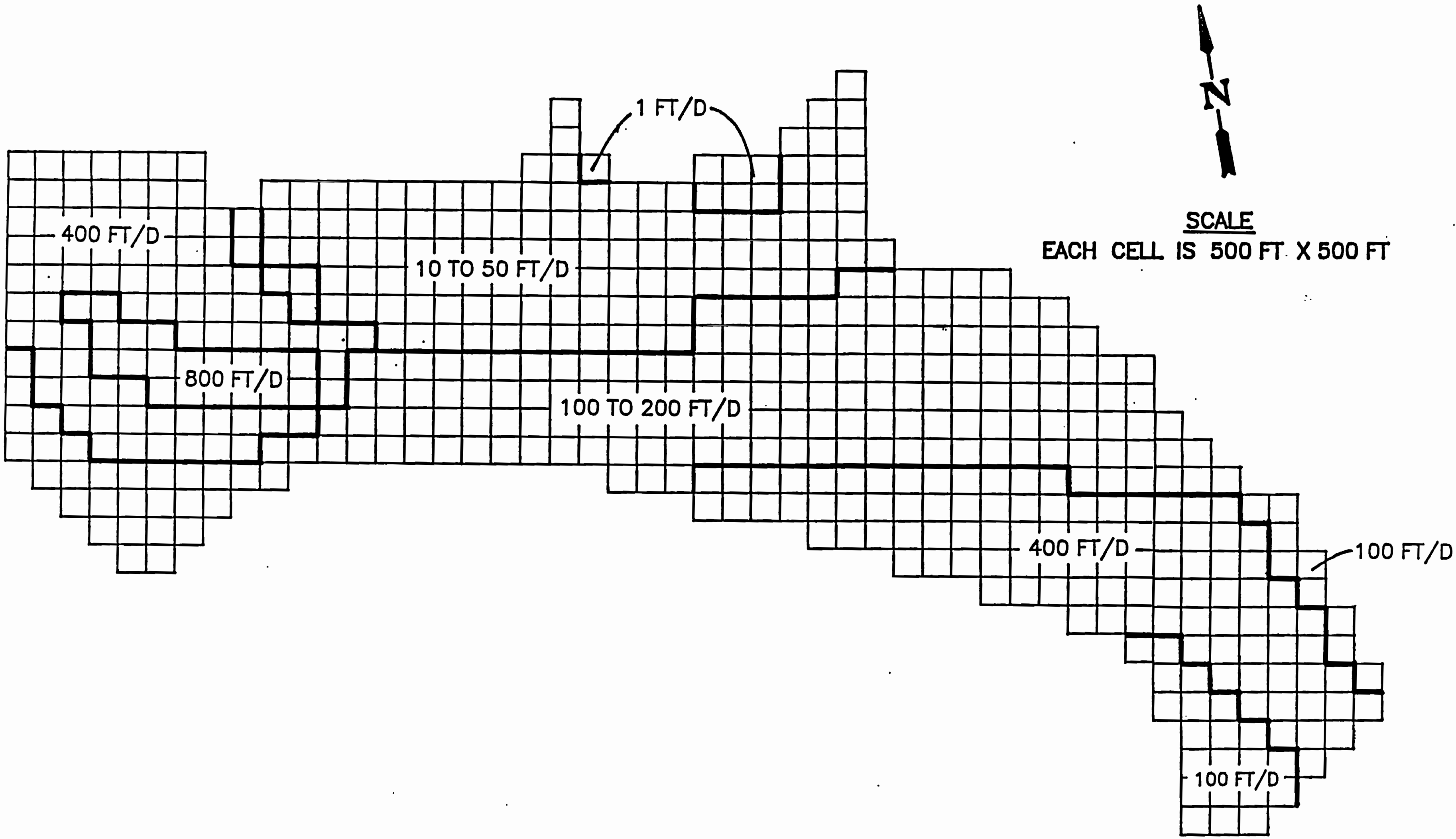
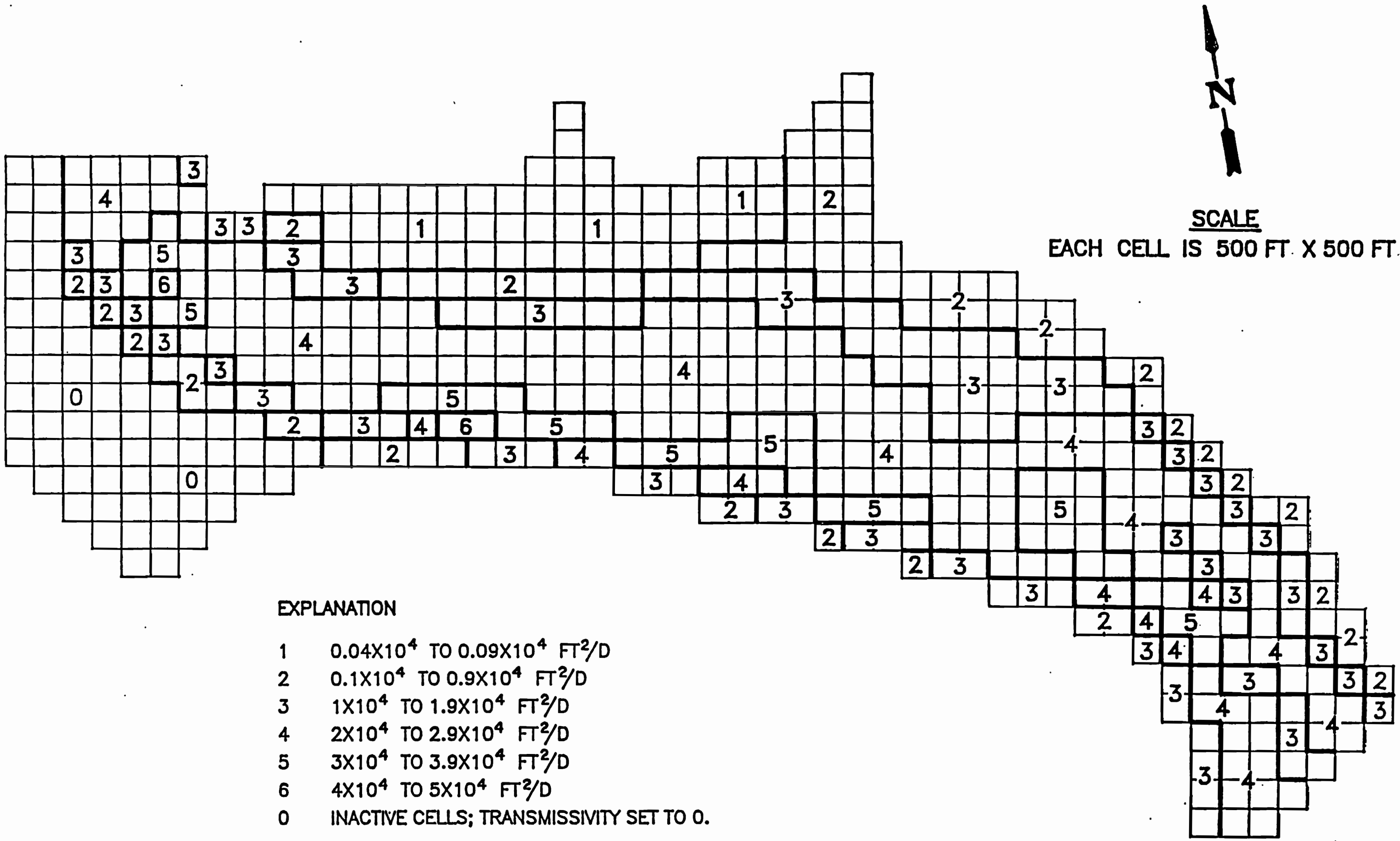


FIGURE 18. DISTRIBUTION OF AVERAGE HORIZONTAL HYDRAULIC CONDUCTIVITY IN LAYER 1.



SCALE
EACH CELL IS 500 FT. X 500 FT.

EXPLANATION

1   0.04×10^4 TO 0.09×10^4 FT^2/D
2   0.1×10^4 TO 0.9×10^4 FT^2/D
3   1×10^4 TO 1.9×10^4 FT^2/D
4   2×10^4 TO 2.9×10^4 FT^2/D
5   3×10^4 TO 3.9×10^4 FT^2/D
6   4×10^4 TO 5×10^4 FT^2/D
0   INACTIVE CELLS; TRANSMISSIVITY SET TO 0.

FIGURE 19. DISTRIBUTION OF AVERAGE HORIZONTAL TRANSMISSIVITY IN LAYER 2.

