# HYDROGEOLOGY OF GLACIAL DRIFT IN THROUGH VALLEYS NEAR DRYDEN AND CORTLAND, NEW YORK

TODD S. MILLER AND ALLAN D. RANDALL

U.S. Geological Survey

## INTRODUCTION

The Appalachian Plateau physiographic province encompases nearly all of southwestern New York (fig. 1, inset). About 85 percent of this region consists of till-mantled bedrock uplands; the remainder consists of broad valleys that are partly filled with stratified drift. The stratified drift includes coarse-grained sand and gravel deposits that are the only highly productive aquifers in the region; it also includes extensive fine-grained sediments that do not yield usable amounts of water. The divide between streams that drain northward to Lake Ontario and those that drain southward to the Susquehanna River crosses some of these broad valleys, which are termed "through valleys" because they are continuous across a major topographic divide. An area of unusually hummocky topography near the divide in each through valley suggests the former presence of buried ice; these areas were collectively termed the Valley Heads moraine by Fairchild (1932).

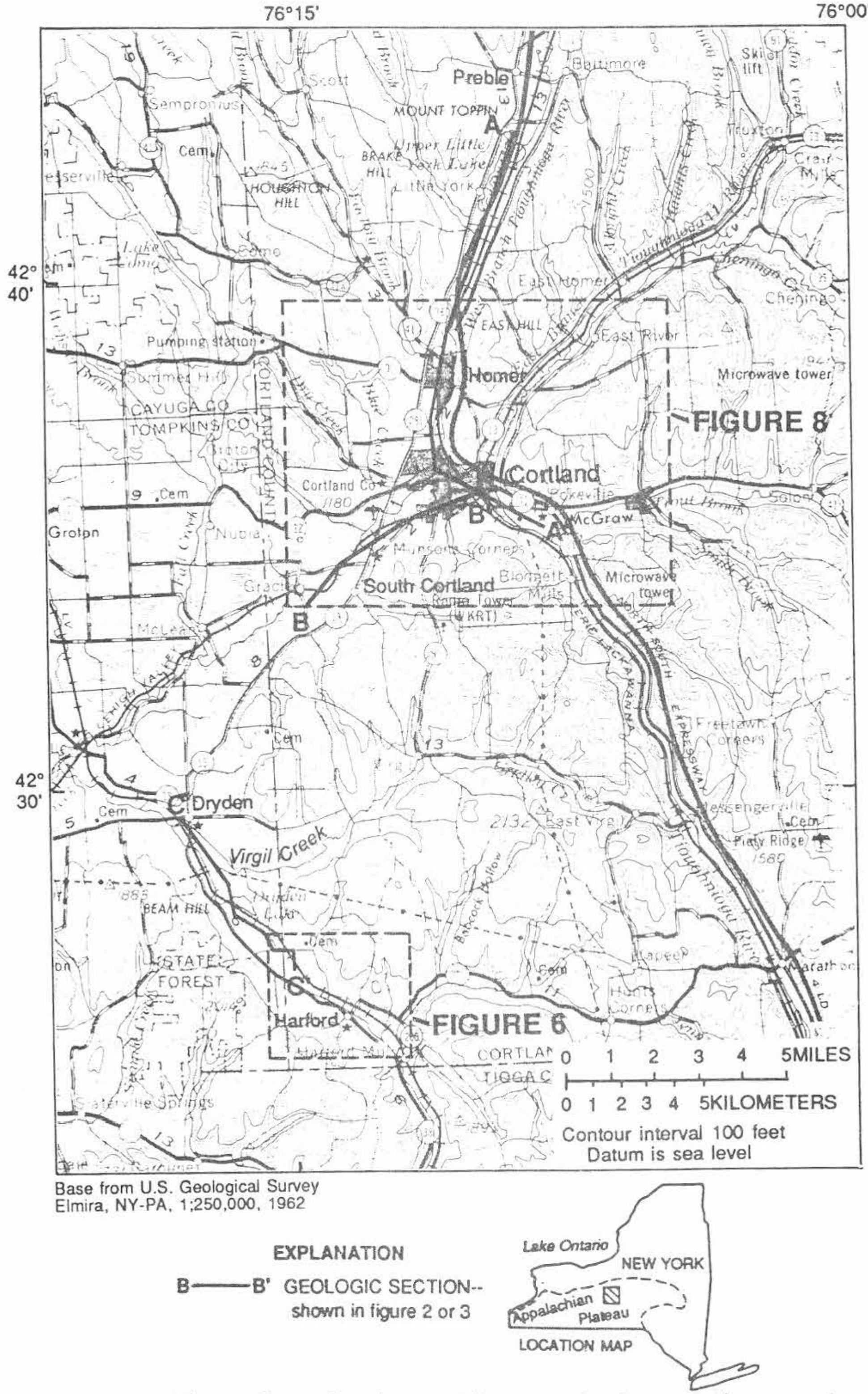
This article briefly describes current concepts of (1) the stratigraphy of stratified-drift aquifers and confining units in valleys within and south of the Valley Heads moraine, (2) recharge to those aquifers, and (3) their potential for use as sources of large water supplies during dry periods. These concepts were developed over the past few years from geohydrologic studies, cited herein, that emphasized or included valleys near Dryden, Harford, and Cortland (fig. 1). The article concludes with the log of a field trip that is intended to illustrate several of these concepts and to offer an opportunity for discussion of what is and is not known about these aquifer systems.

## SOME GENERALIZATIONS ABOUT STRATIGRAPHY OF THE DRIFT IN VALLEYS OF THE APPALACHIAN PLATEAU

Valley fills south of the Valley Heads moraine consist of three facies:

1. Early facies: coarse sand and gravel that was deposited against the ice sheet as deltaic kame terraces along the valley sides and(or) as subaqueous fans atop bedrock in midvalley.
2. Middle facies: fine-grained sediment that was deposited in large lakes beyond the edge of the ice sheet.
3. Late facies: outwash and(or) postglacial alluvial deposits that constitute a surfical layer of coarse sand and gravel.

These facies are time-transgressive; that is, while meltwater was depositing early ice-contact sand and gravel in one reach, it was also depositing middle and(or) late facies in other reaches downvalley. The three facies form a characteristic stratified-drift stratigraphy (coarse over fine over coarse) in many valley reaches, although all three facies are not present at every location. In general, the greater the depth to bedrock, the greater the thickness of lacustrine clay, silt, and fine sand within the valley fill. Although depth to bedrock in valleys of the Susquehanna River basin ranges from 70 feet to as much as 500 feet, the thickness of water-yielding coarse sand and gravel rarely exceeds 150 feet and is commonly much less. Therefore, thickness and transmissivity of stratified-drift aquifers in these valleys is unlikely to correlate well



Base from U.S. Geological Survey
Elmira, NY-PA, 1;250,000, 1962

EXPLANATION

B——B' GEOLOGIC SECTION--shown in figure 2 or 3

Figure 1.--Location of geologic sections and places discussed.

with depth to bedrock. Geologic sections at Cortland (fig. 2) are typical of many valley reaches south of the Valley Heads moraine. Surficial outwash tends to be especially thick close to the moraine, as shown in section B-B' (fig. 2).

Valley fills within the Valley Heads moraine are commonly a few hundred feet thick, and have been described as consisting mostly of till and fine-grained lacustrine sediment, with scattered thin lenses of coarse sand and gravel (Crain, 1974, p. 70-71; MacNish and Randall, 1982). The inferred distribution of surficial and buried stratified-drift aquifers is depicted on a map by MacNish and Randall (1982) that encompasses the Susquehanna River basin and on a map by Miller (1988) that encompasses all of central New York. Several geologic sections representing aquifer geometry in valleys near Cortland are given by Miller and others (1981) and Reynolds (1987).

## STRATIGRAPHY IN THROUGH VALLEYS WITHIN AND NEAR THE VALLEY HEADS MORAINE

This article describes two through valleys within and near the Valley Heads moraine; one is in the towns of Harford and Dryden, the other extends from the city of Cortland southwestward into the town of Cortlandville.

### Valley at Harford and Dryden

The stratigraphy of the valley fill in Harford and Dryden is depicted in figure 3 in a geologic section and a summary diagram. The drift in this valley is predominantly till and lake deposits interlayered with less abundant sand and gravel. From land surface to a depth of 100 feet, till forms about 50 percent of the drift, lake deposits 20 percent, and sand and gravel 30 percent. From depths of 100 to 300 feet, lake deposits are slightly more abundant than till, and only small amounts of sand and gravel are present. Coarse sand and gravel is present as multiple discontinuous layers, each generally less than 15 feet thick. The dashed lines in figure 3 are speculative and suggest more continuity than may actually be present. The sand and gravel might have originated in several ways:

1. As Collapsed Outwash. Meltwater might have deposited south-sloping outwash (valley trains), in part over buried ice. When the ice melted, the outwash collapsed to altitudes lower than the present divide. The stratigraphy and altitude of layers penetrated by the five southernmost boreholes in figure 3 are similar enough to suggest such an origin.

2. As Interstadial Alluvium. Alluvium must have been deposited by generally northward-draining local streams during intervals between ice advances. Such deposits could be expected to slope toward the valley axis (where deposited by tributaries) and northward along the valley axis. Also, they probably contain mostly fragments of local bedrock, because till in the uplands and alluvium of tributaries from the uplands contain few exotic stones derived from regions to the north. The slope and pebble content of the thin surficial deposits labeled Sd (fig. 3) and discontinuous lenses labeled C1 (fig. 3) are generally consistent with such an origin.

3. As Subglacial Channels or Fans. The sand and gravel layers north of the divide that lie below the altitude of the divide might have been deposited by south-draining meltwater, in subglacial channels, or as

