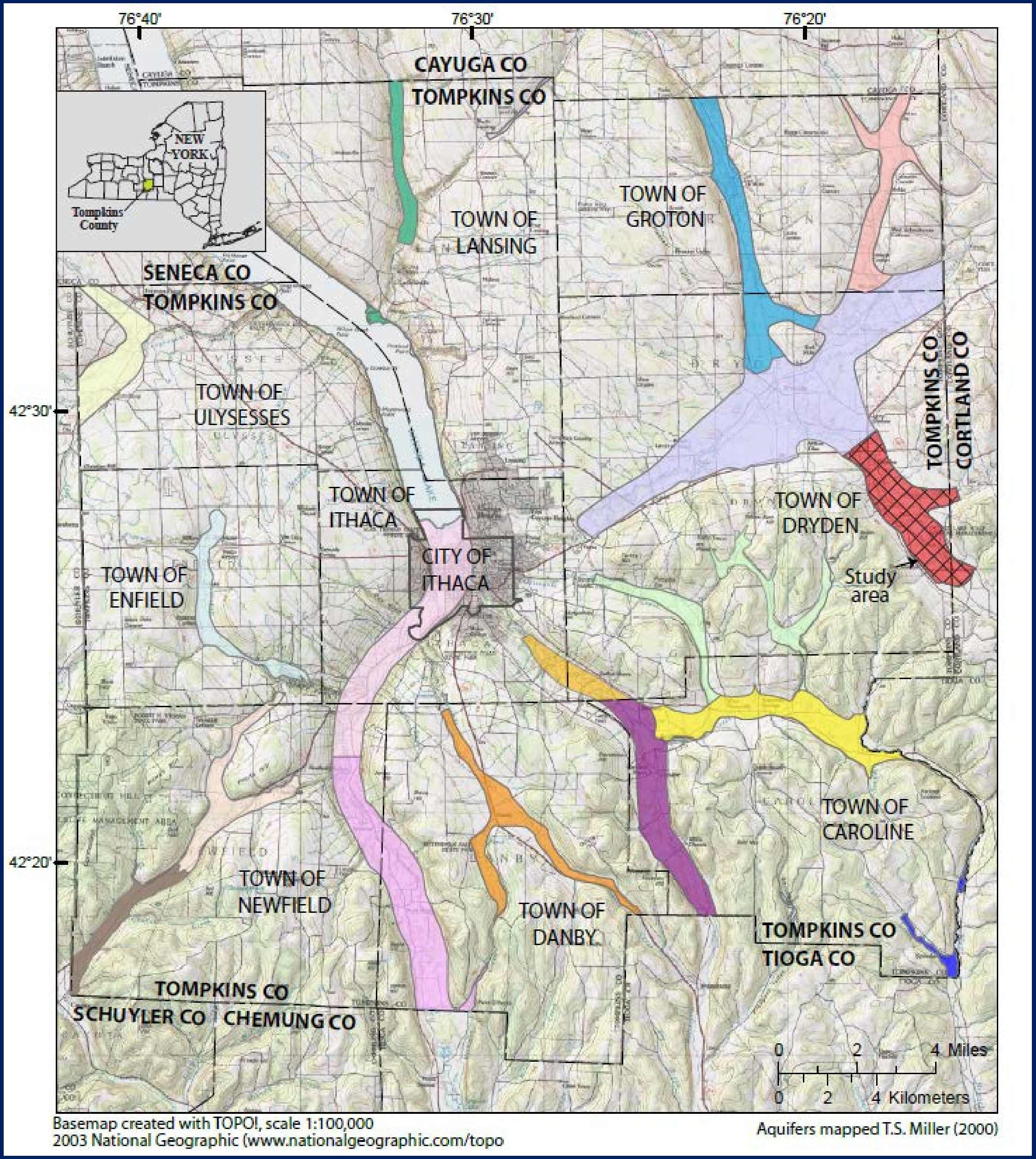
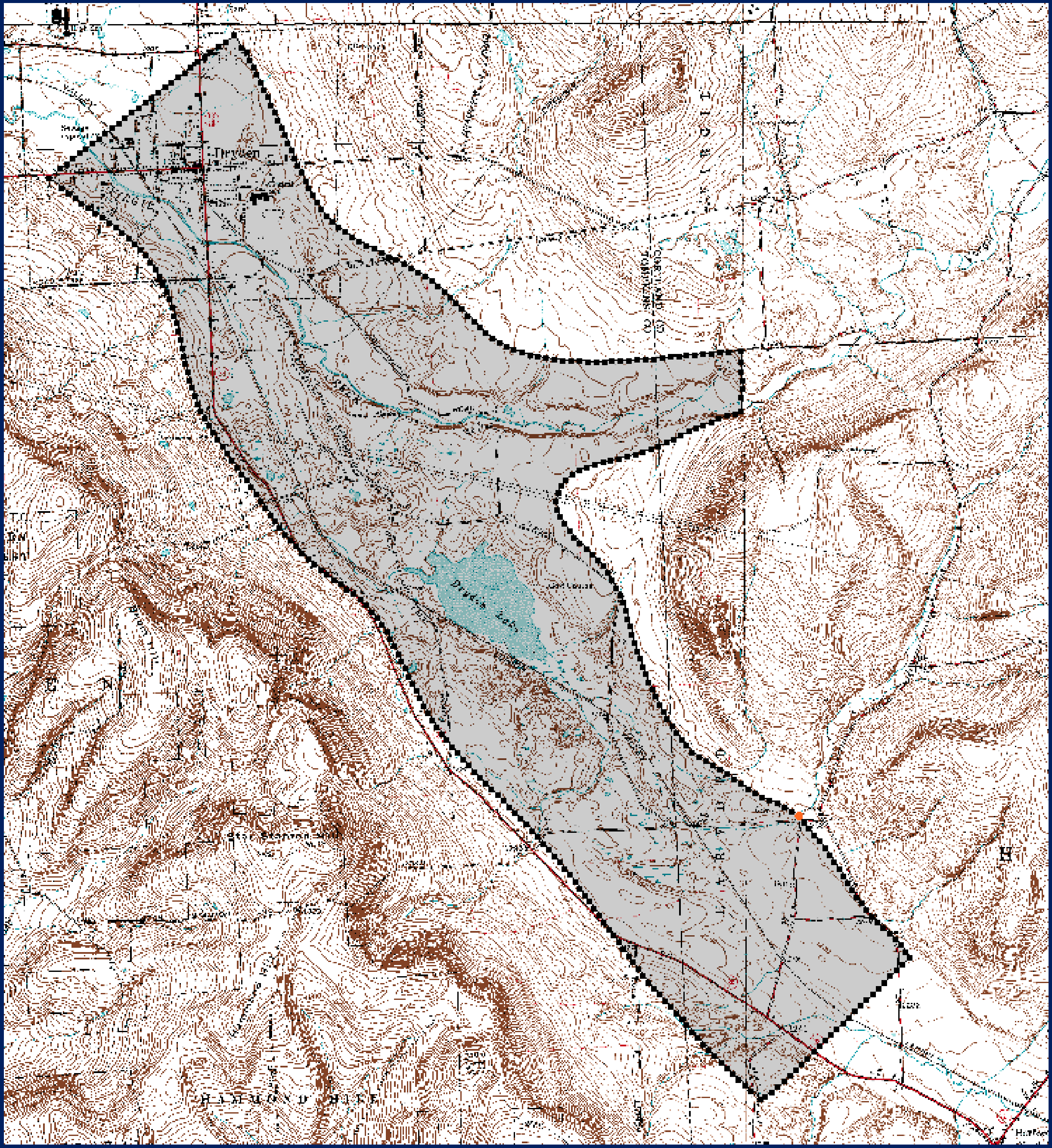
# Geohydrology, Water Quality, and Simulation of Groundwater Flow in the Stratified-drift Aquifer System in Virgil Creek and Dryden Lake Valleys, Town of Dryden, Tompkins County, New York