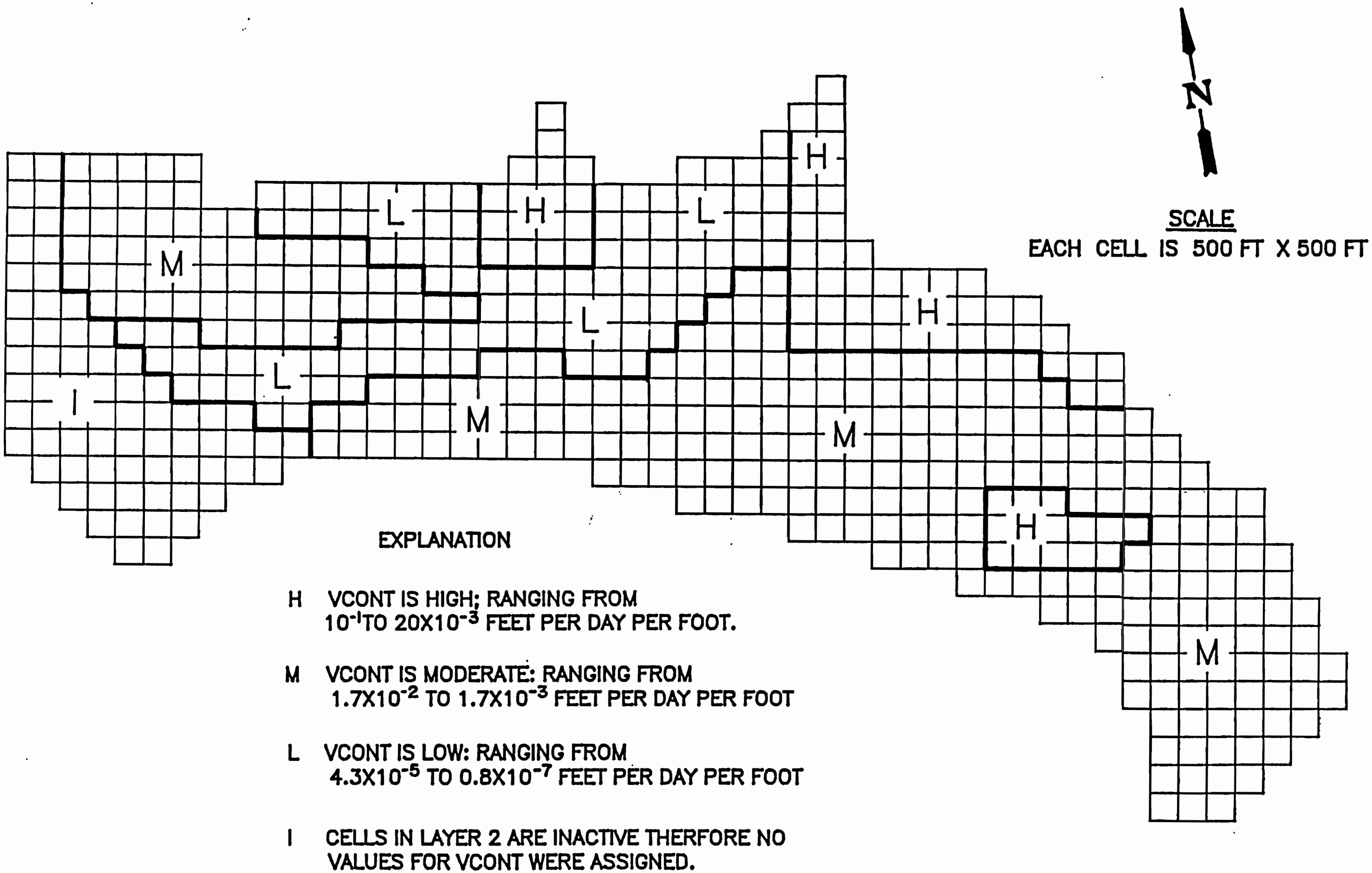


FIGURE 20. "VCONT" DISTRIBUTION USED IN SIMULATION.

The model-generated water budget is presented in Table 10. These rates and volumes are the sums of rates and volumes for all the individual model cells. Direct areal recharge and runoff from hillsides and boundary flow account for 58 percent of sources to the stratified drift under steady-state conditions. Leakage from rivers and streams accounts for the remainder, 33 percent of sources from the Chemung, Cohocton and Tioga Rivers and 9 percent from Post and Cutler Creeks. Pumpage accounts for 84 percent of the discharges.

Transient-State Calibration

The model was used to simulate transient conditions resulting from a two-foot increase in stage of the Chemung River recorded at the Corning gage during the first week of October, 1986, and the coincident recharge event. The aquifers are sensitive to even small changes in river stage and usually respond rapidly according to charts from continuous water-level recorders. This two-foot rise in stage, although not of remarkable magnitude, follows a 30-day period during which daily average stage varied less than 0.2 ft, recharge from precipitation was minimal, and water levels in the observation well network were at their lowest for the year.

The head distribution used as the initial conditions for transient simulations was provided by a steady-state simulation of ground-water conditions for September 1986. The use of the calibrated steady-state model assumed that the ground-water

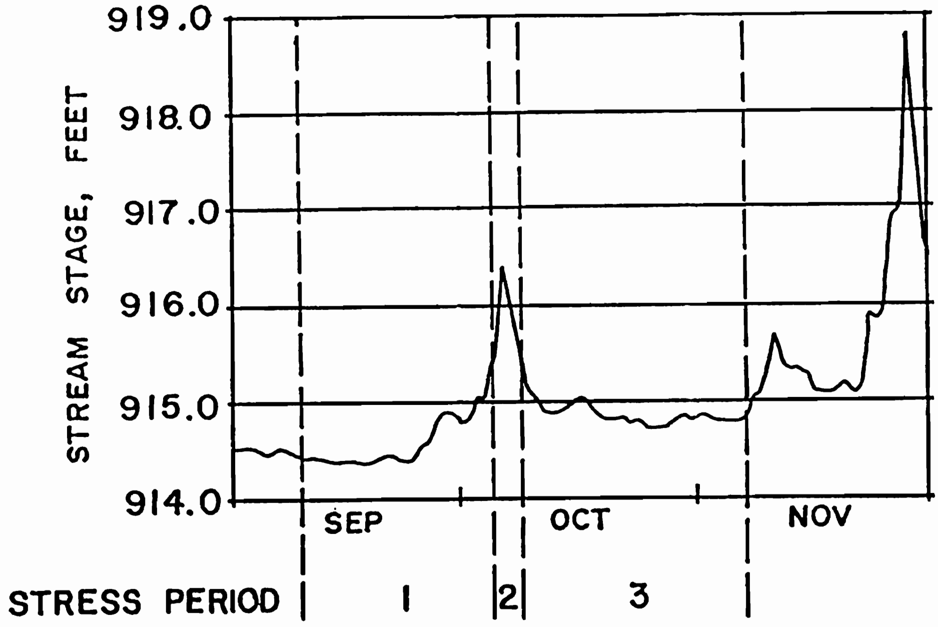
TABLE 10. Model-Generated Water Budget for Steady-State Conditions Based on Average Annual Hydrologic Data. Cumulative volumes expressed in ft^3/d.

	IN:	OUT:
Storage	0.	0.
Wells	0.	1367300.
Recharge	655600.	0.
River and Stream Leakage	692770.	150732.
Head Dependent Boundaries	282040.	113010.
Total	1630400.	1631000.

IN - OUT = -636.00
Percent Discrepancy = -0.04

system was in a period of short-term equilibrium during late summer. A number of adjustments were required in input data: river and stream stages were lowered to September levels, conductance of Post and Cutler Creeks was reduced to account for changes in stream width and to more accurately reflect observed seasonal seepage patterns, and pumping rates were adjusted at major production wells based on reported ground-water withdrawals. This includes a significant increase in pumpage over annual estimates for air conditioning at Corning Glass' Houghton Park Complex. Recharge rate was reduced, through trial and error, until simulated water levels approximately matched those measured in the aquifers. Differences between simulated and estimated heads were considered acceptable if they were within 2 ft of each other in the Chemung River valley; larger departures were considered acceptable nearer the valley walls. A rate of recharge of about 7 in/yr is approximately what would be required to maintain water levels observed in September indefinitely.

The transient-state simulation was designed to include three stress periods: the first beginning on September 9 (to coincide with the monthly synoptic water level measurement) was assigned a stage of 914.4 ft at the Corning gage; the stage was increased to 915.95 ft on October 4 through October 7 comprising the second stress period; and on October 8 the stage was lowered to 914.9 ft and water levels were tracked for 30 days. Figure 22 summarizes the design of the simulation and model input. Stages assigned to



	Stress Period 1	Stress Period 2	Stress Period 3
Chemung River Stage (ft)	914.4	915.95	914.9
Recharge (ft/d)	---	0.0092	0.0026
Pumping Wells (ft^3/d):			
Layer Row Col			
2 6 7	63814	63814	63814
2 6 8	21271	21271	21271
1 9 3	79418	79418	79418
1 11 10	80220	80220	80220
1 11 11	80220	80220	80220
2 15 30	30082	30082	30082
2 12 29	154020	154020	154020
2 12 30	115520	115520	115520
2 12 31	67385	67385	67385
2 13 21	126500	136410	244150
2 13 28	57191	179690	115910
2 13 33	95810	---	97284
2 15 26	218420	211050	22110
2 15 38	173810	173810	173810
2 16 37	100270	100270	100270
2 18 40	---	---	19162

FIGURE 22. DESIGN FOR THE TRANSIENT SIMULATION AND MODEL INPUT.

reaches of rivers and streams, recharge rates and withdrawal rates for pumping wells change during the stress periods. Values for the aquifer framework (hydraulic conductivity and aquifer bottom of the upper layer, transmissivity of the lower layer, and Vcont) were the same as in the average annual steady-state simulation. Specified head boundaries used in the September, 1986, steady-state simulation remained unchanged in all stress periods of the transient simulation.

Recharge from direct precipitation on the aquifer was calculated as precipitation minus evapotranspiration for each stress period, as follows: Estimates of monthly evapotranspiration, in inches of water, were computed by multiplying annual evapotranspiration (21.6 in for 1986) by percentages of annual evapotranspiration that likely occurred during September, October, and November (from Olmstead and Hely, 1962, p. A-13). Monthly recharge was calculated as the difference between precipitation and evapotranspiration for each month, then distributed among the stress periods according to the percentage of monthly precipitation that occurred in each stress period. Estimated evapotranspiration exceeded precipitation in September, the deficit was carried over into early October so that no recharge was applied during stress period 1. In stress period 2, 0.44 in (or 0.0092 ft/d) of the 1.01 in of precipitation was estimated to recharge the aquifers. Recharge was estimated at 0.95 in (or 0.0026 ft/d) in stress period 3.

Storage coefficient (10^{-3}) and specific yield (0.22) were assigned as a single value for each model layer. The transient simulation indicates gradual water level declines during the first stress period, followed by an increase of about 0.01 to 2.5 ft over starting heads in the Chemung River valley during stress period 2, followed by a decline and stabilization of water levels in stress period 3. Comparison of water level contour maps drawn from simulated and observed water level changes shows reasonable agreement, considering inherent errors in observed altitudes and differences allowed for September starting heads. Additionally, further adjustment to coefficients of storage or varying coefficients of storage within model layers was not justified by the limited data available.