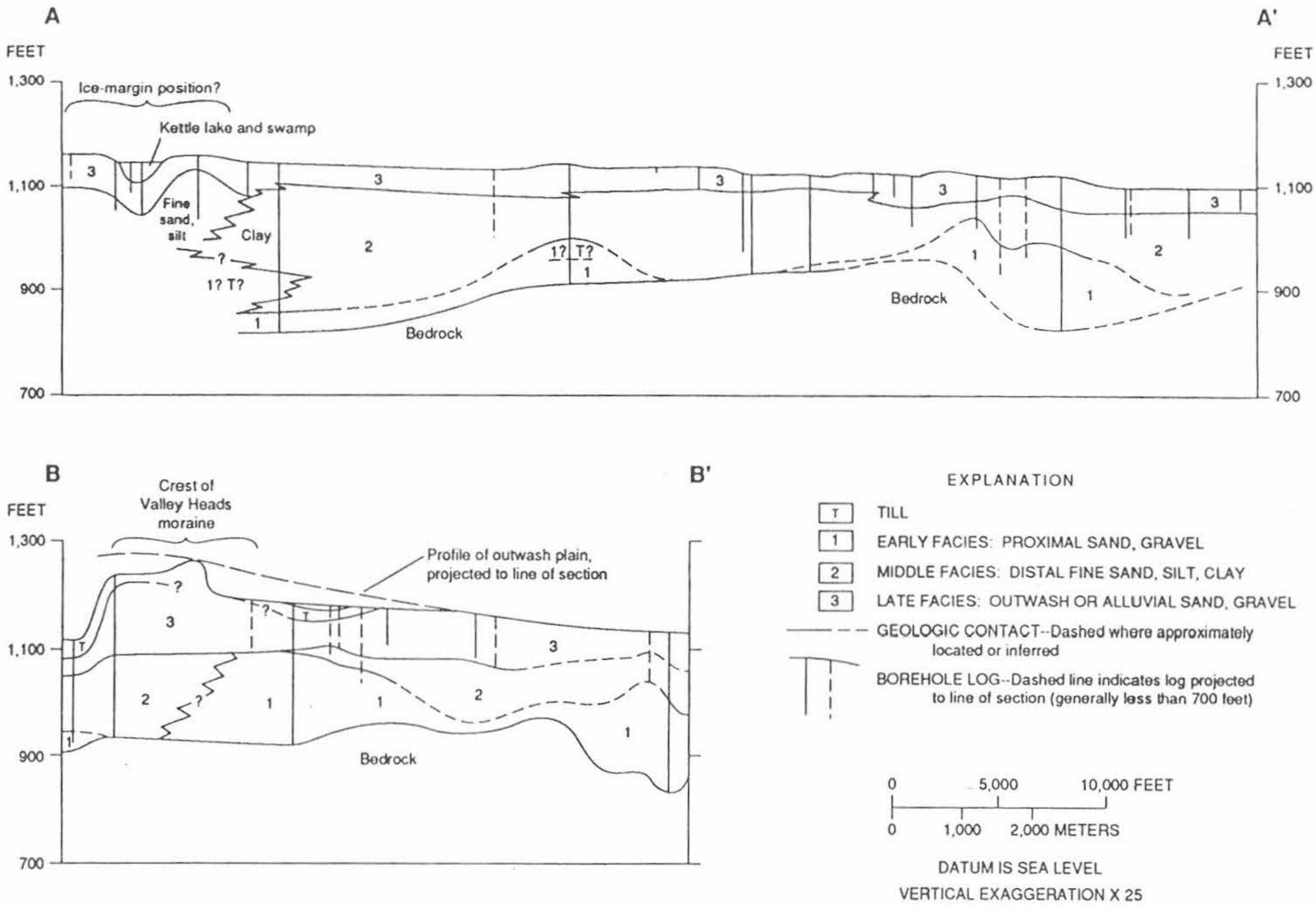


Figure 2.--Geologic sections near Cortland. Traces of sections are shown in figure 1. Logs and exact locations of most boreholes are given in Reynolds (1987), Miller and others (1981), or references cited therein; a few are recent unpublished data (T.S. Miller, U.S. Geological Survey).

A-A': Along West Branch Tioughnioga River valley at Homer and Preble, and Tioughnioga River Valley at Cortland.

B-B': Along Otter Creek-Dry Creek valley at Cortland and South Cortland. Meltwater spilling across the moraine late in deglaciation lowered land surface below the outwash plain in midvalley.

subaqueous fans where the channels emptied into a proglacial lake. Fans deposited in large proglacial water bodies during deglaciation have been widely reported in the literature (Thompson and Smith, 1983; DeSimone and LaFleur, 1986; Miller, in press) but are probably not a major component of the drift here. The downward-coarsening stratigraphy (lake fines over sand and gravel over till) that characterizes subaqueous fans at a retreating ice margin is not prominent in figure 3, and, as noted earlier, lake deposits form only 20 percent of the upper 100 feet of drift.

4. As Kame Moraine Derived from Stagnant Ice. North of Dryden Lake is an area of hummocky moraine that consists of diamicton (till or debris-flow deposits) and fluvial and lacustrine deposits. The composition and complex interlayering of these deposits (fig. 4) suggests ablation, resedimentation by mass movements, and the inversion of topography that occurs when debris slides off high parts of the ice surface and accumulates in low places, only to become topographic highs after the ice melts. Lake deposits and subaqueous fans are not prominent in the section; if proglacial lakes formed during retreat of the later ice sheets, perhaps the water drained away through tunnels or crevasses before most of the ice melted. Thereafter, localized deposition from and upon stagnant ice would have predominated. Layers C4, C5, and parts of C3 (fig. 3) contain a substantial percentage of exotic pebbles, suggesting deposition by streams flowing from a melting ice tongue (rather than by tributaries from the uplands). They also have hummocky top surfaces that include southward slopes and are suggestive of kames. The water level in layer C4 in the spring is as much as 12 feet higher than that in C3, suggesting that C4 is connected to some source of recharge at higher elevation, most likely kame terraces or kame moraine on the valley side.

Among the notable geologic aspects of the stratigraphy in Dryden Lake-Harford valley is the surficial or near-surficial till layer near the divide (D1 in figs. 3 and 4). After more than 100 feet of sand and gravel had accumulated in Harford valley south of the divide, the last glacial event was a readvance that extended more than a mile south across outwash (fig. 3). The ice then dissipated, leaving no lacustrine sediment and only minimal outwash. (Much of the sand and gravel that locally overlies the till layer is postglacial alluvial-fan deposits). The absence of surficial lake beds implies that the ice of the last readvance was thin and that, before a large lake could form between the ice and the saddle at Harford, the ice stagnated to the point that meltwater drained northward and westward through crevasses to some lower saddle. Surficial or near-surface diamicton layers that extend a short distance south over outwash have been observed in several other valleys along the Valley Heads moraine, which suggests some regional pattern of ice dynamics, perhaps a surge (Randall and others, 1988).

### Otter Creek-Dry Creek Valley at Cortland

At the crest of the Valley Heads moraine southwest of Cortland, 60 to 100 feet of surficial outwash and ice-contact sand and gravel were deposited during the Valley Heads glaciation (unit 3 in fig. 2B). These sediments overlie less permeable silty sand and gravel that may correlate with kame deposits that mantle the bedrock hillside at South Cortland and were deposited during the older (Olean) glaciation. Records of wells that penetrate the moraine indicate a discontinuous till layer near or at land surface that was deposited during a readvance of ice during the late stages

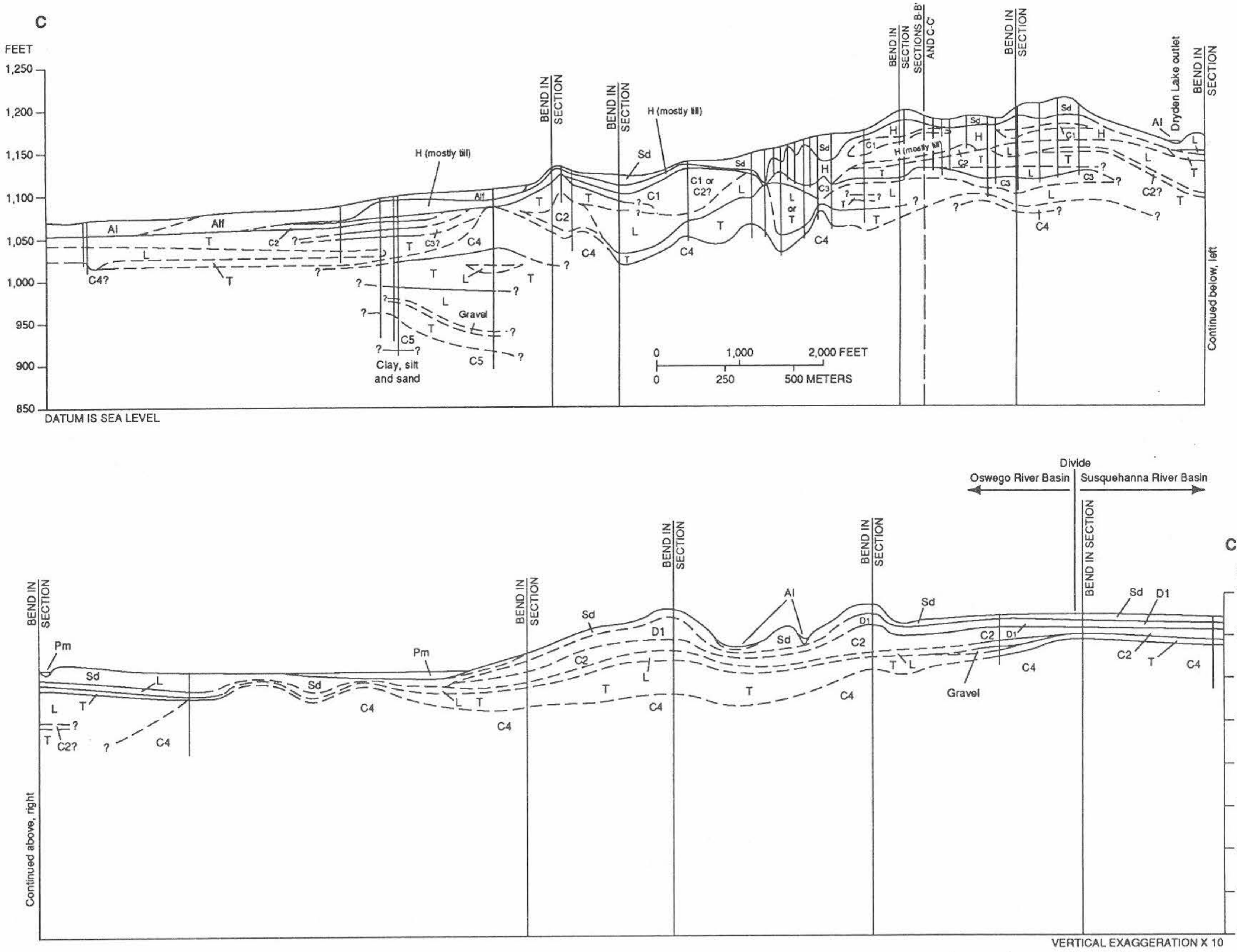
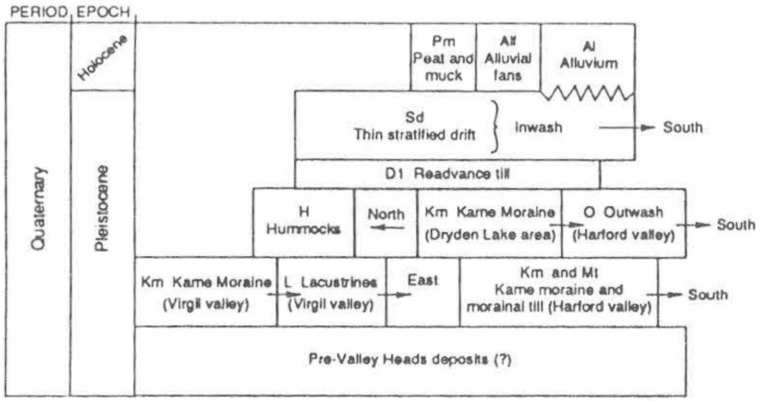


Figure 3.--Geologic section C-C' along Dryden Lake-Harford valley. Trace of section shown in figure 1. Diagram depicts correlation of deposits; arrows and compass points indicate direction of meltwater drainage away from each deposit. (Modified from Miller, in press; identification, narrative logs, and exact locations of boreholes are given therein.)