# Tompkins County Aquifer Mapping Program



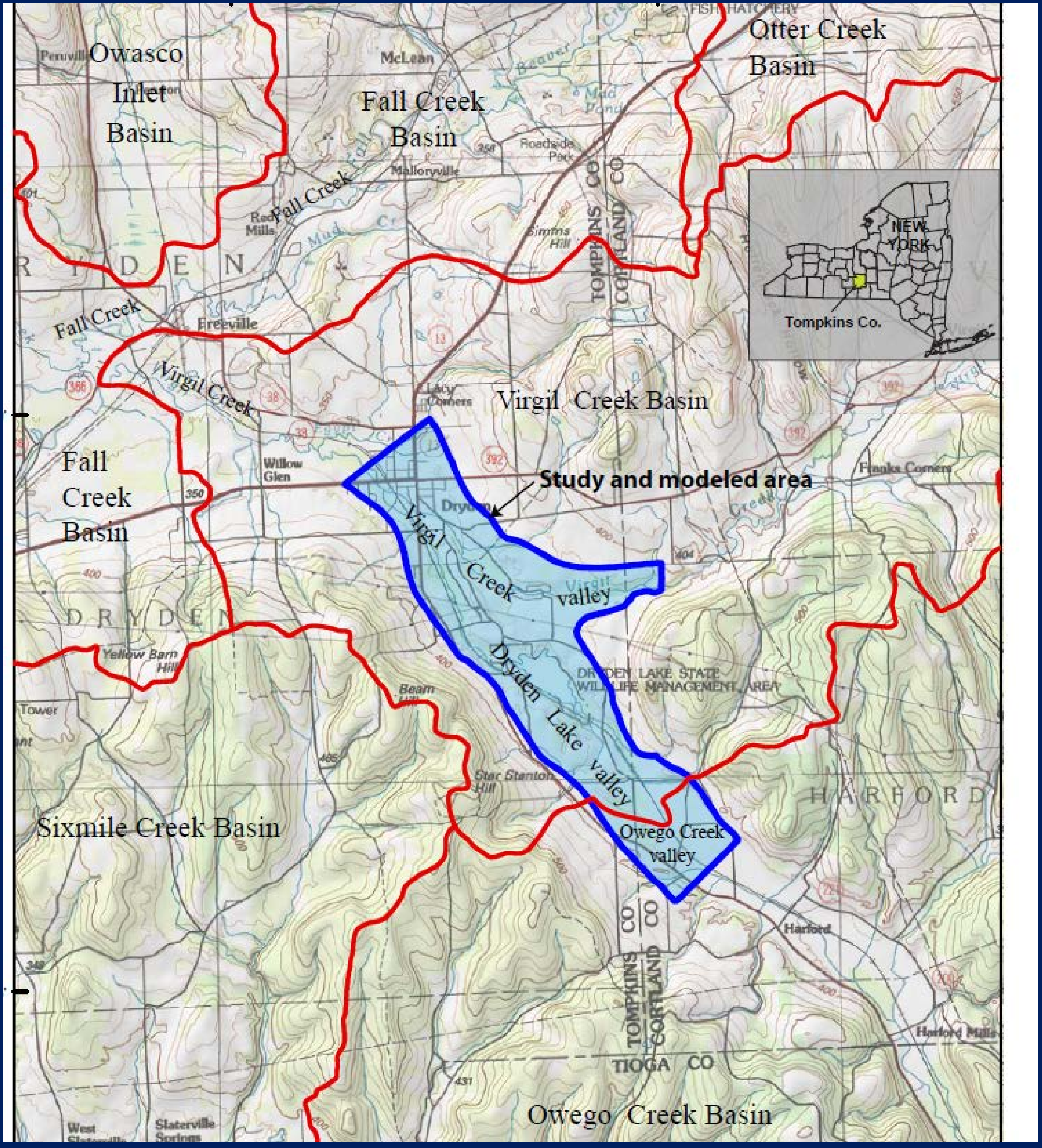

- Cascadilla Creek valley and upland Sixmile Creek valley
- Enfield Creek valley
- Lower Cayuga Inlet valley
- Lower Fall Creek valley
- Lower Sixmile Creek valley (Towns of Dryden and Ithaca)
- Owasco Inlet valley
- Pony Hollow valley
- Salmon Creek/Myers Point/Locke Creek

- Taughannock Creek valley and delta
- Upper Buttermilk Creek and Danby Creek valleys
- Upper Cayuga Inlet valley
- Upper Fall Creek valley