Table 11 shows a comparison of changes in water levels computed by the transient-state simulation with changes in water levels measured in 44 observation wells and 10 production wells. Overall, 70 percent of the simulated drawdowns are within 0.5 ft of the drawdowns measured in observation wells, and 53 percent were within 0.3 ft. However, average water levels simulated by the model do not reflect water level changes measured in production wells. In general, the model underestimates the magnitude of water level rise in stress period 2: the largest change measured in an observation well was a rise of 2.23 ft and most water levels were observed to rise 1 ft or less. Simulated water levels in corresponding model cells rise only about 0.5 to 1 ft over starting heads.

TABLE 11. Comparison of Measured and Simulated Transient-State Water Levels in the Corning Area, Steuben County, New York

Well Owner and Number or Name	Model Layer[a]	Model Cell[b] (row, column)	September Observed	October Observed	Observed Drawdown	Simulated Drawdown Run 1	Simulated Drawdown Run 2	November Observed	Observed Drawdown	Simulated Drawdown Run 1	Simulated Drawdown Run 2
(S. of Chemung R. in Corning)											
SRB 1	1	19,42	905.92	907.00	-1.08	-0.64	-0.12	906.41	-0.49	-0.66	-0.21
SRB 2	1?	18,39-40	906.99	908.44	-1.45	-0.11	-0.01	907.76	-0.77	-0.56	-0.03
SRB 3	1?	16,39-40	906.88	908.45	-1.57	-0.23	-0.05	907.69	-0.81	-0.69	-0.22
SRB 4	1	16-17,37	906.92	908.52	-1.60	-0.55	-0.22	908.68	-1.76	-0.70	-0.11
SRB 5	1	16,32-33	908.30	910.53	-2.23	-0.91	-0.40	909.16	-0.86	-0.61	-0.13
SRB 44	2	19-20,41-42	907.01	908.43	-1.42	-0.50	-0.14	907.90	-0.89	-0.64	-0.18
CC 4	2	16-17,41	902.89	904.89	-2.00	-0.63	-0.31	904.89	-2.00	-0.75	-0.38
CC 5	2	18,40	908.97	898.97	10.00	-0.17	-0.01	912.97	-4.00	-0.59	0.17
CC 8	2	15,26-27	900.71	900.71	0.00	0.26	0.63	911.71	-11.00	-4.78	-4.06
42-21	2	13-14,39-40	907.38	908.92	-1.54	-0.74	-0.43	---	---	---	---
31-13	2	15-16,41	906.83	908.49	-1.66	-0.75	-0.44	---	---	---	---
(N. of Chemung R. in Corning)											
SRB 6	1	11,38	909.15	910.32	-1.17	-0.81	-0.34	---	---	---	---
SRB 7	1	12,36	907.89	907.82	0.07	0.01	0.20	908.56	-0.67	-0.47	0.27
SRB 43	2	12,39	908.61	909.75	-1.14	-0.54	-0.28	909.50	-0.89	-0.71	-0.25
SRB 8	2?	14-15,33-34	907.56	909.40	-1.84	-0.90	-0.43	---	---	---	---
SRB 10	1?	12,33	907.69	907.83	-0.14	-0.07	0.12	907.26	0.43	-0.39	0.28
SRB 11	1	9,33	907.81	908.46	-0.65	0.25	0.48	907.68	0.13	0.19	0.64
SRB 41	2	12,32	907.00	908.29	-1.29	-0.77	-0.30	907.16	-0.16	-0.34	0.27
SRB 12	2?	13,29	907.97	907.71	0.26	0.52	0.87	908.06	-0.09	0.55	0.18
CG E	2	12,29-30	900.15	902.15	-2.00	0.37	0.70	901.15	-1.00	-0.45	0.27
CG B	2	12,30-31	876.27	876.27	0.00	0.11	0.54	875.27	1.00	-0.46	0.26
CG Center	2	12,31	888.75	886.75	2.00	-0.05	0.54	888.75	0.00	-0.46	0.27
SRB 13	1	9,29-30	905.86	905.59	0.27	0.32	0.52	905.44	0.42	0.28	0.68
SRB 14	1	3,29	933.65	934.44	-0.79	0.55	0.81	934.34	-0.69	0.76	1.40
SRB 42	2	3-4,29	925.31	925.21	0.10	0.45	0.84	925.09	0.22	0.65	1.44
SRB 15	1?	5,25	964.54	964.92	-0.38	0.18	0.85	965.02	-0.48	-0.37	1.70
SRB 16	1	8,27	916.76	916.63	0.13	0.09	0.26	916.55	0.21	0.01	0.52
SRB 17	1?	11,25-26	909.05	909.81	-0.76	0.16	0.35	909.86	-0.81	-0.38	0.17
SRB 18	1	13,26	908.62	909.61	-0.99	-0.80	-0.47	909.65	-1.03	-0.94	-0.42
SRB 20	2?	6,23	923.00	922.51	0.49	-0.22	1.30	922.35	0.65	0.24	1.98
SRB 21	1	9-10,24	919.16	918.78	0.38	0.13	0.22	918.99	0.17	0.00	0.45
SRB 39	2	9,24	911.23	911.80	-0.57	-0.25	0.55	911.95	-0.72	-0.01	0.64
SRB 22	1	13,21-22	910.19	911.04	-0.85	-0.65	-0.53	910.80	-0.61	-0.39	-0.30
SRB 40	2	10-11,27-28	900.70	901.33	-0.63	-0.41	0.65	901.37	-0.67	-0.52	0.25

TABLE 11. Continued

Well Owner and Number or Name	Model Layer[a]	Model Cell[b] (row, column)	September Observed	October Observed	Observed Drawdown	Simulated Drawdown		November Observed	Observed Drawdown	Simulated Drawdown	
						Run 1	Run 2			Run 1	Run 2
(N. of Chemung R. in Corning)											
SRB 23	1	7,21	932.53	932.34	0.19	0.33	0.53	932.71	-0.18	0.07	0.68
SRB 26	1	6,19	948.28	949.34	-1.06	1.33	4.40	949.29	-1.01	2.21	6.82
SRB 27	2?	6,18	932.83	932.41	0.42	1.22	1.86	---	---	---	---
CC 1	2	13,20-21	910.27	910.27	0.00	0.17	0.39	899.27	11.00	2.01	2.20
CC 2	2	13,21	899.76	900.76	-1.00	0.24	0.47	900.76	-1.00	1.28	2.57
CC 7	2	14,33	907.84	900.71	7.13	-0.56	-0.62	907.84	0.00	-0.62	0.06
CC 9	2	13,33	900.59	912.59	-12.00	-2.04	-1.77	903.59	-3.00	-0.53	0.17
(Riverside)											
SRB 24	1	12,17-18	917.38	918.24	-0.86	-0.42	-0.20	917.74	-0.36	-0.22	0.06
SRB 25	1	9-10,16-17	925.86	927.18	-1.32	0.13	0.52	---	---	---	---
SRB 38	2	8,17	925.58	925.04	0.54	0.17	0.42	924.74	0.84	0.56	1.11
SRB 29	1	6-7,14-15	946.62	945.52	1.10	0.15	0.22	944.96	1.66	0.12	0.77
(Painted Post)											
SRB 28	1	5,14	944.32	946.11	-1.79	0.23	1.23	945.24	-0.92	-0.57	2.39
SRB 30	1	8-9,10-11	924.44	924.06	0.38	-0.01	0.17	923.84	0.60	-0.13	-0.01
SRB 31	1?	6-7,9	924.19	924.24	-0.05	-0.05	0.24	924.66	-0.47	-0.65	-0.08
SRB 32	1	9,5	925.54	926.22	-0.68	-0.99	-0.87	925.98	-0.44	-1.24	-1.02
SRB 33	1	8-9,6	925.47	926.15	-0.68	-0.50	-0.36	925.88	-0.41	-0.67	-0.41
SRB 35	2	9,5	925.56	926.28	-0.72	-0.22	-0.07	926.01	-0.45	-0.59	-0.31
SRB 36	2	8,5-6	925.40	925.78	-0.38	-0.17	-0.02	925.58	-0.18	-0.50	-0.26
SRB 37	2	6,7	922.71	921.04	1.67	-0.14	0.04	923.06	-0.35	-0.49	-0.19
1R 5	1	11-12,11-12	920.60	921.40	-0.80	-0.43	-0.22	921.62	-1.02	-0.96	-0.57

NOTE:

[a] 1, upper; 2, lower

[b] Cell locations are shown on Figure 12. Hyphenated numbers indicate well is close to boundary between two rows or columns.

A second transient run was made with no areal recharge added during stress periods 2 and 3, in order to isolate the effects of changes in river stage on ground-water levels. Results for model cells where monitoring wells are located are shown in Table 11. Without the benefit of recharge from precipitation (and from bedrock and runoff from hillsides), cells near valley walls show water level declines throughout the simulation. Cells near rivers show rising water levels during stress period 2, although the magnitude of the change is not as great as with the combined effects of recharge and rising stream stage of Run 1. Nevertheless, the simulation demonstrates the aquifers are sensitive to small changes in river stage.

Simulation of Natural Conditions

The calibrated steady-state model was used to simulate ground-water levels under natural, non-pumping conditions. Recharge rate, river and stream stage, and riverbed conductance were the same as in simulations of average-annual steady-state conditions. No pumping wells were simulated.

Results for layer 1 are shown in Figure 23. Water levels in this layer are as much as 9 ft higher than those under pumping conditions. In the lower layer near the center of Corning, heads are elevated 2 to 3 ft above average-annual conditions. Under simulated non-pumping conditions, ground-water discharges to the master rivers; there are no natural losing river reaches.