# EXPLANATION

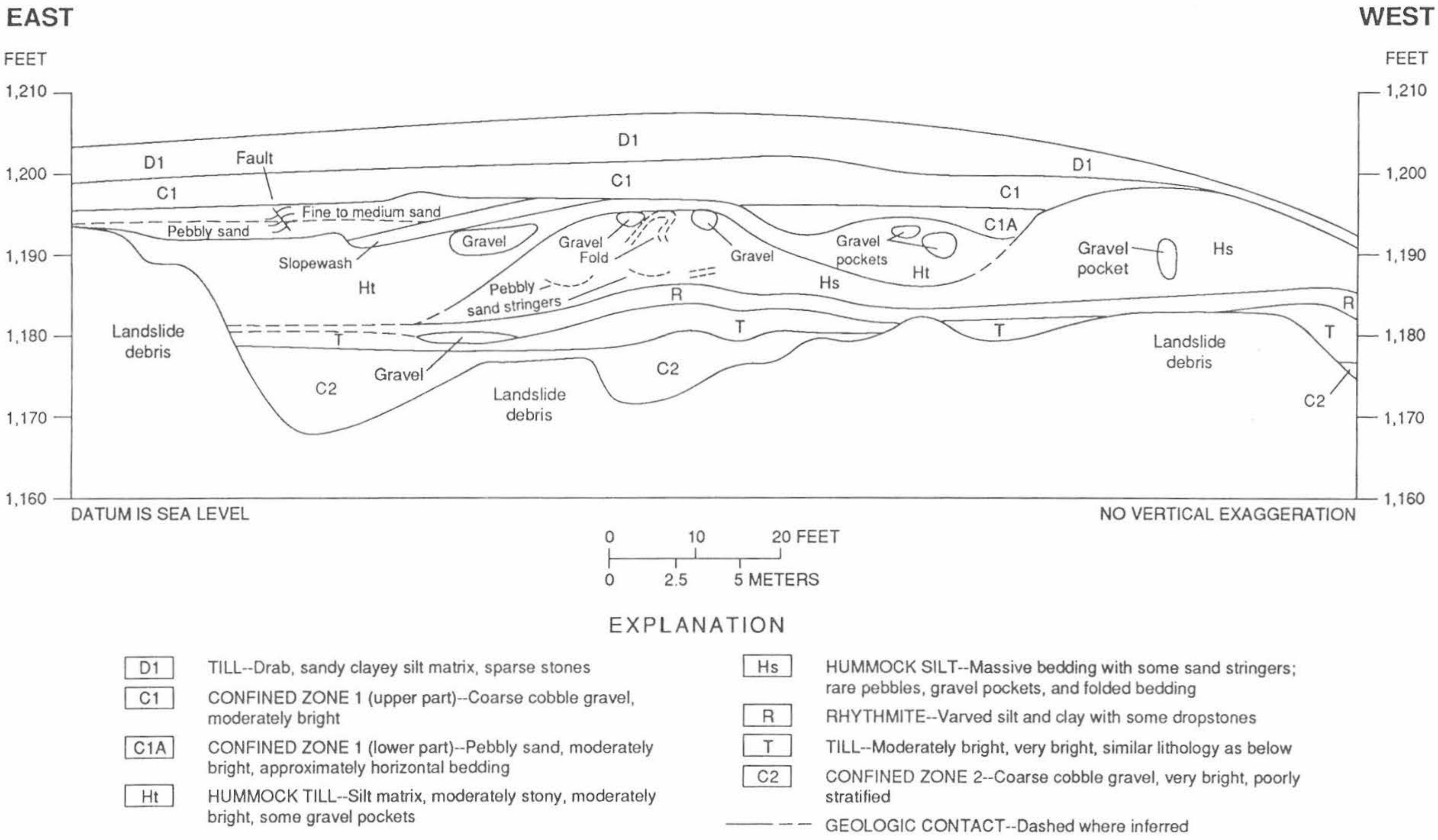
| | |
|---|---|
| Sd | STRATIFIED DRIFT--Alluvial, kame, outwash, and inwash sand and gravel deposited during retreat of last Valley Heads readvance; typically 3 to 10 feet thick; generally unsaturated except in low areas which have unconfined conditions |
| Al | ALLUVIAL CHANNEL AND FLOOD-PLAIN DEPOSITS--Mostly gravel and sand that may be overlain or interbedded with overbank silt |
| Alf | ALLUVIAL FAN--Gravel and sand |
| Pm | PEAT AND ORGANIC-RICH SILT--Deposited in kettles |
| D1 | DRAB TILL--Uppermost till deposited during last readvance |
| H | HUMMOCKS--Complex of till and debris flow, glaciofluvial and glaciolacustrine deposits |
| T | TILL--May be any till unit older than D1; moderate to bright clasts |
| L | LAKE DEPOSITS--Fine sand, silt, and clay |
| K | KAME--Ice-contact deposit of sand and gravel |



## CONFINED WATER-YIELDING ZONES

| | |
|---|---|
| C1 | CONFINED ZONE 1--Thin and discontinuous sand and gravel lenses that underlie the upper till in the hummocky area in the central part of the aquifer; drab pebbles suggest an alluvial or inwash origin; partly or seasonally saturated |
| C2 | CONFINED ZONE 2--Thin and discontinuous sand and gravel; bright pebbles suggest a glaciofluvial origin such as outwash or ice-contact deposits |
| C3 | CONFINED ZONE 3--Semicontinuous to continuous sand and gravel in the northern part of the study area; origin is uncertain |
| C4 | CONFINED ZONE 4--Continuous and sand and gravel; an undulating surface and bright clasts suggest an ice-contact origin such as kames |
| C5 | CONFINED ZONE 5--Extent determined only in a small area in the northern part of the study area; consists of silty sand and gravel; bright pebbles and an upper surface that slopes to the southeast suggest an ice-contact origin |
| ——— — — | GEOLOGIC CONTACT--Dashed where approximate |
| ⊤ | BOREHOLE--Log available |

Figure 3.--Geologic section C-C' along Dryden Lake-Harford valley. Trace of section shown in figure 1. Diagram depicts correlation of deposits; arrows and compass points indicate direction of meltwater drainage away from each deposit. (Modified from Miller, in press; identification, narrative logs, and exact locations of boreholes are given therein.) (continued)



| | |
|---|---|
| D1 | TILL--Drab, sandy clayey silt matrix, sparse stones |
| C1 | CONFINED ZONE 1 (upper part)--Coarse cobble gravel, moderately bright |
| C1A | CONFINED ZONE 1 (lower part)--Pebbly sand, moderately bright, approximately horizontal bedding |
| Ht | HUMMOCK TILL--Silt matrix, moderately stony, moderately bright, some gravel pockets |
| Hs | HUMMOCK SILT--Massive bedding with some sand stringers; rare pebbles, gravel pockets, and folded bedding |
| R | RHYTHMITE--Varved silt and clay with some dropstones |
| T | TILL--Moderately bright, very bright, similar lithology as below |
| C2 | CONFINED ZONE 2--Coarse cobble gravel, very bright, poorly stratified |
| ——— – – | GEOLOGIC CONTACT--Dashed where inferred |

Figure 4.--Sketch of cutbank along Virgil Creek at Southworth Road, Dryden (stop 8), as exposed in 1984. (From Miller, in press, fig. 8.)

of Valley Heads glaciation. The till layer also mantles the lower parts of the kame deposits on the hillsides. The buried kame deposits consist largely of poorly sorted, silty sand and gravel with silt lenses; therefore, hydraulic conductivity and well yields are smaller than those typical of the surficial outwash. For example, a test-drilling program to locate a water supply at an industrial property included installation of eight test wells and test borings, but the two most productive sites yield only modest amounts of water -- 150 gallons per minute with 22 feet of drawdown, and 235 gallons per minute with 17 feet of drawdown.

The valley fill at the proximal (back or western) side of the Valley Heads moraine at South Cortland consists mostly of fine-grained sediments (such as till and lacustrine fine sand, silt, and clay) with only small amounts of sand and gravel. Water-supply wells at a fish hatchery at Gracie Road (fig. 1) penetrated mostly till and lacustrine sediment, then relatively thin confined aquifers at depths of 130 to 200 feet below land surface. These confined aquifers also yield moderate amounts of water (100 to 200 gallons per minute) to production wells.

Meltwater issuing from the Valley Heads ice deposited 45 to 100 feet of well-sorted coarse sand and gravel as outwash in front of the moraine. The outwash extends northeastward from the crest of the moraine at South Cortland to the eastern part of Cortland and then follows the Tioughnioga River valley to the southeast (fig. 2). Outwash overlies an extensive fine-grained lacustrine layer 60 to 150 feet thick that, in turn, overlies a basal sand and gravel zone atop bedrock. The basal sand and gravel is 10 to 30 feet thick in the Cortland-Homer-Preble valley, but is 50 to 170 feet thick in Otter Creek valley, southwest of Cortland (Section B-B', fig. 2; see also Miller and others, 1981). The surficial outwash aquifer is highly productive and capable of yielding several thousand gallons per minute to large-diameter wells. For example, the city of Cortland wellfield pumps 4.0 million gallons of water per day, and individual wells at the well field can pump 2,000 to 4,000 gallons per minute. Horizontal hydraulic conductivity of the surficial outwash aquifer is greatest, 1,000 to 2,000 feet per day, near the head of the outwash at South Cortland and decreases with increasing distance from the moraine. It is 1,000 feet per day in the central part of Cortland and 500 feet per day further east near the Tioughnioga River (Cosner and Harsh, 1978; Reynolds, 1987).

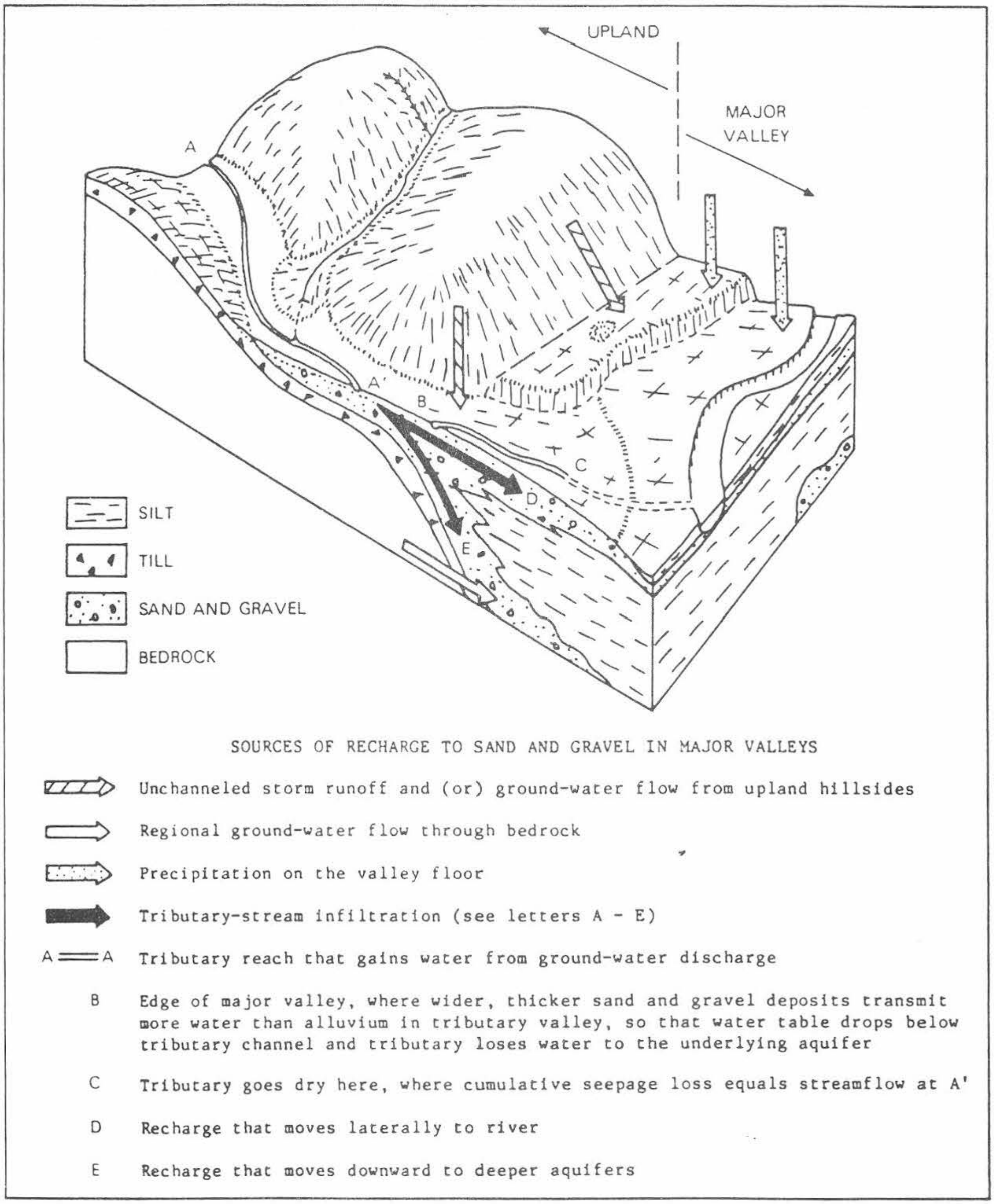
## SOURCES OF RECHARGE TO STRATIFIED DRIFT IN VALLEYS OF THE APPALACHIAN PLATEAU