- Upper Sixmile Creek and W Br Owego Creek valleys
- Virgil Creek valley (this study area)
- West Br. Cayuga Inlet and Fish Kill valleys
- West Br. Owego Creek valley and tributaries
- Lower Sixmile Creek and Willseyville Creek valleys (Town of Caroline)

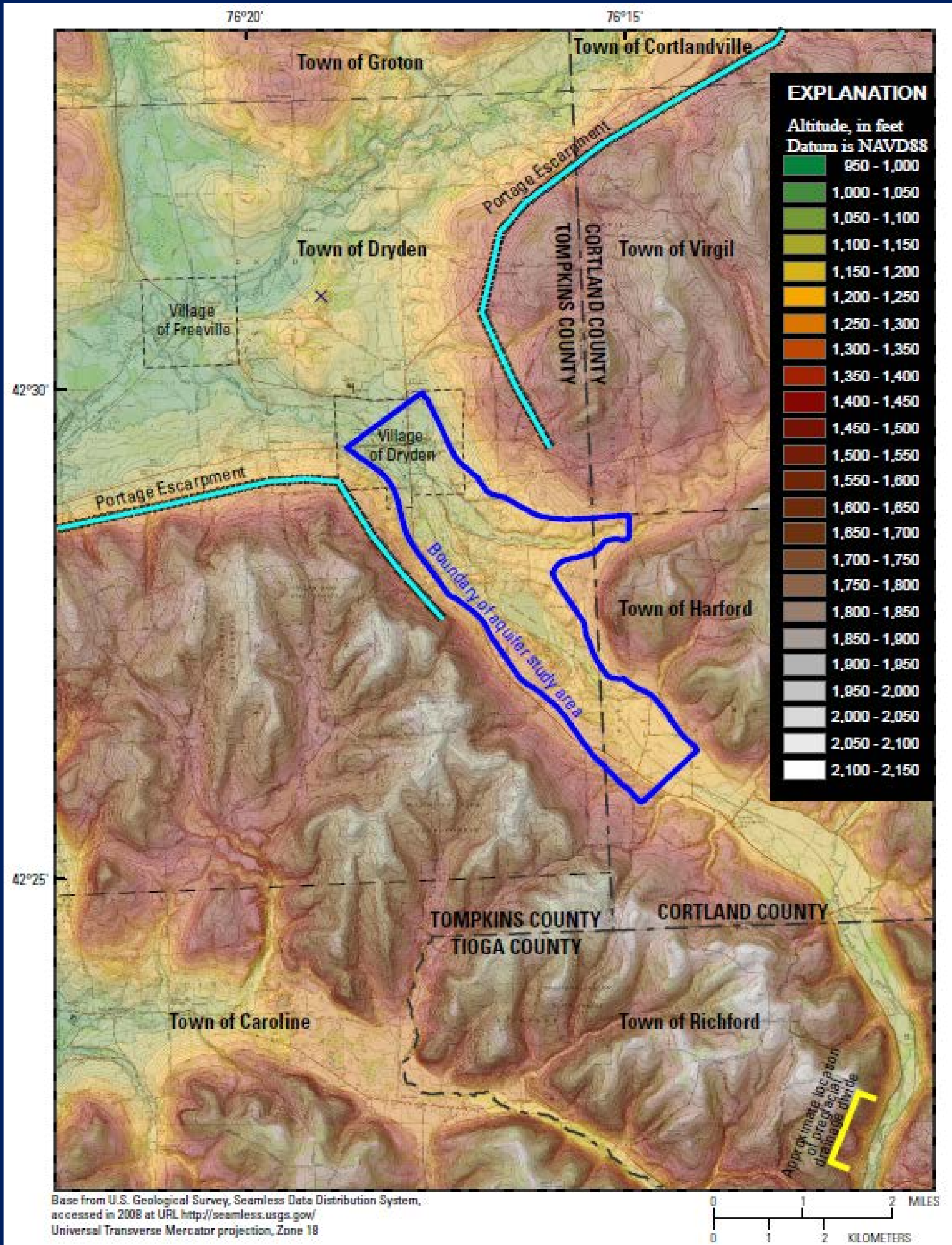


# EXTENT OF AQUIFER STUDY AREA

The study area is 5.3 mi long, 1.0 mi wide, and encompasses 5.4 $mi^2$ in the Dryden Lake valley and parts of the Virgil Creek and Owego Creek valleys