The cell-by-cell water budget that the model computes for river reaches was used to estimate the percentage of well discharge that is derived from stream flow. The non-pumping water budget was subtracted from the pumping water budget to determine the amount of water diverted to wells. This number was divided by well discharge to obtain the percentage of well discharge that is recharged to the aquifer from adjacent river reaches. In Painted Post, wells owned by Corning Glass and Ingersoll-Rand pump water from layer 1 and derive about 90 percent of their discharge from stream flow. Most wells in Corning are so close together that it is impossible to determine the quantity of flow induced by a particular well. When calculations were performed on these wells as a group, it was determined that about 70 percent of the discharge of municipal and industrial wells in Corning is recharged to the aquifer from river reaches in the vicinity of these wells.

Simulation of Drought Conditions

Periods of low recharge (droughts) are commonly temporary and a ground-water flow system would not be expected to reach steady-state conditions. However, during a period of sustained drought such as the 1960's, the ultimate effects predicted by steady-state simulation would probably be achieved. The model was used to simulate ground-water levels that might be produced from the combined effects of a long-term drought and current pumpage rates.

Model input for hydraulic conductivity and pumping wells was the same as that used for average annual steady-state conditions. The river file was modified to reflect low flows. Although there was no stream gaging station at Corning during the 1960's, synthesized flow data are available for the period of October 1, 1963 to September 30, 1965. Discharge from the week of September 12, 1963, considered to be representative of low base flow conditions, was converted to a stage of 914.05 ft using the published stage/discharge relationship. Model input for river stage at other locations along the Tioga, Cohocton, and Chemung Rivers was estimated from the water surface profile. Stages for Post and Cutler Creeks were estimated from observations of staff gages during August and September 1986. Model input for conductance and riverbed thickness was not changed from September 1986 conditions.

Recharge was estimated as follows. Examination of precipitation records for Corning from 1963-1965 indicated that 28 inches was a reasonable value for annual precipitation during the drought. According to Taylor (1988), the long-term average amount of evapotranspiration is 21.4 inches, based on data from 1975 through 1985 at the Corning gage. However, evapotranspiration during a drought would be expected to be less than average. For the Chemung River at the Chemung gage, evapotranspiration during the 1960's drought is only about 94 percent of the long-term average; therefore, estimates of evapotranspiration at Corning were reduced to 20.1 inches.

Subtracting evapotranspiration from total precipitation yields about 8 inches of recharge to the ground-water system from precipitation. Runoff from hillsides was reduced proportionately. Recharge from bedrock to selected cells in the lower layer remained at 7 inches per year.

A contour plot of water levels in layer 1 during the simulated drought is shown in Figure 24. Water levels decline about 5 ft in the City of Corning and about 3 ft near the municipal wells in Painted Post. Declines are more pronounced at the valley margin where sediments are less transmissive. In layer 2 the model predicts declines of up to 7 ft from average. Effects of the drought would be more severe if withdrawals were increased to typical summer levels.

The model-generated water budget for drought conditions is shown in Table 12. Simulated discharges from wells represent 88 percent of total recharge. Leakage from rivers increases to 688440 ft^3/d or 45 percent of recharge. Leakage in this simulation amounts to 96 percent of flow of the Chemung River at the Corning gage. Thus, the potential exists for a reduction in streamflow and a loss in aquifer yields during an extended drought as a result of ground-water pumpage.

TABLE 12. Model-Generated Water Budget for Hypothetical Drought Conditions. Cumulative volumes expressed in ft^3/d.

	IN:	OUT:
Storage	0.	0.
Wells	0.	1367300.
Recharge	403040.	0.
River and Stream Leakage	795510.	104000.
Head Dependent Boundaries	345570.	68704.
Total	1544100.	1540000.

IN - OUT = 4125
Percent Discrepancy = -0.27

SUMMARY AND CONCLUSIONS

The three-dimensional geologic framework of the stratified drift deposits in the area around Corning was investigated by a program of well drilling, examination of drilling cuttings and analysis of published well logs. In this part of the Chemung River Valley, the valley fill is comprised chiefly of sand and gravel of variable siltiness. Total thickness of the unconsolidated sediments ranges from about 100 ft in Corning to 135 ft in Gang Mills. Highly permeable sand and gravel, presumably outwash, forms a near surface aquifer that is areally extensive but only thinly saturated over most of the valley. Outwash is underlain by extensive beds of fine-grained lacustrine sediments. The presence and thickness of these beds of silt and clay or their absence is variable and can only be determined by logs from closely-spaced wells. A deep confined aquifer is buried beneath the outwash and lacustrine sediments. Although commonly siltier than the outwash, the deep aquifer provides large yields to municipal and industrial wells.

The valley fill sediments were likely deposited during the waning stages of glaciation when ice stagnated in the valley. This mode of deposition would account for the heterogeneity of the sediments, the complex stratigraphy, and the apparent collapse features evident in the geologic sections.

Results from the study of nature of the valley fill led to the development of a conceptual framework for the ground-water flow system that could be represented by a numerical model. The system can adequately be simulated by assuming horizontal flow in two layers and vertical flow between these layers. The upper layer represents the unconfined surficial aquifer and the lower layer generally represents the deep buried aquifer. The confining beds of lacustrine silts are not simulated directly, but control vertical leakage between the active layers.

Transmissivities of both aquifers were initially determined from grain size descriptions in geologic logs, pumping test data, and specific capacity data. There were several limitations in this data: grain size descriptions were dependent on the detail available in the log and the reliability of the published relationship between grain-size and hydraulic conductivity, and tend to be only a qualitative measure of transmissivity; pumping test data are believed to be reliable but are sparsely distributed in the study area; and estimates from specific capacity data assume a uniform value of specific yield. Base values of hydraulic conductivity for the upper aquifer and transmissivity for the lower aquifer were adjusted during steady-state calibration. In the upper model layer, final values for hydraulic conductivity ranged from 800 ft/d for permeable stratified drift to 1 ft/d for fine-grained sediments at the valley margins. In the lower layer, transmissivity in the aquifer tapped by production wells varies from about 42,300 ft^2/d to 27,000 ft^2/d.

Vertical flow between model layers is governed by a term, "Vcont", that represents the effective vertical hydraulic conductivity divided by the vertical grid spacing. Vcont can be expected to vary areally because of the changing distribution and thickness of lacustrine sediments. Vcont is especially important in the model due to the fact it controls the location and rate of recharge to the simulated lower aquifer where many municipal and industrial wells are screened. Yet Vcont is the aquifer parameter least perfectly known. There are no direct measurements of vertical conductance in the study area. It is also conceptually difficult to handle very thin beds of silt and "windows" in the lacustrine sediments, smaller than the area of an individual cell, that seemingly occur in the Corning area. Estimates were developed from typical values in the literature and adjusted by trial-and-error during calibration. The distribution of final values is believed to be adequate for current modeling efforts. Additional water level measurements from strategically located pairs of observation wells, that are screened at different depths, would improve the reliability of the calibrated values.

Under natural conditions, the unconfined outwash aquifer receives recharge primarily from four sources: (1) direct precipitation on the aquifer that infiltrates to the water table, (2) runoff and shallow underflow from adjacent hillsides that slope towards the valley floor, (3) infiltration from tributary streams, and (4) underflow from stratified drift beyond the boundary of the study area. The shallow aquifer is hydraulically connected to surface water. Aquifers rapidly respond to river-stage rises as demonstrated in the transient simulation. Numerical simulations indicate that under natural, non-pumping steady-state conditions, the aquifers discharge to the major controlling rivers.

The lower aquifer receives recharge from the upper aquifer, either as leakage through confining beds or directly wherever the intervening confining beds are absent. The areas of highest potential recharge, as defined by the final calibrated values of Vcont, include areas underlying Post and Cutler Creeks and an area north of the Chemung River in Corning.

Under pumping conditions, induced infiltration from the Chemung and Cohocton Rivers enters the aquifer. The potential for induced infiltration is greatest for wells screened in outwash. Production wells of Corning Glass and Ingersoll-Rand, located in Gang Mills and Painted Post respectively, induce an estimated 90 percent of their discharge from adjacent reaches of the Cohocton River under average steady-state conditions. About 70 percent of total well discharges in Corning is diverted into the aquifer from river reaches in the vicinity of pumping wells.

Numerical simulations quantify recharge from different sources and generate water budgets. Under average steady-state conditions, 58 percent of recharge, amounting to about 660,000

ft^3/d, is derived from precipitation directly on the land surface and slopes draining towards the valley floor. Nine percent of recharge is from infiltration along Post and Cutler Creeks. Recharge induced from the major rivers amounts to about 540,000 ft^3/d or 33 percent of total recharge during average steady-state conditions. During simulation of the hypothetical drought, this source increased to 45 percent of total recharge.

Accuracy of these results is dependent on how well the conceptualization of the interaction between ground water and surface water reflects actual conditions. Although no formal sensitivity analysis was performed, the calibration process demonstrated that the model is sensitive to conductance of the riverbed. Yeager (1986) found, in an investigation of stratified drift aquifers in Kirkwood, NY; that riverbed hydraulic conductivity was the factor to which induced-infiltration rate and size of well-field catchment areas are most sensitive. In this study, hydraulic conductivity of the riverbed was based on several slug-injection tests in wells driven into riverbed sediments and was adjusted during steady-state calibration. Other independent methods to estimate the hydraulic conductivity of the riverbed are necessary to verify riverbed conductance. These methods could include analysis of water-quality data to estimate the contribution of river water to a production well or the modeling of ground-water temperature to estimate the quantity of river water infiltrating into the aquifer.

The model as developed could be used to simulate natural or artificial stresses that might create regional changes in water levels, such as the impacts of surface water impoundments, changes in major well fields, seasonal variation in recharge, or droughts of various magnitudes. Calibration to transient conditions was not sufficiently rigorous enough to be predictive.