Under natural (unpumped) conditions, surficial stratified-drift aquifers in the Appalachian Plateau receive recharge from the three sources listed below, as illustrated in figure 5 and explained by MacNish and Randall (1982), Morrissey and others (1988), and others.

1. Infiltration of precipitation on the aquifer. Part of the precipitation on surficial sand and gravel is returned to the atmosphere by evapotranspiration, but the remainder infiltrates to become recharge, except in ponds or swamps, where the water table is at land surface and precipitation runs off directly to streams.

2. Runoff from upland hillsides that border the aquifer. Most stratified-drift aquifers are bordered by hillsides of till-covered bedrock. Till in the Appalachian Plateau contains a large percentage of silt and clay and is poorly permeable, so only a small part of rain and snowmelt can

infiltrate beyond the top foot or two. The excess water moves downslope in rivulets or through shallow openings in the soil. Where a stratified-drift aquifer lies at the base of the hillside, runoff infiltrates the permeable sand and gravel and percolates to the water table. Where a stream channel abuts the base of the hillside, the runoff enters the



SOURCES OF RECHARGE TO SAND AND GRAVEL IN MAJOR VALLEYS

Unchanneled storm runoff and (or) ground-water flow from upland hillsides

Regional ground-water flow through bedrock

Precipitation on the valley floor

Tributary-stream infiltration (see letters A - E)

A ═ A Tributary reach that gains water from ground-water discharge

B Edge of major valley, where wider, thicker sand and gravel deposits transmit more water than alluvium in tributary valley, so that water table drops below tributary channel and tributary loses water to the underlying aquifer

C Tributary goes dry here, where cumulative seepage loss equals streamflow at A'

D Recharge that moves laterally to river

E Recharge that moves downward to deeper aquifers

Figure 5.--Sources of recharge to stratified drift in valleys of the Appalachian Plateau. (From Morrissey and others, 1988, fig. 1.)

stream. In addition to hillside runoff, a small but steady flow of ground water moves through the bedrock from upland areas toward the major valleys and into the stratified drift.

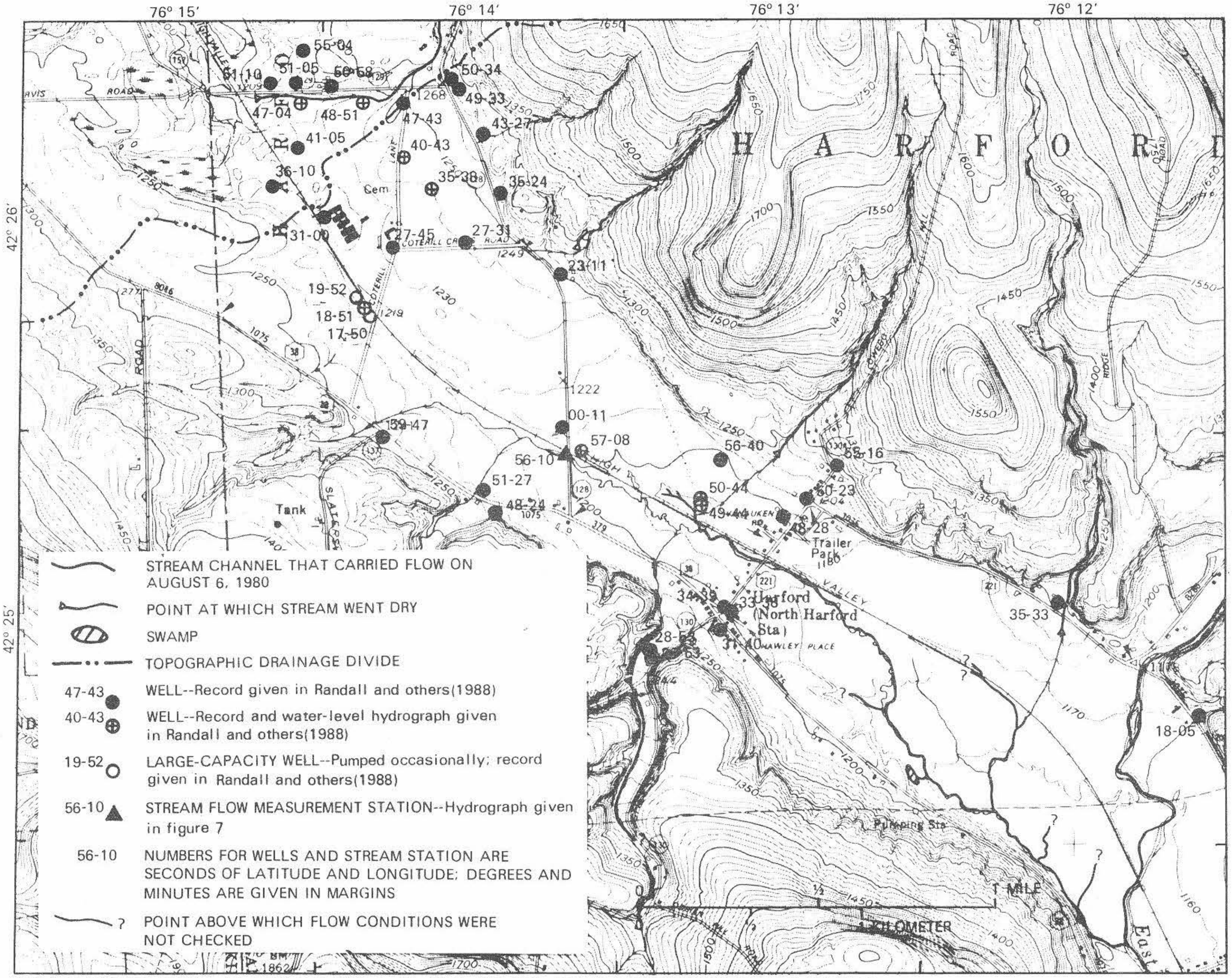
3. Infiltration from upland tributary streams. Several studies have shown that tributary streams draining upland basins can be important sources of recharge to stratified drift. Small streams in the Appalachian Plateau of New York go dry seasonally because their flow seeps into the streambed where they leave their upland valleys and cross stratified drift or alluvial fans in the larger valleys. This phenomenon was noted by Wetterhall (1959) as a source of recharge and described by Ku and others (1975) as a typical feature of the region. Crain (1966) demonstrated that seepage from tributaries on alluvial fans near the sides of Cassadaga Creek Valley in southwestern New York is a principal source of recharge to a gravel layer tapped by municipal wells beneath 100 feet of silt and clay. Randall (1978) investigated the magnitude and distribution of seepage from tributary streams in south-central New York and concluded that seepage rates were small at the edges of the main valley but were at least 1 cubic foot per second per 1,000 feet of channel farther downstream. More recent studies in the Appalachian Plateau of Pennsylvania (Williams, 1991) led to similar conclusions.

After reviewing studies of recharge in several localities, Morrissey and others (1988) concluded that upland runoff can be the largest source of recharge to stratified-drift aquifers under natural conditions in much of the glaciated Northeast. The percentage of recharge derived from upland sources tends to increase as topographic relief increases and valley width decreases. In areas of moderate to high relief, such as the Appalachian Plateau, upland runoff typically provides at least 75 percent of total natural recharge to valleys $^1/_2$ mile wide, and at least 60 percent to valleys 1 mile wide.

## Recharge from Tributary Streams in Through Valley at Harford

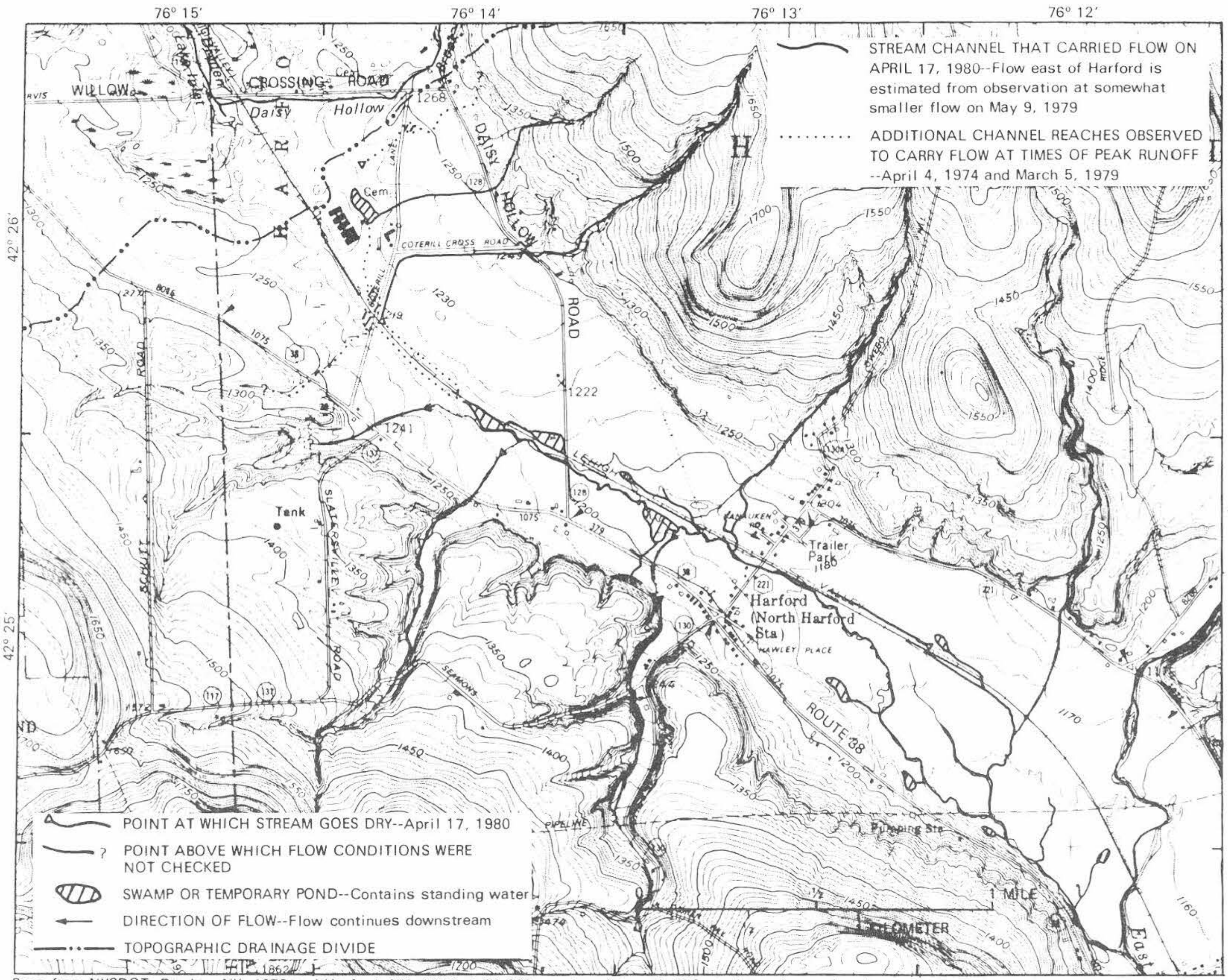
The distribution of streamflow in Harford valley is a function of geologic conditions (Randall and others, 1988). Small streams originate in the uplands, lose water by seepage as they flow across stratified drift in the valley, and during much of the year cease flowing a short distance downstream from where they begin to cross the stratified drift (fig. 6A). Occasionally, however, during the spring snowmelt period and during periods of unusually heavy rain, water becomes ponded in low-lying areas, upland tributaries flow continuously to the valley axis, and streamflow eastward along the valley axis begins just west of Cotterill Lane (figs. 6A, 6B). The extent of the stream network during peak runoff conditions and a few days after the last of several runoff peaks in March and early April 1980 are shown in figure 6B.