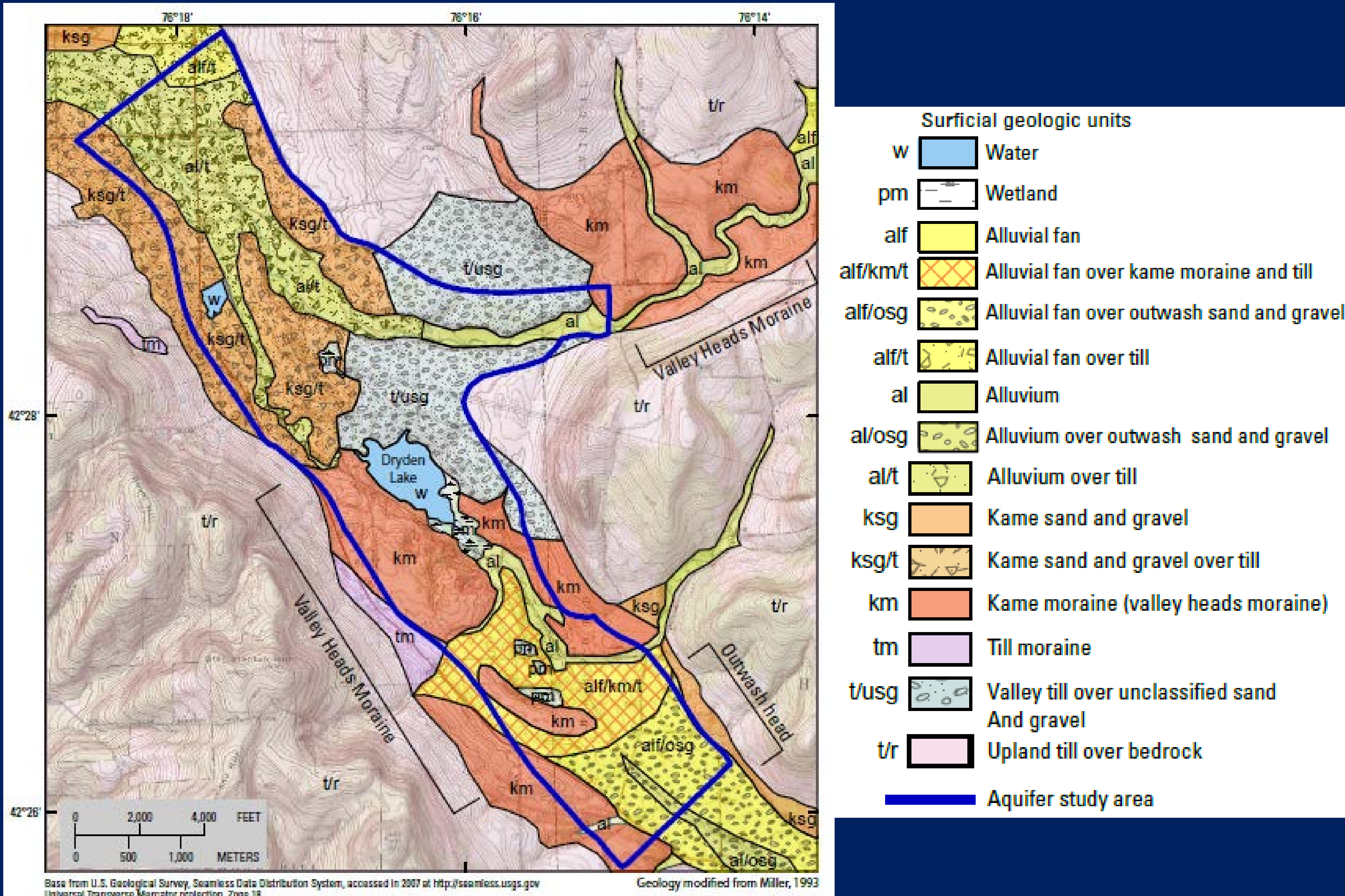


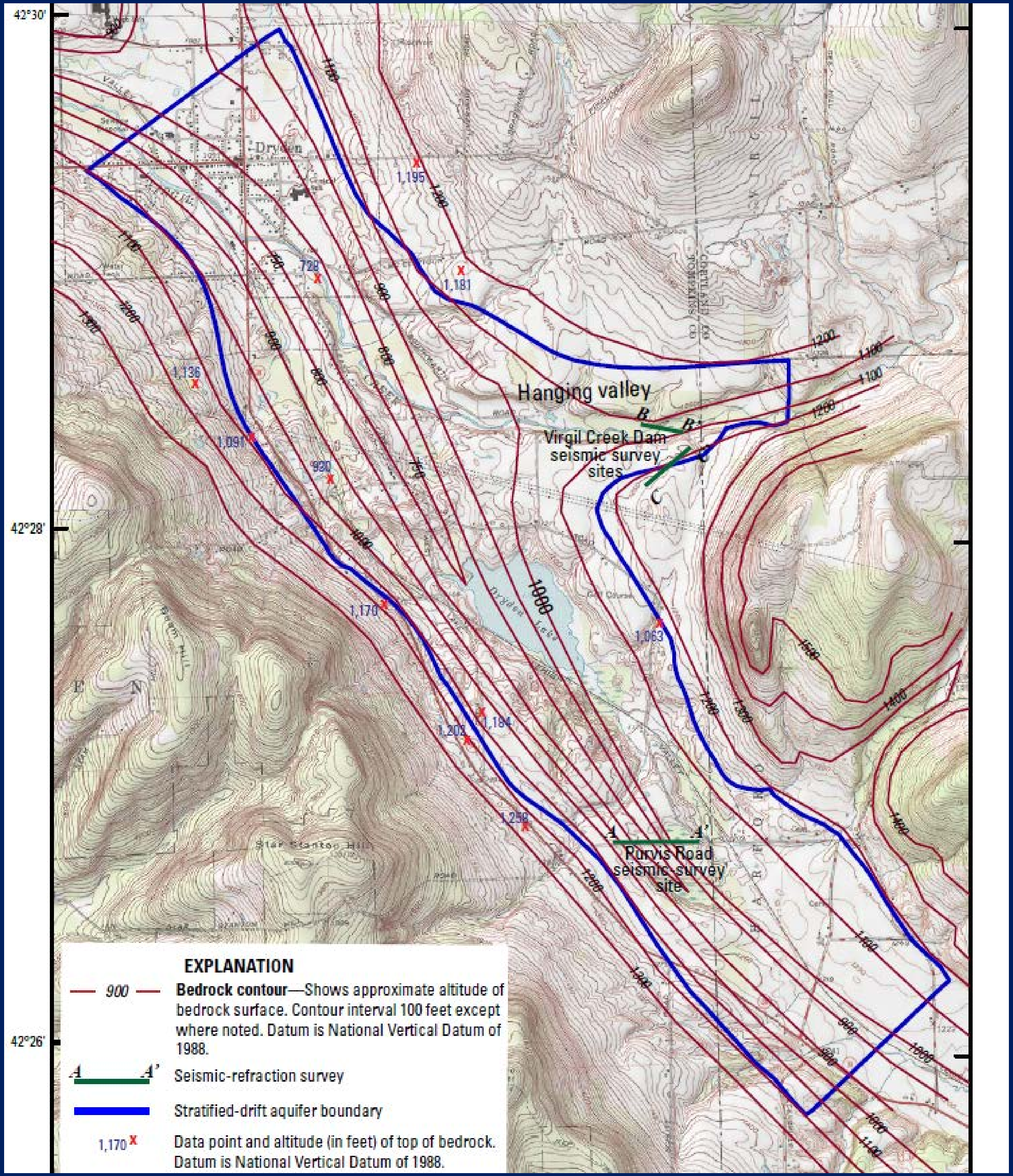

# The aquifer extends into Virgil Creek, Dryden Lake, and Owego Creek valleys




# The Study area is an "Intrusive Valley" in the northern rim of the Allegheny Plateau

# Surficial