The model could be improved as knowledge of the system increases and an independent data set becomes available for verification runs. The routine, systematic collection of ground-water data is recommended towards this end. Data collection might include: (1) filing drilling reports with a central agency; (2) requiring meters for accurate measurements of ground-water withdrawals from all commercial, industrial and municipal production wells; and (3) keeping complete records of variations in pumping rates over time.

Although the primary output from the model is concerned with heads, information used in the development and generated by the use of the model has implications for water quality management. In particular, the model can provide insight into sources and amounts of recharge available under different circumstances. The quality of recharge must be protected to prevent degradation of ground-water quality.

Model-generated water budgets provide estimates of recharge from different sources. Aquifers receive a substantial portion of recharge from precipitation directly on the surface and from slopes draining to the valley floor so it is important to manage activities on the land surface that might impact water quality. Associated with the high yield of surficial outwash aquifers is an inherent vulnerability to pollution from surface sources. Deeper confined aquifers were thought to be less vulnerable, but these aquifers receive recharge from the outwash. Even where confining layers are present, they thin laterally in some areas and are discontinuous in others; therefore any protection from contaminants originating at the surface is limited.

Aquifers receive a smaller fraction of their recharge from seepage from tributary streams flowing across the stratified drift. Recharge from this source might increase in importance during certain periods of the year, particularly if high flows coincided with a depressed water table, so maintenance of good water quality is desirable. Although the quality of surface water was not tested during this study, staff observed evidence of contamination from sewage along Cutler Creek on several occasions.

Recharge from the Cohocton and Chemung Rivers induced by pumping wells is a particularly important source and increases potential yields from the aquifers. Unified management of surface and subsurface water quality needs to be emphasized in any ground-water protection plan because contamination of either source cannot be prevented without controlling contamination of both.

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APPENDIX 1.

Selected Well and Test-Hole Logs
(Locations are shown in Figure 1)

Wells listed in this appendix are identified on Figure 1 by either a Commission number or a hyphenated, four digit number representing the location of the well in seconds of latitude and longitude.

Susquehanna River Basin Test Hole 1 (SRB 1)
at Location 4208 18 7702 18

Drilled with NY DEC hollow-stem auger rig November 16, 1983. Log based on field examination of drill cuttings. Depths are in ft below land surface. Land surface is approximately 916 ft above sea level. Finished 1.5-in. diameter PVC observation well screened from 25 to 27 ft below land surface. Measuring point is top of coupling, 915.91 ft above sea level. Depth to water at time of drilling was 9.22 ft.

Depth interval	Materials penetrated
0 - 10 ft	Fill
10 - 13 ft	Gravel
13 - 30 ft	Gravel with very well-rounded cobbles.

Susquehanna River Basin Test Hole 2 (SRB 2)
at Location 4208 21 7702 28

Drilled with NY DEC hollow-stem auger rig October 22, 1985. Log based on field examination of drill cuttings. Depths are in ft below land surface. Land surface is approximately 922.6 ft above sea level. Finished 2-in. diameter observation well screened from 35 to 40 ft below land surface. Measuring point is top of casing, 922.87 ft above sea level. Depth to water in November, 1985 was 13.07 ft.

Depth interval			Materials penetrated
0 -	5	ft	Brown fill
5 -	8	ft	Silty fine sand
8 -	19	ft	Silty sand and gravel, some cobbles
19 -	22	ft	Gravel; small cobbles
22 -	29	ft	Well-rounded medium gravel in silt/clay matrix; hardly any angular fragments.
29 -	35	ft	Compact gray clay and silt
35 -	40	ft	Sand and gravel

Susquehanna River Basin Test Hole 3 (SRB 3)
at Location 4208 32 7702 25

Drilled with NY DEC hollow-stem auger rig October 22, 1985. Log based on field examination of drill cuttings. Depths are in ft below land surface. Land surface is approximately 924 ft above sea level. Finished 2-in. diameter observation well screened from 42 to 47 ft below land surface. Measuring point is top of casing, 923.85 ft above sea level. Depth to water in November, 1985 was 13.95 ft.

Depth interval			Materials penetrated
0 -	3	ft	Fill
3 -	5	ft	Fine sand and silt
5 -	9	ft	Silt
9 -	13	ft	Silty sand (wet at 12 ft)
13 -	19	ft	Gravel with some silt
19 -	23	ft	Sand and gravel (interbedded?)
23 -	27	ft	Sand and gravel
27 -	31	ft	Gravel in silt matrix?
31 -	47	ft	Sand and gravel

Susquehanna River Basin Test Hole 4 (SRB 4)
at Location 4208 28 7702 43

Drilled with NY DEC hollow-stem auger rig December 1, 1983. Log based on field examination of drill cuttings. Depths are in ft below land surface. Land surface is approximately 925 ft above sea level. Finished 1.5-in. diameter PVC observation well screened from 18.7 to 20.7 ft below land surface. Measuring point is top of coupling, 925.32 ft above sea level. Depth to water in December, 1983 was 17.17 ft.

Depth interval	Materials penetrated
0 - 3 ft	Fill
3 - 25 ft	Coarse gravel with fine brown sand.

Susquehanna River Basin Test Hole 6 (SRB 6)
at Location 4208 56 7702 29

Drilled with NY DEC hollow-stem auger rig December 1, 1983. Log based on field examination of drill cuttings. Depths are in ft below land surface. Land surface is approximately 916 ft above sea level. Finished 1.5-in. diameter PVC observation well screened from 20.2 to 22.2 ft below land surface. Measuring point is top of coupling, 916.40 ft above sea level. Depth to water in December, 1983 was 6.55 ft.

Depth interval	Materials penetrated
0 - 5 ft	Medium sand
5 - 12 ft	Gravel with cobbles
12 - 16 ft	Silty gravel
16 - 20 ft	Gravel with cobbles
20 - 25 ft	Coarse gravel with gray clay

Susquehanna River Basin Test Hole 7 (SRB 7)
at Location 4208 51 7702 45

Drilled with NY DEC hollow-stem auger rig December 7, 1983. Log based on field examination of drill cuttings. Depths are in ft below land surface. Land surface is approximately 924.5 ft above sea level. Finished 1.5-in. diameter PVC observation well screened from 25.7 to 27.7 ft below land surface. Measuring point is top of coupling, 924.57 ft above sea level. Depth to water in December, 1983 was 18.35 ft.

Depth interval		Materials penetrated
0 - 10	ft	Fill
10 - 20	ft	Sand and gravel
20 - 30	ft	Wet sand with trace of gravel

Susquehanna River Basin Test Well 8 (SRB 8)
at Location 4208 43 7703 04

Drilled by Tully Drilling Co., Poyntelle, Pa., with air rotary rig September 23, 1983. Log based on field examination of drill cuttings. Depths are in ft below land surface. Land surface is approximately 917 ft above sea level. Finished 7-in. diameter steel-cased observation well screened from 36 to 41 ft below land surface with 6-in. diameter X 5 ft, 0.160 slot stainless-steel Johnson-type screen. Measuring point is top of casing (extended above land surface for flood protection), 923.84 ft above sea level. Depth to water at time of drilling approximately 20 ft below land surface. Driller's estimate of yield is 40 gal/min.

Depth interval		Materials penetrated
0 - 2	ft	Alluvial soil
2 - 5	ft	Alluvium, sand and fine gravel
5 - 14	ft	Sand and gravel, some clay, "heavy" drilling
14 - 25	ft	Coarse and fine sand and gravel; "softer" material at 18-19 ft.
25 - 30	ft	Gravel, some sand
30 - 41	ft	Coarse and fine gravel, some sand

Susquehanna River Basin Test Well 9 (SRB 9)
at Location 4208 48 7703 16

Drilled by Tully Drilling Co., Poyntelle, Pa., with air rotary rig September 23, 1983. Log based on field examination of drill cuttings. Depths are in ft below land surface. Land surface is approximately 916 ft above sea level. Finished 7-in.

diameter steel-cased observation well screened from 15 to 20 ft below land surface with 6-in. diameter X 5 ft 0.160 slot stainless-steel Johnson-type screen. Measuring point is top of casing (extended above land surface for flood protection) 917.02 ft above sea level. Depth to water at time of drilling approximately 10 ft below land surface. Driller's estimate of yield is 25 gal/min.

Depth interval		Materials penetrated
0 - 5	ft	Alluvium
5 - 10	ft	Gravel and sand, gray, some clay
10 - 14	ft	Heavy gravel, sand, some clay; wet
14 - 19	ft	Coarse and fine gravel
19 - 20	ft	Coarse and fine gravel and black silt

Susquehanna River Basin Test Hole 11 (SRB 11)
at Location 4209 10 7702 58

Drilled with NY DEC hollow-stem auger rig October 2, 1985. Log based on field examination of drill cuttings. Depths are in ft below land surface. Land surface is approximately 929 ft above sea level. Finished 2-in. diameter observation well screened from 24 to 29 ft below land surface. Measuring point is top of casing, 929.03 ft above sea level. Depth to water November, 1985 was approximately 19 ft.

Depth interval		Materials penetrated
0 - 7	ft	Fill
7 - 8	ft	Brown sand and medium gravel
8 - 11	ft	Gravel with sand
11 - 25	ft	Coarse gravel, very little sand
25 - 27	ft	Coarse gravel with sand
27 - 29	ft	Coarse gravel; auger refusal

Susquehanna River Basin Test Hole 12 (SRB 12)
at Location 4208 57 7703 33

Drilled with NY DEC hollow-stem auger rig November 29, 1983. Log based on field examination of drill cuttings. Depths are in ft below land surface. Land surface is approximately 933 ft above sea level. Finished 1.5-in. diameter PVC observation well screened at 36 to 38 ft below land surface. Measuring point is top of coupling, 933.26 ft above sea level. Depth to water December, 1983 was 25.38 ft.