Surface runoff along the valley axis normally begins in a narrow wetland about 0.4 mile upstream of the bridge at Harford (fig. 6A), although it may begin further upstream for a time in the spring (fig. 6B). Whenever the tributaries go dry, all flow in the mainstem along the valley axis is derived from ground-water discharge. The mainstem becomes a source of recharge during most periods of high runoff, however, as illustrated in figure 7, which compares stage in the mainstem at station 56-10 (fig. 6A) with water level in nearby well 57-08 from February 1979 through February 1980. The annual flow regime observed at this location may be divided into six periods, as described in the following paragraphs:



Base from NYSDOT, Dryden, NY, 1978, and Harford, NY, 1973, 1:24,000, contour interval 10 feet, datum is sea level

Figure 6A.--Stream network in Harford valley on August 6, 1980, and location of wells. (Modified from Randall and others, 1988, fig. 6A.)



Base from NYSDOT, Dryden, NY, 1978 and Harford, NY, 1973, 1:24,000, contour interval 10 feet, datum is sea level

Figure 6B.--Stream network in Harford valley on April 17, 1980. (From Randall and others, 1988, fig. 6B)

1. February 1979. Surface runoff from the uplands was negligible because air temperature was mostly below freezing, and precipitation fell as snow. The water table declined steadily.

2. Late February through early March. Warmer temperatures after February 24 and heavy rain on February 25 and March 5 resulted in snowmelt and abundant runoff. The mainstem carried surface runoff from the uplands downvalley past the measurement station, where stage rose to a peak about 3 feet above the channel bed. Seepage from the stream into the aquifer caused an abrupt 4-foot rise in the water table.

3. March 5 through at least April 22. Surface flow past the measurement station was continuous, and the water table near the valley axis remained within 0.5 feet of stream grade.

4. Late April through early October. Streamflow at the measurement station ceased near the end of April. The water table declined until early October as ground water flowed downvalley toward the wetland 0.4 mile northwest of Harford, the nearest point of discharge.

5. October through December. An inch or more of rain fell during each of four storms after September 1. The first storm had little effect on the water table at well 57-08, but each of the next three storms caused the water table to rise abruptly 1 to 3 feet (fig. 7). A smaller storm on December 24-25, perhaps augmented by snowmelt, produced a similar effect. The magnitudes of the water-table rises indicate that a principal source of recharge was seepage when upland runoff from these storms flowed briefly past the measurement station. This conclusion is supported by the following reasoning: Unsaturated sand and gravel typically contains 10 to 25 percent air-filled pore space available to be filled with water as the water table rises. If this pore space (specific yield) were 10 percent, the water table would rise 10 times the amount of rainfall; if 25 percent, it would rise 4 times the amount of rainfall. This relation, and the fact that some precipitation would not reach the water table if soil moisture had been depleted, indicate that a water-table rise of much less than 10 times the amount of rainfall could be expected if recharge were derived only from local rainfall. Water-table rises much more than tenfold were observed, however. Two measurements of stream stage indicate that runoff did in fact flow past the measurement station during the November 25-26 storm (fig. 7).

6. January-February 1980. Negligible precipitation and subfreezing temperatures resulted in little recharge. The water table declined steadily as ground water continued to drain downvalley.

## Recharge from Tributary Streams in Otter Creek-Dry Creek Through Valley at Cortland

Two small streams, Otter Creek and Dry Creek, occupy the broad valley that extends from the Valley Heads moraine at South Cortland to the Tioughnioga River in the eastern part of Cortland. Before glaciation, valleys draining from the north, northeast, east, and south converged at Cortland and drained southwestward through that valley (Muller, 1966). Glaciation diverted the Tioughnioga River to a southeastward course through Blodgett Mills along a former north-draining tributary.

The headwaters of Otter Creek include an upland drainage basin and Stupke pond, which is fed by ground water in the middle of the valley at South Cortland (fig. 8). Otter Creek loses water to the aquifer between the valley wall and its confluence with Stupke Pond outlet, then gains water from the aquifer between that confluence and the bedrock hill (umlaufberg) at Cortland. The reach between the umlaufberg and the Tioughnioga River is generally a losing reach.

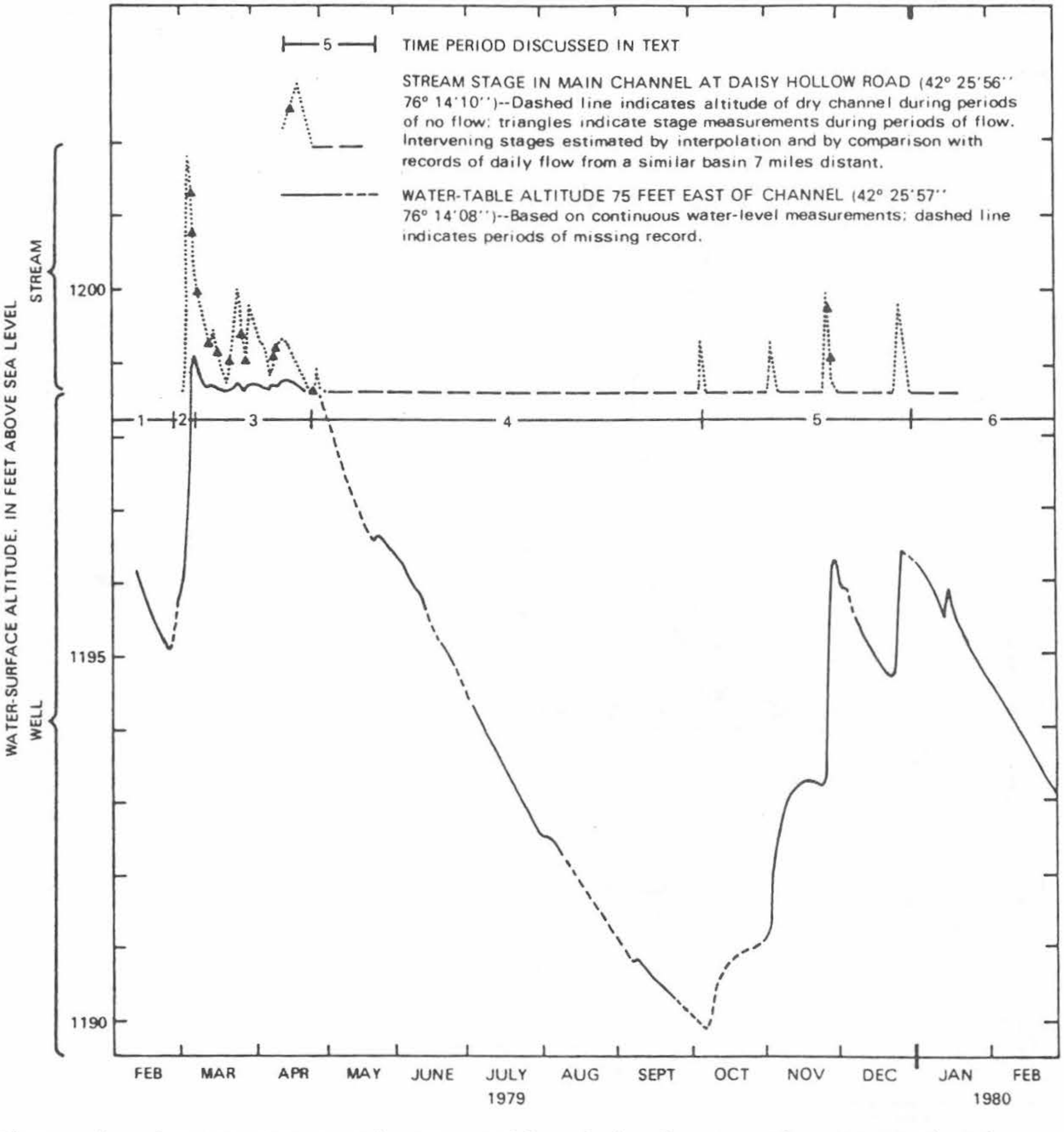
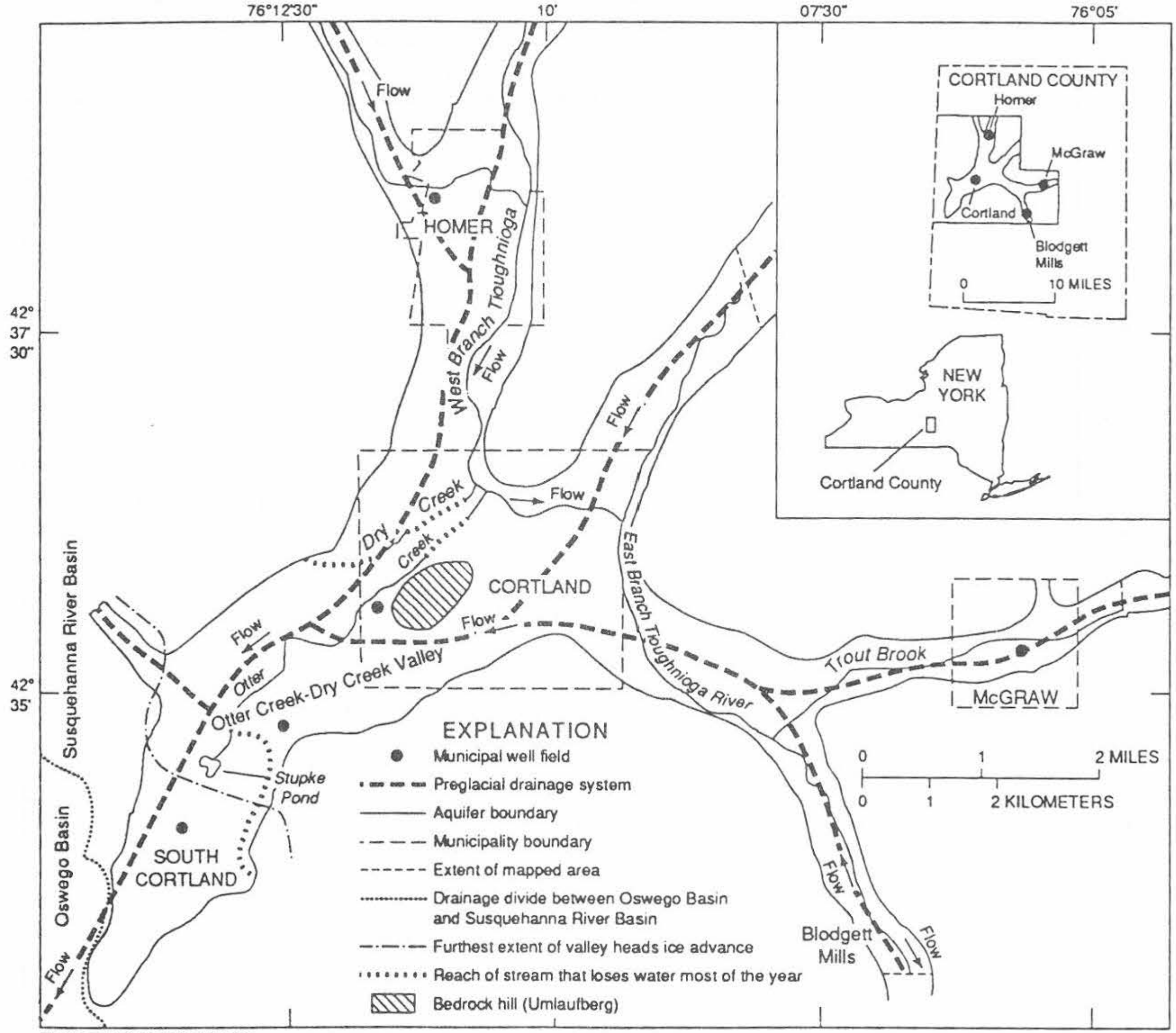