Geology





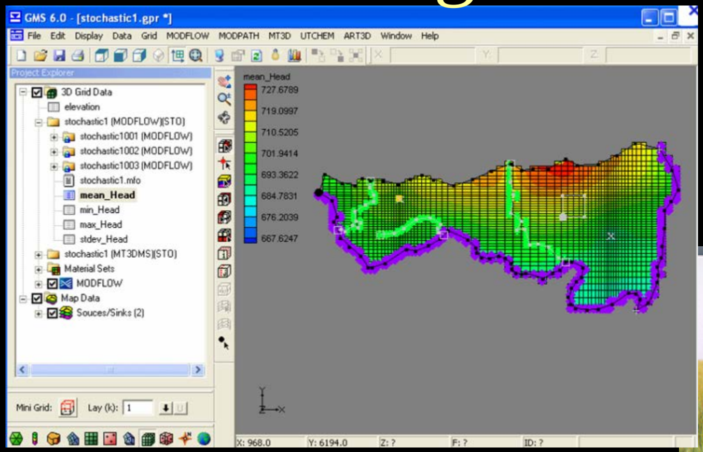

# Scouring by ice and subglacial meltwaters played a major role in modifying the preglacial landscape

Depth to bedrock is as deep as 400 ft in Dryden Lake valley–only 100 ft in Virgil Cr. Valley (hanging valley)