Depth interval		Materials penetrated
0 - 8	ft	Fill
8 - 12	ft	Brown silty clay; fill?
12 - 20	ft	Black gravel; fill?
20 - 25	ft	Gravel with silt
25 - 30	ft	Fine sand
30 - 35	ft	Clay
35 - 40	ft	Fine sand

Susquehanna River Basin Test Hole 13 (SRB 13)
at Location 4209 14 7703 25

Drilled with NY DEC hollow-stem auger rig November 1983. Log based on field examination ofdrill cuttings. Depths are in ft below land surface. Land surface is approximately 922 ft above sea level. Finished 1.5-in. diameter PVC observation well screened 18 to 20 ft below land surface. Measuring point is top of coupling, 922.10 ft above sea level. Depth to water December, 1983 was 15.73 ft.

Depth interval		Materials penetrated
0 - 1	ft	Topsoil
1 - 17	ft	Brown sandy gravel
17 - 20	ft	Brown sandy gravel, coarser than above

Susquehanna River Basin Test Hole 14 (SRB 14) at Location 4209 41 7703 18

Drilled with NY DEC hollow-stem auger rig October 23, 1985. Log based on field examination of drill cuttings. Depths are in ft below land surface. Land surface is approximately 946 ft above sea level. Finished 2-in. diameter observation well screened 18 to 23 ft below land surface. Measuring point is top of casing, 946.03 ft above sea level. Depth to water November, 1985 was 10.40 ft.

Depth interval		Materials penetrated
0 - 10	ft	Fill
10 - 14	ft	Gray clay
14 - 18	ft	Gravel
18 - 21	ft	Silt and clay
21 - 23	ft	Gravel; refusal at 23 ft

Susquehanna River Basin Test Hole 15 (SRB 15) at Location 4209 35 7703 47

Drilled with NY DEC hollow-stem auger rig November, 1983. Log based on field examination of drill cuttings. Depths are in ft below land surface. Land surface is approximately 987 ft above sea level. Finished 1.5-in. diameter PVC observation well screened 38 to 40 ft below land surface. Measuring point is top of coupling, 986.91 ft above sea level. Depth to water December, 1983 was greater than 40 ft.

Depth interval		Materials penetrated
0 - 9	ft	Brown sand
9 - 12	ft	Fine gravel, sandy
12 - 13	ft	Silty sand
13 - 32	ft	Fine to medium gravel
32 - 40	ft	Coarse gravel
40 - 42	ft	Clay

Susquehanna River Basin Test Hole 16 (SRB 16)
at Location 4209 23 7703 38

Drilled with NY DEC hollow-stem auger rig October 2, 1985. Log based on field examination of drill cuttings. Depths are in ft below land surface. Land surface is approximately 932 ft above sea level. Finished 2-in. diameter observation well screened 23 to 28 ft below land surface. Measuring point is top of casing, 932.10 ft above sea level. Depth to water November, 1985 was approximately 14 ft.

Depth interval	Materials penetrated
0 - 5 ft	Brown, medium sand and gravel
5 - 12 ft	Medium to coarse gravel, little sand
12 - 20 ft	Medium pea-sized gravel, easy drilling
20 - 25 ft	Coarse gravel
25 - 27 ft	Coarse gravel, very difficult drilling
27 - 29 ft	Gravel and cobbles
29 - 30 ft	Gray till

Susquehanna River Basin Test Hole 17 (SRB 17)
at Location 4209 09 7703 50

Drilled with NY DEC hollow-stem auger rig October 10, 1985.. Log based on field examination of drill cuttings. Depths are in ft below land surface. Land surface is approximately 933 ft above sea level. Finished 2-in. diameter observation well screened 48 to 53 ft below land surface. Measuring point is top of casing, 933.08 ft above sea level. Depth to water November, 1985 was approximately 20 ft.

Depth interval	Materials penetrated
0 - 2 ft	Fill
2 - 5 ft	Pea-sized gravel
5 - 10 ft	Medium sand and gravel, light brown
10 - 12 ft	Medium sand
12 - 15 ft	Brown, medium sand and gravel
15 - 23 ft	Sand and gravel
23 - 27 ft	Sand and gravel with some tight brown silt beds
27 - 31 ft	Gray silt, compact and wet
31 - 40 ft	Fine sand and gray silt
40 - 53 ft	Gray silt with gravel (interbedded?)

Susquehanna River Basin Test Hole 18 (SRB 18)
at Location 4208 56 7703 50

Drilled with NY DEC hollow-stem auger rig October 1, 1985. Log based on field examination of drill cuttings. Depths are in ft below land surface. Land surface is approximately 931 ft above sea level. Finished 2-in. diameter observation well screened 28 to 33 ft below land surface. Measuring point is top of casing, 931.06 ft above sea level. Depth to water November, 1985 was approximately 18 ft.

Depth interval	Materials penetrated
0 - 5 ft	Fill
5 - 7 ft	Sand and gravel
7 - 12 ft	Brown silt and sand, some silt
12 - 30 ft	Sand and gravel, some silt
30 - 33 ft	No returns; very coarse

Susquehanna River Basin Test Hole 20 (SRB 20)
at Location 4209 34 7703 59

Drilled with NY DEC hollow-stem auger rig October 3, 1985. Log based on field examination of drill cuttings. Depths are in ft below land surface. Land surface is approximately 926. ft above sea level. Finished 2-in. diameter observation well screened 50 to 55 ft below land surface. Measuring point is top of casing, 962.01 ft above sea level. Depth to water November, 1985 was approximately 39 ft.

Depth interval		Materials penetrated
0 - 5	ft	Light brown topsoil
5 - 10	ft	Silt with some medium gravel
10 - 11	ft	Gravel
11 - 20	ft	Fine to medium gravel with some silt and clay
20 - 53	ft	Gray silt and clay; more clay with depth
53 - 55	ft	Gravel, water-bearing

Susquehanna River Basin Test Hole 22 (SRB 22)
at Location 4209 01 7704 19

Drilled with NY DEC hollow-stem auger rig December 7, 1983. Log based on field examination of drill cuttings. Depths are in ft below land surface. Land surface is approximately 933.5 ft above sea level. Finished 1.5-in. diameter PVC observation well screened 32 to 34 ft below land surface. Measuring point is top of coupling, 933.60 ft above sea level. Depth to water December, 1983 was 27.21 ft.

Depth interval		Materials penetrated
0 - 5	ft	Fill
5 - 40	ft	Silty sand with traces of gravel

Susquehanna River Basin Test Hole 23 (SRB 23)
at Location 4209 29 7704 15

Drilled with NY DEC hollow-stem auger rig November 30, 1983. Log based on field examination of drill cuttings. Depths are in ft below land surface. Land surface is approximately 949 ft above sea level. Finished 1.5-in. diameter PVC observation well screened 23 to 25 ft below land surface. Measuring point is top of coupling, 948.85 ft above sea level. Depth to water December, 1983 was 17.10 ft.

Depth interval		Materials penetrated
0 - 7	ft	Gravel
7 - 24	ft	Sandy gravel
24 - 25	ft	Cobble gravel

Susquehanna River Basin Test Hole 24 (SRB 24)
at Location 4209 09 7704 46

Drilled with NY DEC hollow-stem auger rig October 22, 1985. Log based on field examination of drill cuttings. Depths are in ft below land surface. Land surface is approximately 935 ft above sea level. Finished 2-in. diameter observation well screened 22 to 27 ft below land surface. Measuring point is top of casing, 935.02 ft above sea level. Depth to water November, 1985 was 14.76 ft.

Depth interval		Materials penetrated
0 - 3	ft	Brown silt, some gravel
3 - 6	ft	Fine to medium gravel
6 - 13	ft	Sand, silt and fine gravel
13 - 14	ft	Coarse gravel
14 - 27	ft	Sand with interbedded gravel

Susquehanna River Basin Test Hole 25 (SRB 25)
at Location 4209 22 7704 50

Drilled with NY DEC hollow-stem auger rig December 6, 1983. Log based on field examination of drill cuttings. Depths are in ft below land surface. Land surface is approximately 938 ft above sea level. Finished 1.5-in. diameter PVC observation well screened 23 to 25 ft below land surface. Measuring point is top of coupling, 937.81 ft above sea level. Depth to water December, 1983 was 17.74 ft.

Depth interval		Materials penetrated
0 - 8	ft	Sand
8 - 15	ft	Clayey sand and gravel
15 - 25	ft	Sand and gravel

Susquehanna River Basin Test Hole 26 (SRB 26)
at Location 4209 38 7704 30

Drilled with NY DEC hollow-stem auger rig October 7, 1985. Log based on field examination of drill cuttings. Depths are in ft below land surface. Land surface is approximately 957 ft above sea level. Finished 2-in. diameter observation well screened 21 to 26 ft below land surface. Measuring point is top of casing, 959.69 ft above sea level. Depth to water November, 1985 was 8.42 ft.

Depth interval		Materials penetrated
0 - 10	ft	Brown medium sand and gravel
10 - 12	ft	Medium gravel with sand
12 - 14	ft	Silt with sand and gravel
14 - 19	ft	Medium to coarse gravel
19 - 33	ft	Silt, sand and gravel
33 - 42	ft	Gray clay and silt, plastic

Susquehanna River Basin Test Hole 27 (SRB 27)
at Location 4209 39 7704 32

Drilled with NY DEC hollow-stem auger rig October 8, 1985. Log based on field examination of drill cuttings. Depths are in ft below land surface. Land surface is approximately 957 ft above sea level. Finished 2-in. diameter observation well screened 52 to 57 ft below land surface. Measuring point is top of casing, 960.57 ft above sea level. Depth to water at time of drilling approximately 18 ft below land surface.

Depth interval		Materials penetrated
0 - 3	ft	Silt, trace gravel, brown
3 - 7	ft	Coarse gravel, clasts are sub-angular to sub-rounded
7 - 12	ft	Fine to medium gravel, some silt
12 - 18	ft	Fine to medium gravel
18 - 19	ft	Gravel, sand, silt; brown, wet
19 - 22	ft	Silt, some sand and gravel
22 - 27	ft	Harder drilling; tight clay?
27 - 35	ft	Silty sand and gravel
35 - 45	ft	Tight gray clay
45 - 54	ft	No returns; easy drilling (silt?)
54 - 57	ft	Sand and gravel
57	ft	Till?