Figure 7.--Stream stage and water-table altitude near the stream in the headwater reach of Harford valley, where streamflow is intermittent. Location of measurement sites shown in fig. 6A. (From Randall and others, 1988, fig. 7.)

Dry Creek is a losing stream throughout the year along its entire reach over the valley floor but carries some flow to the Tioughnioga River during about 11 months in a year of normal precipitation. Dry Creek and the upland branch of Otter Creek dry up from the downstream to upstream direction during low-flow conditions in late summer and fall. By contrast, the main channel of Otter Creek dries up from upstream (near Stupke pond) to downstream, which is typical of small headwater tributaries that follow the axes of through valleys.

Seepage from Dry Creek to the outwash aquifer is controlled largely by the hydraulic conductivity of the streambed or, more likely, the alluvium near the stream. An unsaturated zone beneath the channel of Dry Creek was apparent during construction of two wells adjacent to the creek; at these wells, the water table is below the channel at all times of the year.



Base from U.S. Geological Survey
1:24,000 series: Cortland (1955),
Homer (1978), Groton (1976), McGraw (1979)

Figure 8.--Location and major geographic features of Otter Creek-Dry Creek valley. (Modified from Reynolds, 1987.)

Thus, if the water table were to decline as a result of increased pumping, seepage from Dry Creek probably would not increase much. By contrast, Otter Creek is hydraulically connected to the aquifer in most places, and large pumpage does affect streamflow. When Cortland municipal well 3 is operated during periods of low flow, the nearby reach of Otter Creek dries up; flow resumes when the well is turned off (James Roberts, Cortland Water Dept., oral commun.). Large pumpage southwest of Stupke Pond would intercept ground water that would normally discharge into the pond, its outlet, and Otter Creek. Therefore, large pumping from this area would cause streamflow to cease sooner in summer and resume later in the fall than during nonpumping conditions.

## THROUGH VALLEYS AS POTENTIAL SOURCES OF SEASONAL GROUND-WATER SUPPLIES THAT DO NOT DEPEND ON STREAMFLOW

Streams that follow the axes of large stratified-drift valleys in the Appalachian Plateau normally gain water along their entire length by ground-water discharge from the stratified drift. Pumping from surficial aquifers can reverse the natural water-table gradient toward these streams, however, and thereby induce stream water to recharge the aquifer. This potential for induced recharge far exceeds natural recharge from precipitation and upland runoff in most broad valleys underlain by stratified-drift aquifers. Depletion of streamflow by induced infiltration may be undesirable, however, in periods when streamflow is naturally low and needed for other purposes.

In at least 29 localities along the northern perimeter of the Susquehanna River basin, the drainage divide crosses broad valleys whose floors are underlain by sand and gravel that could provide large yields of ground water from storage during drought periods. Because streams in these localities are small or nonexistent, large withdrawals would not cause equally large concurrent reductions in streamflow downvalley, such as would occur if the same amounts were pumped from aquifers that are crossed by large streams (Randall and others, 1988). These anomalous valley reaches are termed "through valleys." Both the Harford valley and the Otter Creek valley at Cortland are examples, although Otter Creek valley abuts a large stream at one end and hence was classified as a "separated valley" by Randall and others (1988, p. 3). Large-scale seasonal ground-water withdrawals in a through valley would require several wells that tap the aquifer near the divide. The concept is illustrated in figure 9. Large ground-water withdrawals during the summer (fig. 9A) would lower the water table near the divide and would reduce ground-water discharge to the head of the stream that drains the valley axis, and, perhaps, to an equally small headwater stream on the other side of the divide. At the end of the period of seasonal need, the pumps would be shut off, and recharge during the following winter and spring would gradually refill the water-table depression (fig. 9B). Abnormally large or prolonged seepage losses from streams could be expected then, but these losses would be only a small percentage of the large streamflow that occurs then and hence would be of little consequence.

Several possible scenarios for seasonal development in Harford valley were evaluated by use of a numerical ground-water flow model calibrated to transient conditions (Randall and others, 1988). Withdrawal of 10.8 million gallons per day for 2 months in summer near the divide would lower the water table as much as 33 feet near production wells and would cause the point at which streamflow begins along the valley axis to migrate 1,900

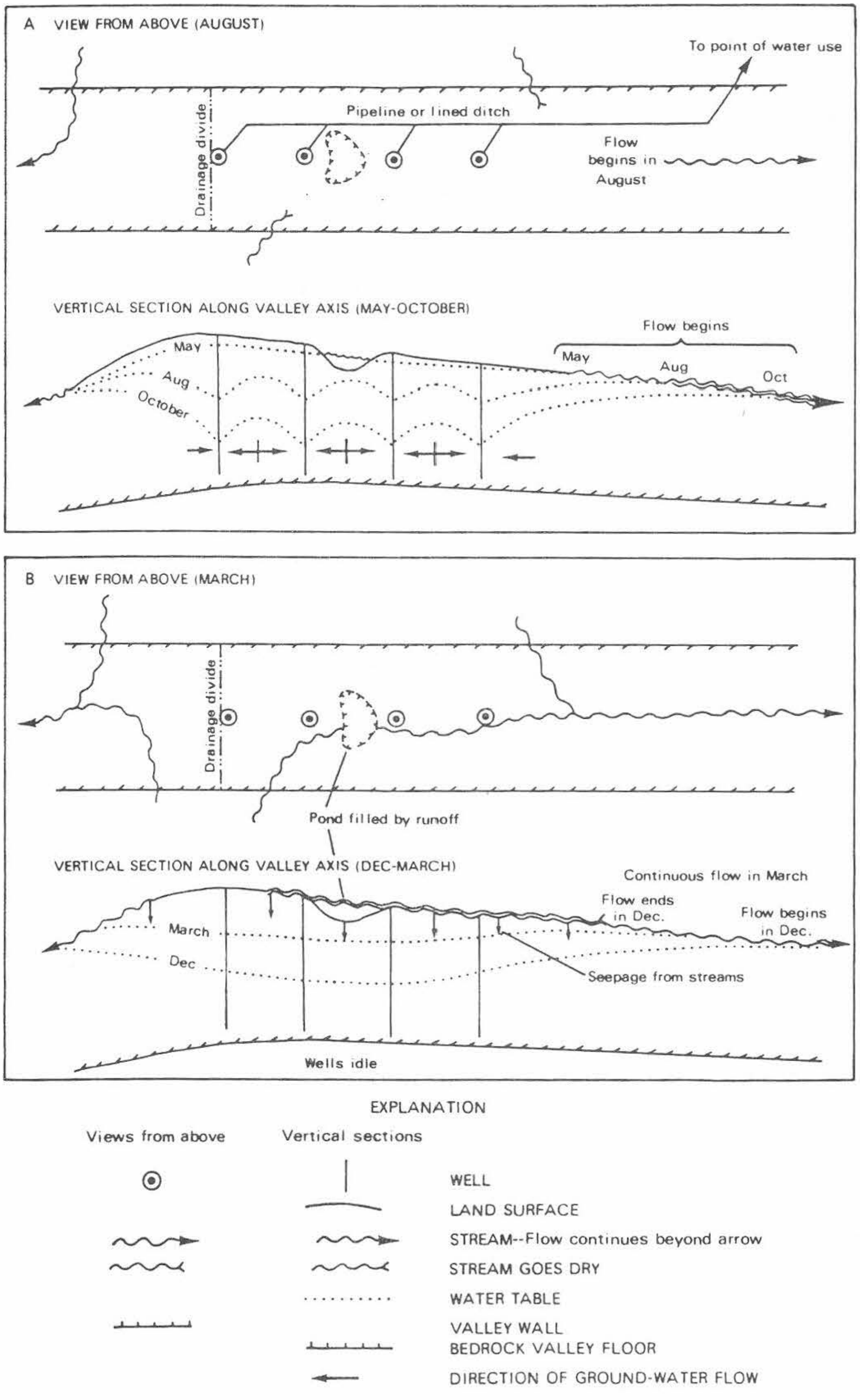


Figure 9.--Ground-water levels and directions of flow in an idealized through valley: A. In summer, with large seasonal ground-water withdrawals. B. In winter, after large seasonal ground-water withdrawals have ceased. (From Randall and others, 1988, fig. 3.)

feet downvalley. Recharge from stream seepage would be greater than normal during the following winter and spring because the aquifer would not fill up to stream grade as quickly as under natural conditions (fig. 9). This increased recharge would allow the same seasonal withdrawals to be repeated each year. The simulated effect of seasonal withdrawal on streamflow in Harford valley is depicted in figure 10, along with the calculated effects