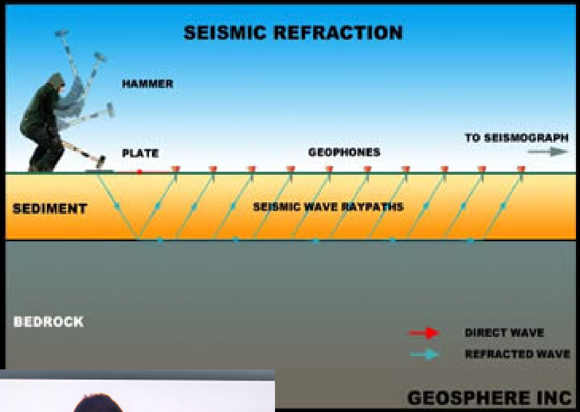
# SCOPE OF WORK

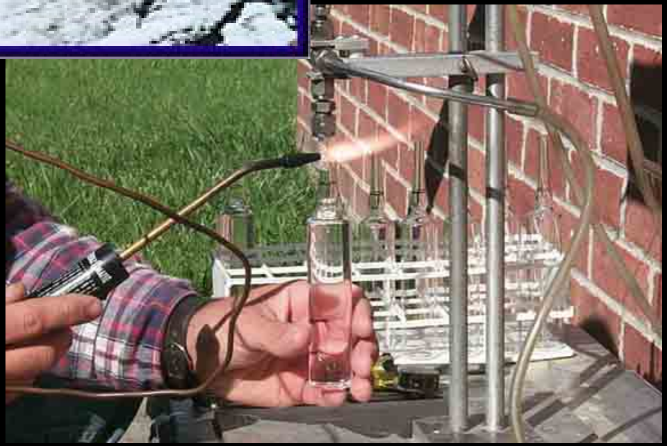
Test drilling

Numerical modeling




Seismic refraction

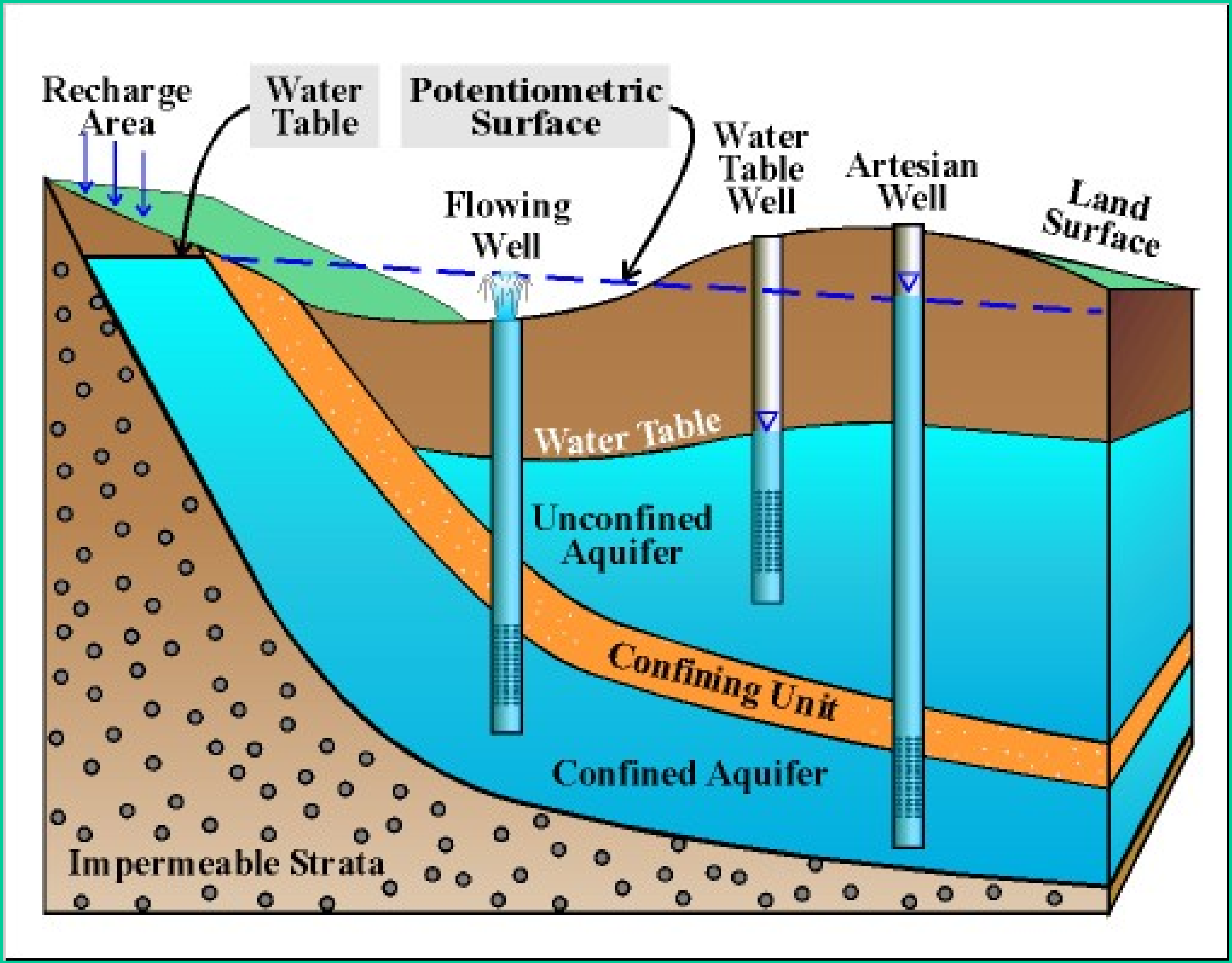


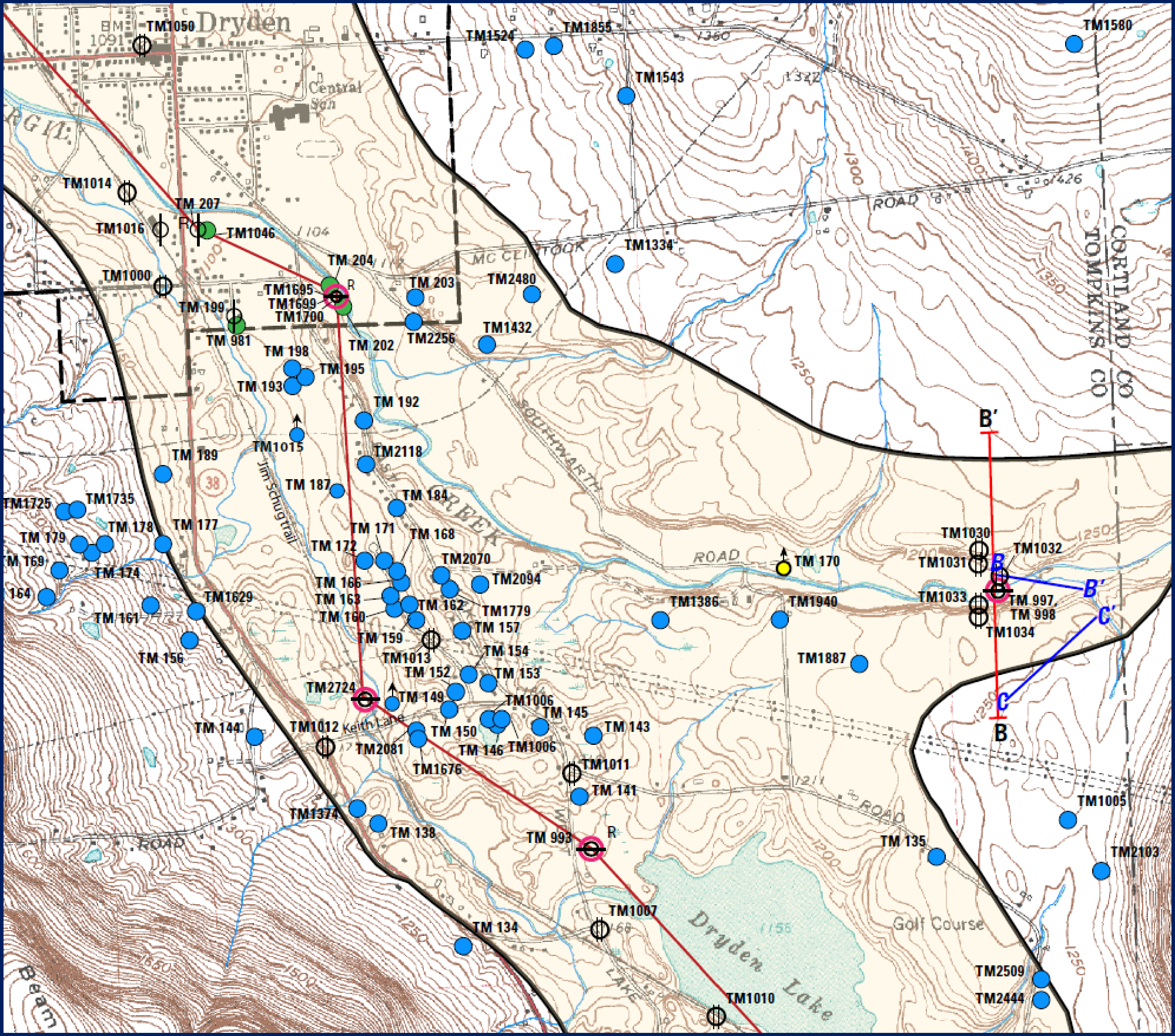
CFC ground-water dating

Ground-water level measure ments

# AQUIFER CHARACTERIZATION




- Aquifer type
- Geometry
- Locate Recharge Areas
- Connections
- GW Flow
- GW Age dating


Dryden
TM1050
TM1524
TM1855
TM1580
TM1543
TM1014
TM 207
TM1016
TM1046
TM 204
TM1000
TM1695
TM1699
TM1700
TM 203
TM2480
TM1334
TM 199
TM 981
TM 202
TM2256
TM1432
TM 198
TM 195
TM 193
TM 192
TM1015
TM2118
TM 189
TM 187
TM 184
TM1725
TM1735
TM 178
TM 177
TM 171
TM 168
TM 179
TM 172
TM2070
TM 170
TM1030
TM1032
TM1031
TM 169
TM 174
TM 166
TM2094
164
TM1629
TM 163
TM 162
TM1779
TM1386
TM1940
TM1033
TM 997,
TM 998
TM 161
TM 160
TM 157
TM1034
TM 159
TM 156
TM1013
TM 154
TM1887
TM 152
TM 153
TM2724
TM 149
TM1006
TM 145
TM 144
TM1012
TM 150
TM 143
TM2081
TM 146
TM1006
TM1676
TM1011
TM 141
TM1005
TM1374
TM 138
TM 993
TM 135
TM2103
TM1007
TM 134
TM2509
TM2444
TM1010
B'
B
C'
C
ROAD
SOUTHWORTH
MC CLINTOCK
CORTLAND CO
TOMPKINS CO
Dryden Lake
Golf Course
Jim Schug trail
Keith Lane
Central Sch