Susquehanna River Basin Test Hole 28 (SRB 28) at Location 4209 47 7705 00

Drilled with NY DEC hollow-stem auger rig December 6, 1983. Log based on field examination of drill cuttings. Depths are in ft below land surface. Land surface is approximately 963 ft above sea level. Finished 1.5-in. diameter PVC observation well screened 24 to 26 ft below land surface. Measuring point is top of coupling, 962.92 ft above sea level. Depth to water at time of drilling approximately 16 ft below land surface.

Depth interval		Materials penetrated
0 - 15	ft	Gravel
15 - 20	ft	Silt sand and gravel, some clay (Till? pbb)

Susquehanna River Basin Test Hole 29 (SRB 29) at Location 4209 37 7704 58

Drilled with NY DEC hollow-stem auger rig October 22, 1985. Log based on field examination of drill cuttings. Depths are in ft below land surface. Land surface is approximately 963 ft above sea level. Finished 2-in. diameter observation well screened 35 to 40 ft below land surface. Measuring point is top of casing, 963.01 ft above sea level. Depth to water November, 1985 was 19.08 ft.

Depth interval		Materials penetrated
0 - 3	ft	Fill
3 - 4	ft	Sand and gravel with silt
4 - 9	ft	Sub-angular to sub-rounded gravel with sand
9 - 11	ft	Fine gravel and sand with some silt, clasts are well-rounded
11 - 14	ft	Fine to medium sand with some silt
14 - 16	ft	Pebble gravel and medium to coarse sand; brown
16 - 29	ft	Coarse gravel; sand and silt matrix
29 - 40	ft	Coarse gravel
40 - 42	ft	Gray clay with medium gravel; clasts are well-rounded

Susquehanna River Basin Test Hole 30 (SRB 30) at Location 4209 33 7705 27

Drilled with NY DEC hollow-stem auger rig December 1, 1983. Log based on field examination of drill cuttings. Depths are in ft below land surface. Land surface is approximately 937 ft above sea level. Finished 1.5-in. diameter PVC observation well screened 36.5 to 38.5 ft below land surface. Measuring point is top of coupling, 936.63 ft above sea level. Depth to water December, 1983 was 13.27 ft.

Depth interval		Materials penetrated
0 - 4	ft	Brown sand
4 - 11	ft	Gravel
11 - 14	ft	Silty gravel
14 - 20	ft	Gravel
20 - 29	ft	Gravel with cobbles
29 - 40	ft	Sand and gravel (wet)

Susquehanna River Basin Test Hole 31 (SRB 31) at Location 4209 41 7705 30

Drilled with NY DEC hollow-stem auger rig October 8, 1985. Log based on field examination of drill cuttings. Depths are in ft below land surface. Land surface is approximately 945 ft above sea level. Finished 2-in. diameter observation well screened 33 to 38 ft below land surface. Measuring point is top of casing, 944.89 ft above sea level. Depth to water at time of drilling approximately 20 ft.

Depth interval	Materials penetrated
0 - 8 ft	Silt, some gravel; brown
8 - 13 ft	Medium gravel with some silt
13 - 20 ft	Brown silt, trace of fine sand, some gravel (wet)
20 - 22 ft	As above with more fine sand and gravel
22 - 25 ft	Medium to coarse gravel and sand (easy drilling)
25 - 38 ft	Medium gravel, clasts are well- to sub-rounded

Susquehanna River Basin Test Hole 32 (SRB 32) at Location 4209 38 7706 02

Drilled with NY DEC hollow-stem auger rig October 9, 1985. Log based on field examination of drill cuttings. Depths are in ft below land surface. Land surface is approximately 936 ft above sea level. Finished 2-in. diameter observation well screened 32 to 37 ft below land surface. Measuring point is top of casing, 935.87 ft above sea level. Depth to water at time of drilling approximately 20 ft below land surface.

Depth interval	Materials penetrated
0 - 8 ft	Brown topsoil with sand and gravel
8 - 15 ft	Medium gravel and sand with some silt
15 - 19 ft	Hard drilling, no returns. Gravel?
19 - 25 ft	Pea-sized gravel and sand, some silt; wet
25 - 30 ft	Medium to coarse gravel; clasts are sub-rounded
30 - 36 ft	Coarse gravel; not many returns
36 - 37 ft	Hard drilling, no returns. Coarse gravel?

Susquehanna River Basin Test Hole 33 (SRB 33) at Location 4209 37 7705 57

Drilled with NY DEC hollow-stem auger rig October 9, 1985. Log based on field examination of drill cuttings. Depths are in ft below land surface. Land surface is approximately 936 ft above sea level. Finished 2-in. diameter observation well screened 32 to 37 ft below land surface. Measuring point is top of casing, 935.58 ft above sea level. Depth to water November, 1985 was 8.48 ft.

Depth interval	Materials penetrated
0 - 4 ft	Medium gravel and silt
4 - 6 ft	Brown silt and gravel
6 - 10 ft	Medium gravel, some silt
10 - 19 ft	Brown silt with some sand, some fine gravel
19 - 26 ft	No returns. Gravel?
26 - 46 ft	Gravel
46 - 52 ft	No returns; hard drilling. Gravel?

Susquehanna River Basin Test Well 34 (SRB 34) at Location 4209 22 7706 14

Drilled by Darnsadt Well Drilling, Caton, NY, with cable tool rig December 4-5, 1985. Log based on field examination of cuttings. Depths are in ft below land surface. Land surface is approximately 940 ft above sea level. Finished 6-in. diameter steel-cased observation well with open-ended casing driven about 2 ft into bedrock. Well depth is 133 ft below land surface. Measuring point is top of casing, 943.22 ft above sea level. Static water level at completion approximately 11 ft below land surface.

Depth interval	Materials penetrated
0 - 3 ft	Topsoil
3 - 10 ft	Sand and fine gravel, silty, loosely packed
10 - 16 ft	Tighter gravel, medium
16 - 33 ft	Sand and very fine gravel. Bails about 16 gal/min
33 - 110 ft	Gray silt and clay, some sand
110 - 126 ft	Very fine sand and silt, gray
126 - 131 ft	Very dirty sand and gravel; considerable silt
131 - 137 ft	Bedrock; fractured shale. Bails about 60 gal/min

Susquehanna River Basin Test Well 35 (SRB 35)
at Location 4209 38 7706 02

Drilled by Havens Well Drilling, Troy, Pa., with air rotary rig December 20, 1985. Log based on field examination of drill cuttings. Depth are in ft below land surface. Land surface is approximately 936.5 ft above sea level. Finished 6-in. diameter steel-cased observation well with open-ended casing. Well depth is 105 ft below land surface. Measuring point is top of casing, 939.58 ft above sea level. Static water level at completion about 8 ft below land surface.

Depth interval	Materials penetrated
0 - 9 ft	Topsoil
9 - 17 ft	Medium pebble gravel and very fine sand, silty; brown. Pebbles to 1 in. are very well-rounded olive siltstone. Silt increases with depth.
17 - 20 ft	Silt and very fine sand, brown.
20 - 55 ft	Pebble and small cobble gravel. Clasts to 1.5 in., predominately red siltstone, dark gray siltstone, buff very-fine-grained sandstone. Matrix material is very fine sand and silt to coarse sand, grayish-brown.
55 - 87 ft	Pebble gravel and very coarse sand, brownish gray. Pebbles are well-rounded, and less than 0.25 in. in diameter. Silty gravel at 80 ft.
87 - 96 ft	Gray silt and clay; some very fine gravel.
96 -110 ft	Pebble gravel and sand, trace of silt, gray. Pebbles are from 1 to 1.5 in., angular and broken.
110 ft	Bedrock

Susquehanna River Basin Test Well 36 (SRB 36)
at Location 4209 39 7706 00

Drilled by Havens Well Drilling, Troy, Pa., with cable tool rig December 5, 1985. Log based on field examination of drill cuttings and office examination of samples. Depths are in ft below land surface. Land surface is approximately 937.5 ft above sea level. Finished 6-in. diameter steel-cased observation well screened from 102 to 107 ft below land surface with 6-in. diameter X 5 ft 0.040-in. slot Johnson galvanized screen. Measuring point is top of casing, 939.36 ft above sea level. Depth to water at time of drilling approximately 32 ft. A 24-hour pumping test produced an average yield of 218.37 gal/min with 65.05 ft of drawdown.

Depth interval		Materials penetrated
0 - 3	ft	Topsoil
3 - 32	ft	Very fine gravel and coarse sand, brown. Pebbles are well-rounded olive and dark gray siltstone; largest pebbles are 1-in. diameter
32 - 54	ft	Coarse sand and fine-gravel; water-bearing
54 - 81	ft	Medium-grained sand, some silt. Cased off water at 60 ft
81 -105	ft	Gray silt and fine sand, some silt
105-110	ft	Gray silt and fine sand, some pebble gravel
110	ft	Bedrock

Susquehanna River Basin Test Well 37 (SRB 37)
at Location 4209 50 7705 40

Drilled by Darnsadt Well Drilling, Caton, NY, with cable tool rig December 9-10, 1985. Log based on field examination of drill cuttings. Depths are in ft below land surface. Land surface is approximately 938.5 ft above sea level. Finished 6-in. diameter steel-cased observation well with open-ended casing. Well depth is 97 ft below land surface. Measuring point is top of casing, 942.04 ft above sea level. Depth to water at time of drilling approximately 35 ft.