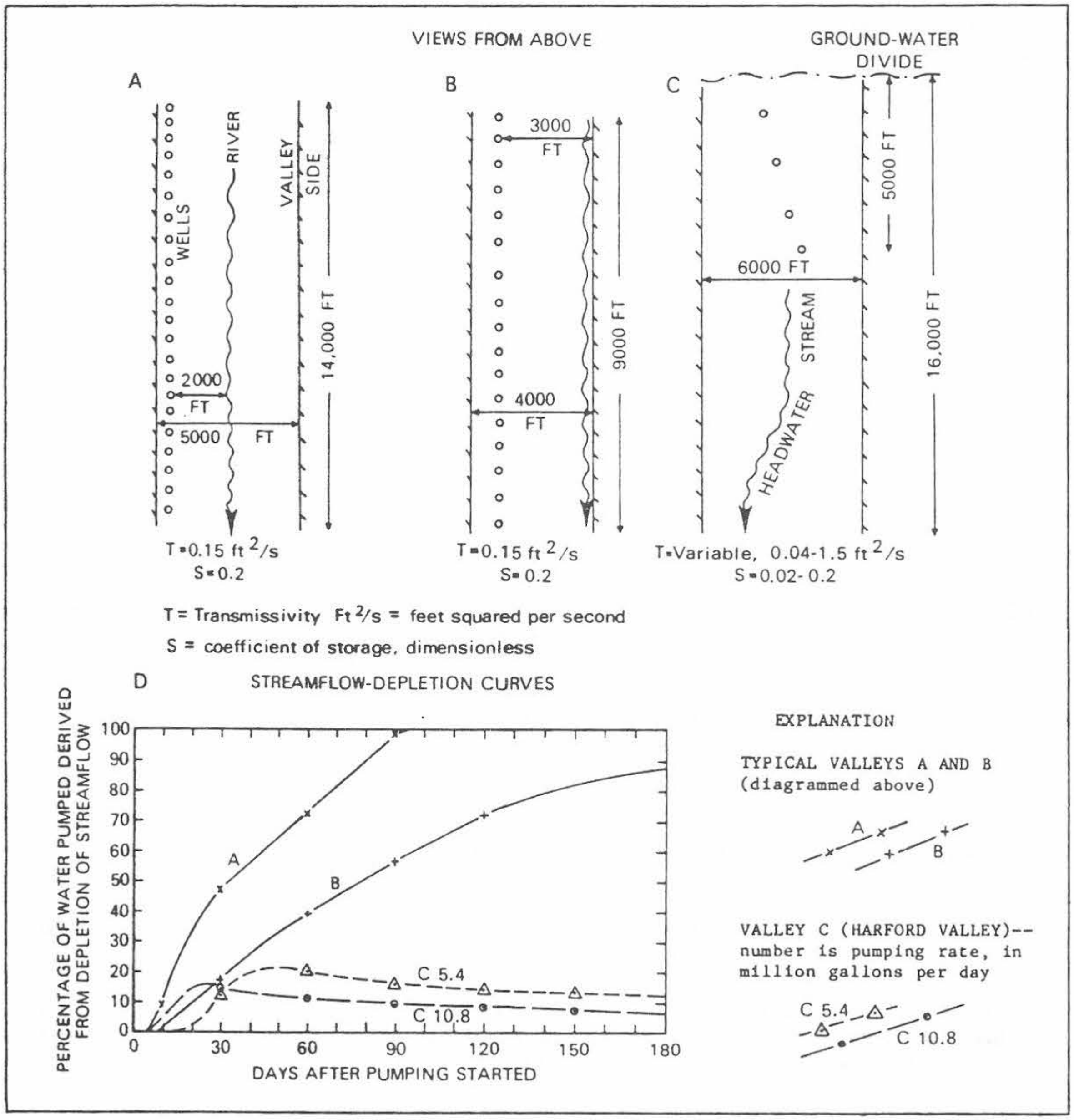


Figure 10.--Streamflow depletion caused by ground-water withdrawals in through valleys compared to that in typical valleys during prolonged drought: A, B. Arrangement of stream and wells postulated by Seaber (U.S. Geological Survey, written commun., 1967) in two typical valley reaches. C. Arrangement of stream and wells postulated in Harford through valley. D. Streamflow depletion as a function of time and pumping rate. Water not derived from streamflow depletion is derived from storage. (From Randall and others, 1988, fig. 17.)

of withdrawals in typical valleys where induced recharge occurs. After 120 days of pumping in the typical valleys, 70 to 100 percent of the water pumped would be derived by depletion of streamflow, and the percentage would increase as pumping continued. After 120 days of pumping in the headwater reach of a through valley such as at Harford, however, the percent depletion of streamflow would be smaller and would decrease as pumping continued. These simulations are discussed in detail by Randall and others (1988).

## REFERENCES

Cosner, O. J., and Harsh, J. F., 1978, Digital-model simulation of the glacial outwash aquifer, Otter Creek-Dry Creek basin, Cortland County, New York: U.S. Geological Survey Water-Resources Investigations Open-File Report 78-71, 34 p.

Crain, L. J., 1966, Ground-water resources of the Jamestown area, New York: New York State Water Resources Commission Bulletin 58, 167 p.

_____, 1974, Ground-water resources of the Western Oswego River basin, New York: New York State Department of Environmental Conservation Basin Planning Report ORB-5, 137 p.

DeSimone, D. J., and LaFleur, R. G., 1986, Glaciolacustrine phases in the northern Hudson lowland and correlatives in western Vermont: Northeastern Geology, v. 8, no. 4, p. 218-229.

Dunn, J. R. and Associates, 1967, Investigation of salt contamination problem at Harford Mills, New York: Averill Park, N.Y., J. R. Dunn Associates, report to Suburban Propane Gas Corporation, 8 p.

_____, 1968, Test drilling of aquifer, Harford Mills, New York: Averill Park, N.Y., J.R. Dunn Associates, report to Suburban Propane Gas Corp., 15 p.

Fairchild, H. L., 1932, New York moraines: Geological Society of America Bulletin, v. 43, p. 627-662.

Ku, H. F. H., Randall, A. D., and MacNish, R. D., 1975, Streamflow in the New York part of the Susquehanna River basin: New York State Department of Environmental Conservation, Bulletin 71, 130 p.

MacNish, R. D., and Randall, A. D., 1982, Stratified-drift aquifers in the Susquehanna River basin, New York: New York State Department of Environmental Conservation Bulletin 75, 68 p.

Miller, T. S., 1988, Unconsolidated aquifers in upstate New York—Finger Lakes sheet: U.S. Geological Survey Water-Resources Investigations Report 87-4122, scale 1:250,000.

_____, Glacial geology and the origin and distribution of aquifers at the Valley Heads moraine in the Virgil Creek and Dryden Lake—Harford valleys, Tompkins and Cortland counties, New York : U.S. Geological Survey Water-Resources Investigations Report 90-4168, 34 p. (in press).

REFERENCES (continued)

_____, Geohydrology and water quality of the Sand Ridge glacial-drift aquifer in Oswego County, New York: U.S. Geological Survey Water-Resources Investigations Report 91-4042 (in press).

Miller, T. S., Brooks, T. D., Stelz, W. G., and others, 1981, Geohydrology of the valley-fill aquifer in the Cortland-Homer-Preble area, Cortland and Onondaga Counties, New York: U.S. Geological Survey Open-File Report 82-1022, 1:24,000 scale, 7 sheets.

Morrissey, D. J., Randall, A. D., and Williams, J. H., 1988, Upland runoff as a major source of recharge to stratified drift in the glaciated Northeast, *in* Randall, A. D. and Johnson, A I., eds., The Northeast glacial aquifers: American Water Resources Association Monograph series no. 11, p. 17-36.

Muller, E. H., 1966, Glacial geology and geomorphology between Cortland and Syracuse; *in* National Association of Geology Teachers, Eastern Section: Field Trip Guidebook, Cortland Area, p. 1-15.

O'Brien & Gere, Inc., 1991, Phase-2 ground-water remediation program status report: Syracuse, N.Y., O'Brien & Gere, Inc., Report to Smith-Corona Corp., Cortlandville, N.Y.

Randall, A. D., 1978, Infiltration from tributary streams in the Susquehanna River basin, New York: U.S. Geological Survey Journal of Research, v. 6, no. 3, p. 285-297.

Randall, A. D., Snavely, D. S., Holecek, T. J., and Waller, R. M., 1988, Alternative sources of large seasonal water supplies in the headwaters of the Susquehanna River basin, New York: U.S. Geological Survey Water-Resources Investigations Report 85-4127, 121 p.

Reynolds, R. J., 1987, Hydrogeology of the surficial outwash aquifer at Cortland, Cortland County, New York: U.S. Geological Survey Water-Resources Investigations Report 85-4090, 43 p.

Thompson, W. B., and Smith G. W., 1983, Pleistocene stratigraphy of the Augusta and Waldoboro areas, Maine: Friends of the Pleistocene, Guidebook, 46th Annual Reunion, Maine Geological Survey Bulletin 27, 37 p.

Wetterhall, W. S., 1959, The ground-water resources of Chemung County: New York State Water Power and Control Commission Bulletin GW-40, 58 p.

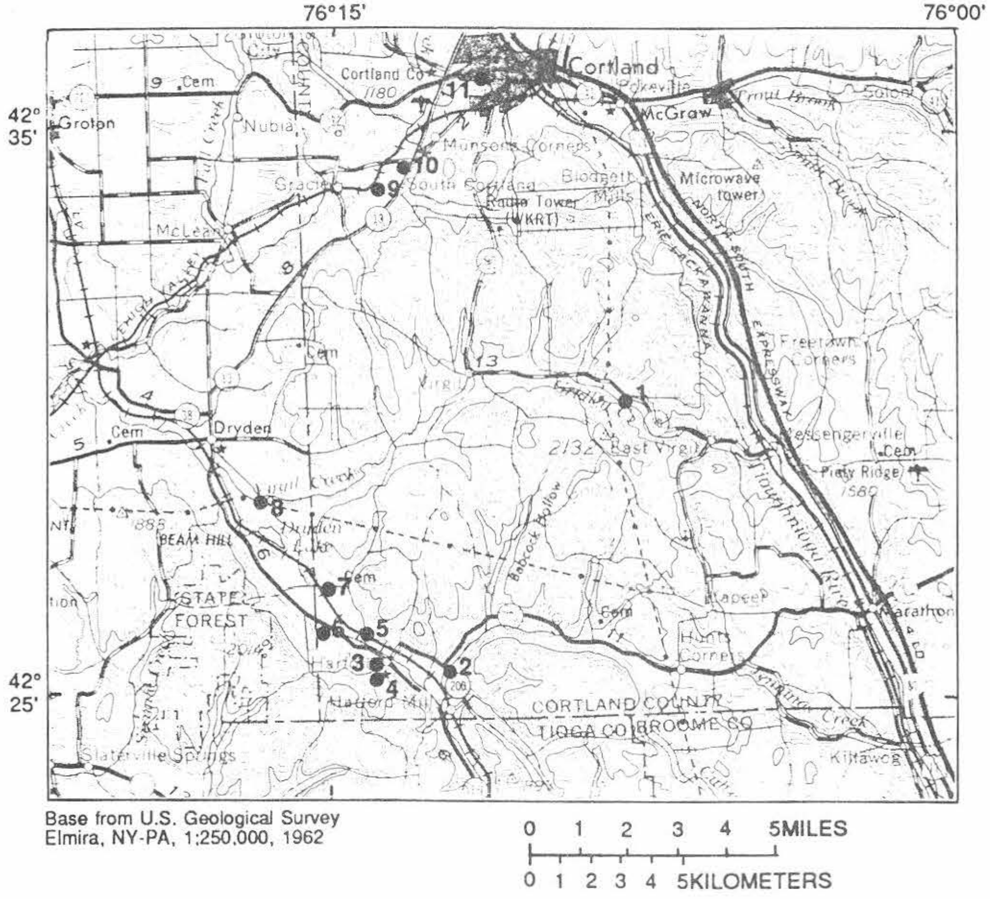
Williams, J. H., 1991, Tributary-stream infiltration in Marsh Creek valley, north-central Pennsylvania: U.S. Geological Survey Water-Resources Investigations Report 90-4052, 39 p.

The following log identifies several possible stops that illustrate topics of this field trip and other points of geohydrologic interest. Locations of these stops are shown in figure 11. The actual itinerary may differ; stops will be selected at the time of the trip, depending on current streamflow conditions, availability of exposures of surficial deposits, and results of current studies near Cortland.

| Cumulative mileage | Miles from last point | |
|---|---|---|
| 0.0 | 0.0 | Intersection of Routes 221 and 11 at Marathon. Go north on Route 11. |
| 3.6 | 3.6 | Turn left on Route 392 to Messengerville; continue on Route 392 beyond Messengerville |
| 7.3 | 3.7 | Turn left on Tone Road. |
| 7.4 | 0.1 | Cross bridge and park. |

STOP 1: SITE OF FORMER USGS GAGING STATION ON GRIDLEY CREEK.

This site is near a preglacial drainage divide now crossed by Gridley Creek, whose flow was reversed by glaciation. It is a good site at which to measure basin yield because the valley fill is only 500 feet wide and probably not thick; therefore, ground-water underflow through permeable sand and gravel is likely to be small, and nearly all runoff leaves the watershed in the stream, where it can be measured.



Base from U.S. Geological Survey
Elmira, NY-PA, 1:250,000, 1962

Figure 11.--Location of field-trips stops.

ROAD LOG (continued)

| Cumulative mileage | Miles from last point | |
|---|---|---|
| 7.5 | 0.1 | Return to Route 392, turn left. |
| 8.5 | 1.0 | Ski area on left. |
| 10.0 | 1.5 | Meltwater spillway ahead on left, incised into south end of mound of drift that Route 392 crosses just ahead. The divide between east-flowing Gridley Creek and west-flowing Virgil Creek is here, in the middle of a valley 2,000 feet wide. |
| 10.8 | 0.8 | Approaching hamlet of Virgil, turn left on Vandonsel Road, go past sign for Power Farms. |
| 11.9 | 1.1 | Turn right. |
| 12.2 | 0.3 | Summit, view (to rear) across valley of Virgil and Gridley Creeks. |
| 12.7 | 0.5 | Cross Haucks Road. |
| 14.6 | 1.9 | T-junction, bear left. |
| 16.4 | 1.8 | Turn right on Route 221. Route follows East Branch Owego Creek. Kame terraces on right side of valley. |
| 17.8 | 1.4 | Turn left on Route 200. Kame terraces on both sides at intersection. |
| 18.0 | 0.2 | Pause, view to right. |

STOP 2: HESITATION STOP: HARFORD UNDERGROUND GAS-STORAGE PROJECT.

In 1953, a cavity was excavated by solution mining in salt beds at a depth of about 3,000 feet to provide storage space for liquified petroleum gas that would arrive here by pipeline. The brine created by mining was discharged to lagoons excavated in the permeable outwash and alluvium on the valley floor. A few years later, many residents of Harford Mills, visible to the south, began to pump salty water from their shallow wells. Water sampling, resistivity surveys, and a test well disclosed that outwash extended to a depth of 56 feet and contained salty water over a large area near the hamlet and Owego Creek, except close to the water table, where water was fresh (Dunn, 1967, 1968). Gravel layers at depths of 97 and 170 to 194 feet yielded fresh water.

The raised, lined pond visible here is now used to contain brine produced during operation of this facility.

| | | |
|---|---|---|
| 18.6 | 0.6 | Junction, bear right and continue on Route 200 through hamlet of Harford Mills. |
| 19.2 | 0.6 | T-junction, turn right on Route 38. |
| 20.7 | 1.5 | Hamlet of Harford, turn left on Cheese Factory Road. |
| 20.95 | 0.25 | Abandoned creamery; park in driveway on south side. |

## ROAD LOG (continued)

### STOP 3: CHEESE FACTORY BROOK.

Except during the spring freshet and other brief periods of unusually heavy runoff, this brook ceases to flow somewhere near or downstream from this former creamery. We hope to view the point of dryness, note exposures along the brook, and discuss the significance of seepage losses from tributaries as a source of recharge.

| Cumulative mileage | Miles from last point | |
|---|---|---|
| 21.95 | 0.2 | Continue south on Cheese Factory Road, park along road. Walk across field to brook. |

### STOP 4: SPRINGS ALONG CHEESE FACTORY BROOK.

About 0.2 mile upstream from the creamery, a reservoir (now in disrepair) was built to develop a spring at the base of the bluff along Cheese Factory Brook. Exposures upstream and downstream show that the bluff consists of sandy, somewhat silty gravel. The presence of the spring suggests that impermeable sediment is not far below. On April 25, 1991, a tributary just upstream went dry 300 feet before it reached Cheese Factory Brook. Seepage from the tributary may be a major source of water to the spring.

| | | |
|---|---|---|
| 21.6 | 0.45 | Return to Route 38, turn left. |
| 22.1 | 0.5 | Turn right on Daisy Hollow Road. |
| 22.3 | 0.2 | Cross former railroad; park. |

### STOP 5: STREAMFLOW AND WATER-LEVEL MEASUREMENT SITES.

This is the location at which the water levels in figure 7 were measured. Most runoff from the 3.42 square-mile watershed above this point occurs as underflow through the stratified drift.

| | | |
|---|---|---|
| 22.5 | 0.2 | Return to Route 38, turn right. |
| 23.2 | 0.7 | Turn left into dirt road, opposite Cotterill Lane. Locked gate ahead, permission from Harford Teaching and Research Center farm manager required to enter; continue 0.1 mile to pit. Brook to left of dirt road flowed past Route 38 April 25,1991. |

### STOP 6: PIT IN CREVASSE FILLING.

This infrequently used pit is on the property of the State College of Agriculture's Harford Teaching and Research Center. About 10 feet of till that contains only rounded pebbles overlies about 20 feet of stratified, sorted but very silty gravel and, in places, deformed medium to fine sand, silt, and clay. Poorly sorted, silty gravel is characteristic of early-deglacial, proximal stratified drift near the Valley Heads moraine.

ROAD LOG (continued)

| Cumulative mileage | Miles from last point | |
|---|---|---|
| 23.3 | 0.1 | Return to Route 38, cross Route 38, follow Cotterill Lane. |
| 23.8 | 0.5 | Harford Teaching and Research Center main buildings on left. |
| 24.2 | 0.4 | Turn left on Willow Crossing Road. |
| 24.4 | 0.2 | Park near gray house, walk down to channel of Daisy Hollow Brook. |

## STOP 7: DAISY HOLLOW BROOK.

Daisy Hollow brook flows farther out onto the valley-floor outwash than any other tributary near Harford. One reason why may be observed here. Also exposed is the flat-stone drab gravel that is typical of alluvium along upland tributaries.

| | | |
|---|---|---|
| 24.8 | 0.4 | Junction, bear right. |
| 26.5 | 1.7 | Turn right. This terracelike flat is capped by till. |
| 26.9 | 0.4 | Sharp turn left. |
| 27.0 | 0.1 | Cross Virgil Creek, turn left. |
| 27.1 | 0.1 | Park, cross field to left to view exposure along creek. |

## STOP 8: SOUTHWORTH ROAD EXPOSURE NEAR DRYDEN.

The large variety of sediments in this exposure illustrate the complexity of the depositional environment at the Valley Heads moraine. Figure 4 shows the appearance of the exposure in 1984. Sediment facies include till, fluvial, and lacustrine deposits. The drab till at the top of the exposure represents a readvance of ice during the late stages of Valley Heads glaciation. The surficial till overlies a coarse, cobbly gravel that in turn overlies either a discontinuous pebbly sand or till hummocks. Till hummocks have pockets of gravel, disturbed sand stringers, and some folded bedding, all of which suggest movement of the sediments such as may occur during topographic inversion. Beneath the hummocks is rhythmic silt/clay with scattered stones, presumably dropped from floating ice. A till containing abundant bright clasts underlies the rhythmite. A bright, coarse, cobbly gravel underlies the bright till.

| | | |
|---|---|---|
| 28.1 | 1.0 | Turn left (west) onto Maclintock Road. |
| 28.5 | 0.4 | Turn right (north) onto Route 38. |
| 28.6 | 0.1 | Straight at intersection at Dryden village, continue north, now on Route 13. |
| 35.4 | 6.8 | Turn left into entrance of gravel pit, stop 9. |

## ROAD LOG (continued)

### STOP 9: GRAVEL PIT AT SOUTH CORTLAND

Coarse outwash and ice-contact sediments deposited by Valley Heads ice. Note boulders 2 to 3 feet in diameter at entrance to pit. Excavation is along the boundary between outwash deposited by northeastward-flowing meltwaters and ice-contact deposits laid down on and adjacent to blocks of ice that were in the middle of the valley. A geologic log of a test well in the gravel pit indicates the following stratigraphy, in feet below land surface: 0-45 feet sand and gravel, 45-50 till, and 50-75 sand and gravel. Mining of sand and gravel will stop 10 feet above the water table so as to minimize the effects on water resources and so that land could be used after mining operations cease.

| Cumulative mileage | Miles from last point | |
|---|---|---|
| | | Return to pit entrance, turn left (north) on Route 13. |
| 36.2 | 0.8 | Turn left (west) on Lime Hollow Road. |
| 36.3 | 0.1 | Pause, view stop 10. |

### STOP 10: HESITATION STOP: REMEDIATION OF A SPILL OF ORGANIC SOLVENT.

A recovery well pumps about 970 gallons per minute to remediate the source area (O'Brien & Gere, 1991). Pumped water is routed through an air stripper, which brings sufficient air into contact with the water to allow the volatile organic solvent to evaporate. The water is then discharged into infiltration lagoons, where it seeps to the water table.

| | | |
|---|---|---|
| 36.4 | 0.1 | Return to Route 13, turn left (north) on Route 13. |
| 38.2 | 1.8 | Turn left (north) on Broadway. |
| 39.3 | 0.5 | Turn left (west) into entrance to City of Cortland well field. |

### STOP 11: CITY OF CORTLAND WELL FIELD.

Otter Creek flows through the well field but is usually dry from midsummer to late fall. During low-flow periods, when well 3 is turned on and streamflow disappears in Otter Creek because of induced infiltration. When the well is turned off, streamflow reappears. Abundant vegetation in the channel indicates a relatively large amount of nutrients in the water. In contrast, the channel of nearby Dry Creek contains little or no vegetation, which suggests that runoff from that drainage basin contains relatively few nutrients.

An air-stripping tower was installed beside the main plant in anticipation that the plume of organic solvents (source about 2 miles southwest, stop 10) would reach the well field. Concentrations of trichlorethylene within the plume decrease with distance from the source, and only trace amounts have been detected at the well field, not enough to warrant use of the air stripper. The decrease in concentrations has been attributed to volatilization, discharge to Otter Creek, and biological degradation and transformation of the trichlorethylene.

Well 4 at plant 2 is one of the most productive municipal wells in New York. It is capable of pumping 4,000 gallons per minute. The well taps outwash 63 feet in saturated thickness. At present, it is used only intermittently.