Depth interval		Materials penetrated
0 - 5	ft	Silty loam
5 - 19	ft	Pebble gravel, coarse sand, some clay
19 - 32	ft	Brown silt and clay, some sand and very fine gravel
32 - 47	ft	Brown pebble gravel and coarse sand; water-bearing
47 - 70	ft	Coarser gravel, clean, makes clear water
70 - 76	ft	Predominantly medium to coarse sand, some silt, with interbeds of very fine gravel
76 - 96	ft	Fine gravel
96	ft	Bedrock

Susquehanna River Basin Test Well 38 (SRB 38)
at Location 4209 26 7704 44

Drilled by Havens Well Drilling, Troy, Pa., with cable tool rig December 10-13, 1985. Log based on field examination of drill cuttings. Depths are in ft below land surface. Land surface is approximately 942 ft above sea level. Finished 6-in. diameter steel-cased observation well screened from 85 to 90 ft below land surface with 6-in. diameter X 5 ft 0.060-in. slot stainless steel Johnson screen. Measuring point is top of casing, 944.15 ft above sea level. Depth to water at time of drilling was 17.95 ft. A 24-hour pumping test produced an average 233.68 gal/min with 15.35 ft of drawdown.

Depth interval		Materials penetrated
0 - 16	ft	Fill
16 - 27	ft	Brown very-fine gravel, some sand, silty
27 - 30	ft	Gray gravel and clay
30 - 42	ft	Gray pebble gravel and coarse sand
42 - 62	ft	Predominantly medium sand, with very well-rounded pebbles, largest about 1-in. diameter; matrix supported.
62 - 90	ft	Medium to coarse sand; some pebble gravel with very well-rounded clasts, largest are cobble-sized.
90 - 91	ft	Flowing sand, fine
91 - 92	ft	Pebble gravel
92	ft	Bedrock

Susquehanna River Basin Test Well 39 (SRB 39)
at Location 4209 16 7704 01

Drilled by Darnsadt Well Drilling, Caton, NY, with cable tool rig December 12-13, 1985. Log based on field examination of drill cuttings and office examination of samples. Depths are in ft below land surface. Land surface is approximately 929 ft above sea level. Finished 6-in. diameter steel-cased observation well screened from 75 to 80 ft below land surface with 6-in. diameter X 5 ft 0.060-in. slot Johnson galvanized screen. Measuring point is top of casing, 936.61 ft above sea level. Depth to water at time of drilling was 21.05 ft. A 24-hour pumping test produced an average 193 gal/min with 20.45 ft of drawdown.

Depth interval	Materials penetrated
0 - 2.5 ft	Topsoil
2.5- 5 ft	Clay, originally transported there for a racetrack
5 - 19 ft	Loosely-packed brown pebble gravel and sand, some silt. 12-16 ft has well-rounded clasts as large as 2-in. diameter. Sand is predominantly coarse, some medium.
19 - 37 ft	Sand and gravel; 26 to 27 ft gravel is pea-sized, well-rounded, some silt; 30 to 34 ft finer gravel and very coarse sand, trace silt.
37 - 39 ft	Clay and gravel; largest clasts are 0.25-in. diameter, subangular siltstone
39 - 40 ft	Coarser gravel
40 - 50 ft	Gravel and coarse sand
50 - 70 ft	Sand, coarse to fine, trace very fine gravel and silt
70 - 80 ft	Gravel and medium to coarse sand, silty
80 - 83 ft	Very clean medium sand, some very fine gravel
83 ft	Bedrock

Susquehanna River Basin Test Well 40 (SRB 40)
at Location 4209 08 7703 38

Drilled by Darnsadt Well Drilling, Caton, NY, with cable tool rig December 16-19, 1985. Log based on field examination of drill cuttings and office examination of samples. Depths are in ft below land surface. Land surface is approximately 926 ft above sea level. Finished 6-in. diameter steel-cased observation well with open-ended casing. Well depth is 90 ft below land surface. Measuring point is top of casing, 928.72 ft above sea level. Depth to water at time of drilling was 24.65 ft. A 24-hour pumping test produced an average 87 gal/min with 28.29 ft of drawdown.

Depth interval		Materials penetrated
0 - 5	ft	Topsoil and fill
5 - 10	ft	Coarse gravel and sand
10 - 27	ft	Medium gravel with considerable silt and clay
27 - 60	ft	Fine gray sand and silt with many cobbles; water-bearing; finer at 38 ft. Cased-off water at 39 ft.
60 - 70	ft	Sandy silt and clay
70 - 79	ft	Gravel and sand
79 - 90	ft	Sandy gravel, very bright; estimated yield of 100 gal/min
90 - 93	ft	Gravel; as above with less sand
93	ft	Bedrock

Susquehanna River Basin Test Well 41 (SRB 41)
at Location 4208 56 7703 07

Drilled by Havens Well Drilling, Troy, Pa., with cable tool rig December 16, 1985. Log based on field examination of drill cuttings and office examination of samples. Depths are in ft below land surface. Land surface is approximately 926 ft above sea level. Finished 6-in. diameter steel-cased observation well screened from 57 to 62 ft below land surface with 6-in. diameter

X 5 ft 0.030-in. slot galvanized Johnson screen. Measuring point is top of casing, 927.75 ft above sea level. Depth to water at time of drilling was approximately 18 ft. An 8-hour pumping test produced an average yield of 250 gal/min with 10.69 ft of drawdown.

Depth interval		Materials penetrated
0 - 5	ft	Silty loam
5 - 17	ft	Dark brown silt and clay; trace of pebble gravel at 17 ft. Pebbles are well-rounded, approximately 0.75-in. diameter.
17 - 20	ft	Sand and gravel, some silt
20 - 32	ft	Coarse gravel with cobbles, brownish gray. Matrix is very coarse sand and silt; clasts are very well-rounded.
32 - 40	ft	Fine to very fine sand, brown
40 - 60	ft	Sand; 40 to 46 ft coarse sand; 46 to 60 ft coarse and medium sand, some fine sand. Many sand grains are rock fragments.
60 - 62	ft	Sand, coarser than above, some fine gravel. Pebbles are very well-rounded.
62	ft	Bedrock

Susquehanna River Basin Test Well 42 (SRB 42)
at Location 4209 41 7703 20

Drilled by Havens Well Drilling, Troy, Pa., with air rotary rig December 18, 1985. Log based on field examination of drill cuttings and office examination of samples. Depths are in ft below land surface. Land surface is approximately 942 ft above sea level. Finished 6-in. diameter steel-cased observation well screened from 52 to 57 ft below land surface with 6-in. diameter X 5 ft 0.080-in. slot stainless steel Johnson screen. Measuring point is top of casing, 946.03 ft above sea level. Depth to water at time of drilling was 39.95 ft. A 7-hour pumping test produced an average yield of 45 gal/min with 16.3 ft of drawdown.

Depth interval		Materials penetrated
0 - 11	ft	Fill
11 - 14	ft	Dark gray pebble gravel and some very fine sand; clasts are angular, approximately 0.5-in. diameter. Water-bearing.
14 - 16	ft	Gray silt with some fine gravel
16 - 31	ft	Gray silt and clay
31 - 36	ft	Silty pebble gravel and some coarse sand, gray; largest clasts are 1-in. diameter and very well-rounded.
36 - 40	ft	Very silty pebble gravel, gray; clasts are larger than above
40 - 48	ft	Clean pebble gravel and sand, water-bearing. Clasts are dark gray siltstone, very well-rounded, up to 1.5-in. diameter. Sand is coarse to fine, very clean.
48 - 50	ft	Very silty pebble gravel, gray
50 - 57	ft	Fine gravel and coarse sand, with trace of silt
57	ft	Bedrock

Susquehanna River Basin Test Well 43 (SRB 43) at Location 4208 52 7702 27

Drilled by Darnsadt Well Drilling, Caton, NY with cable tool rig December 20-23, 1985. Log based on field examination of drill cuttings and office examination of samples. Depths are in ft below land surface. Land surface is approximately 920.5 ft above sea level. Finished 6-in. diameter steel-cased observation well with open-ended casing. Well depth is 78 ft below land surface. Measuring point is top of casing, 923.15 ft above sea level. Depth to water March, 1986 was 8.65 ft.

Depth interval		Materials penetrated
0 - 12	ft	Brown silty loam and some sand
12 - 20	ft	Brown silty gravel; largest clasts are 0.75-in. diameter and very well-rounded
20 - 51	ft	Gray silty very coarse sand and very fine gravel; some fine sand at 46 to 51 ft
51 - 64	ft	Silty fine gravel, grayish brown, some coarse to fine sand. Largest pebbles are 0.75-in. diameter.
64 - 74	ft	Very silty, very coarse sand and very fine gravel
74 - 83	ft	Sand and silt, medium to fine and brownish gray
83 - 88	ft	Very coarse sand, not as silty as above; dark gray
88	ft	Bedrock

Susquehanna River Basin Test Well 44 (SRB 44)
at Location 4208 11 7702 15

Drilled by Darnsadt Well Drilling, Caton, NY, with cable tool rig December 27-28, 1985. Log based on field examination of drill cuttings and office examination of samples. Depths are in ft below land surface. Land surface is approximately 914.5 ft above sea level. Finished 6-in. diameter steel-cased observation well with open-ended casing. Well depth is 80 ft below land surface. Measuring point is top of casing, 917.99 ft above sea level. Depth to water January, 1986 was 6.92 ft.

Depth interval		Materials penetrated
0 - 5	ft	Loam
5 - 20	ft	Sandy, fine to medium gravel, grayish brown
20 - 25	ft	Silt and gravel, gray. Largest clasts are 0.25-in. diameter, sub-angular to rounded
25 - 60	ft	Clean gravel, grayish brown
60 - 70	ft	Sand, medium to coarse, with trace of very fine gravel
70 - 82	ft	Sand and gravel; clean; brownish gray. Gravel is comprised of very well-rounded rock fragments.
82 - 83	ft	Very coarse gravel with dark gray matrix of very coarse sand; some cobbles larger than 2-in. diameter

SUSQUEHANNA RIVER BASIN COMMISSION

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