# Well data

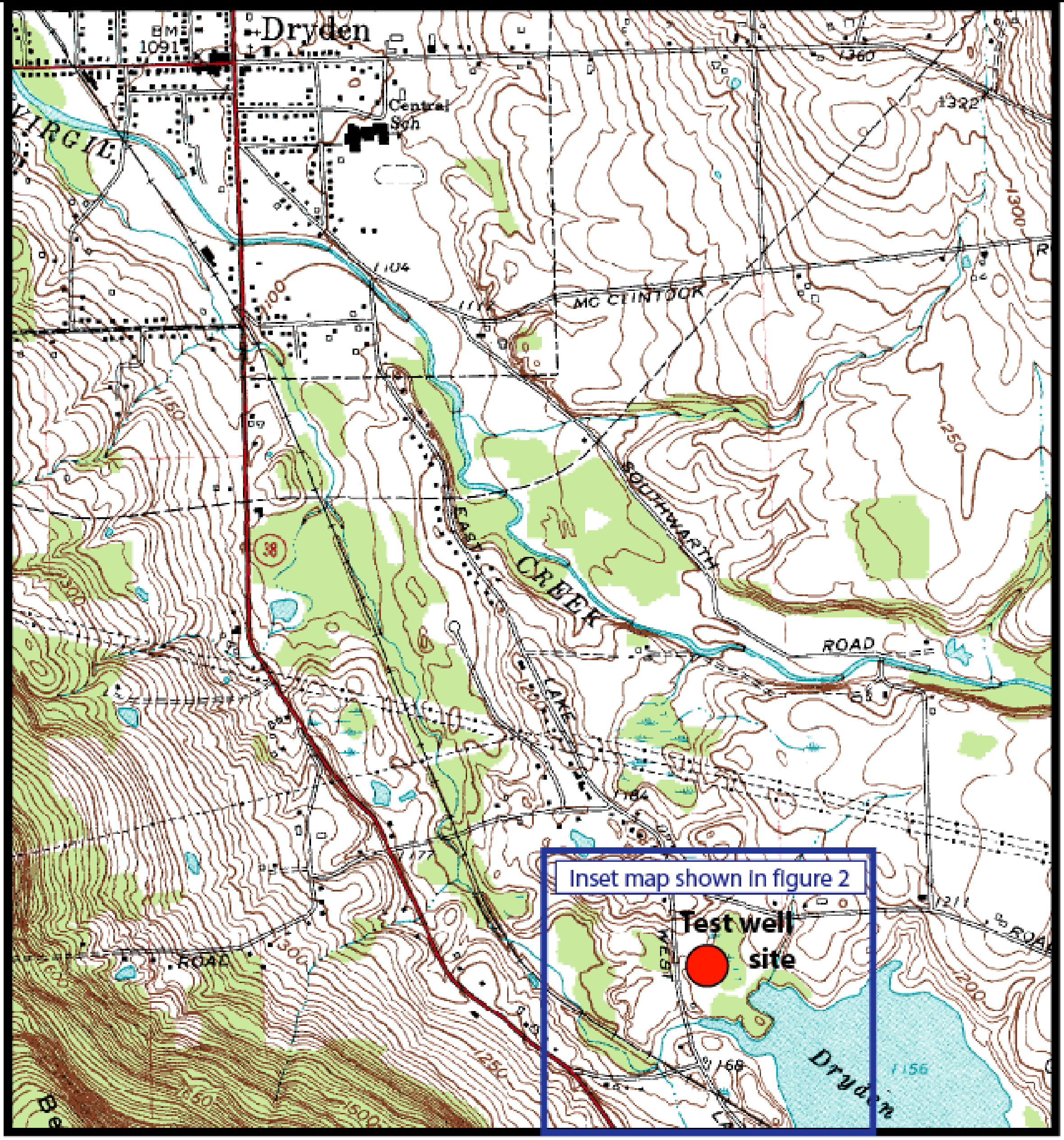
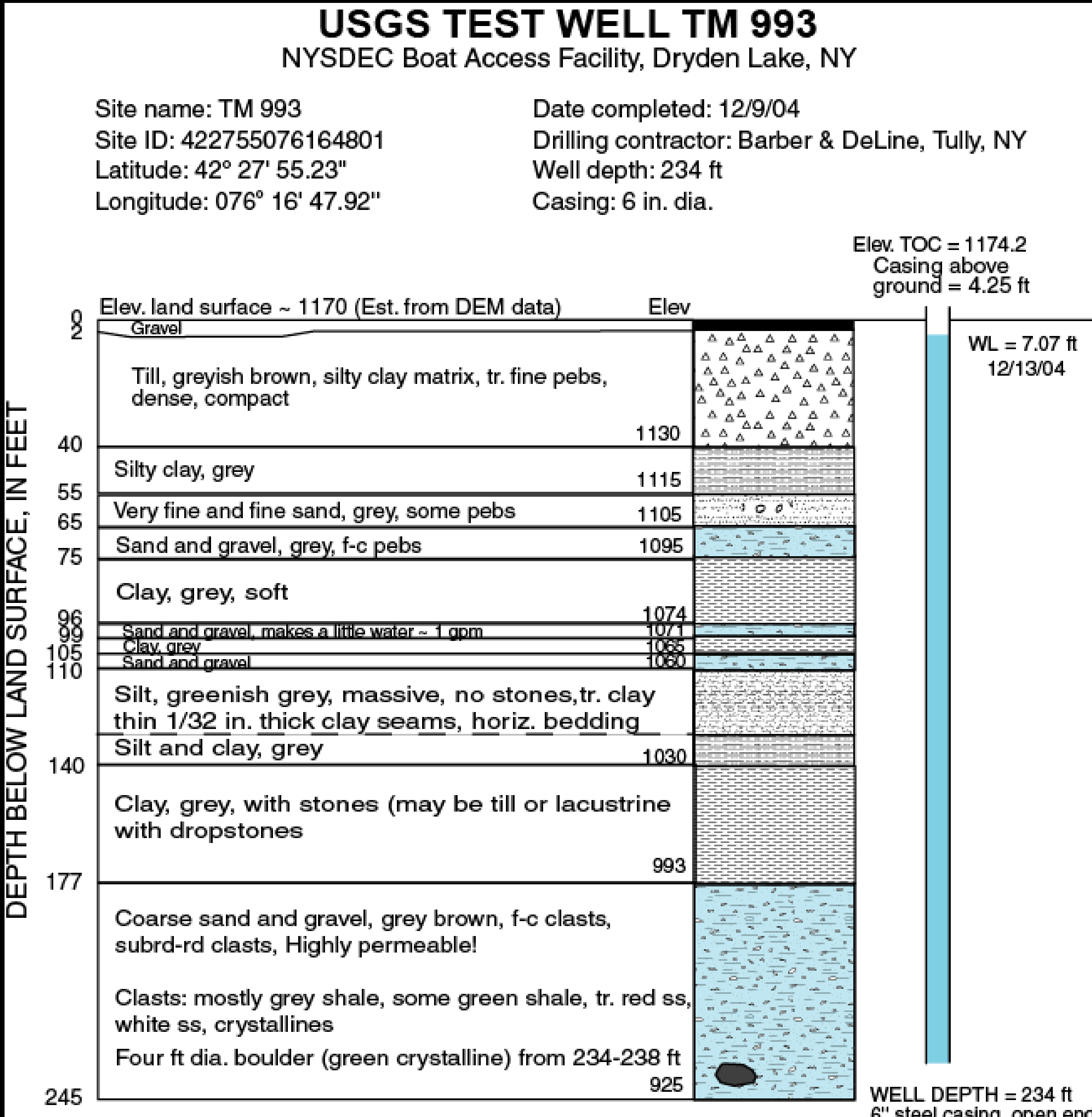



Figure 1.-- Location of test well site at the NYS Department of Conservation Boating Access property near the outlet to Dryden Lake, NY

# LOCATION OF ONE OF THE TEST WELLS

# DRILLING THROUGH THE CONFINING LAYER
(lots of silt and clay)

# WELL LOG OF DRYDEN LAKE TEST WELL

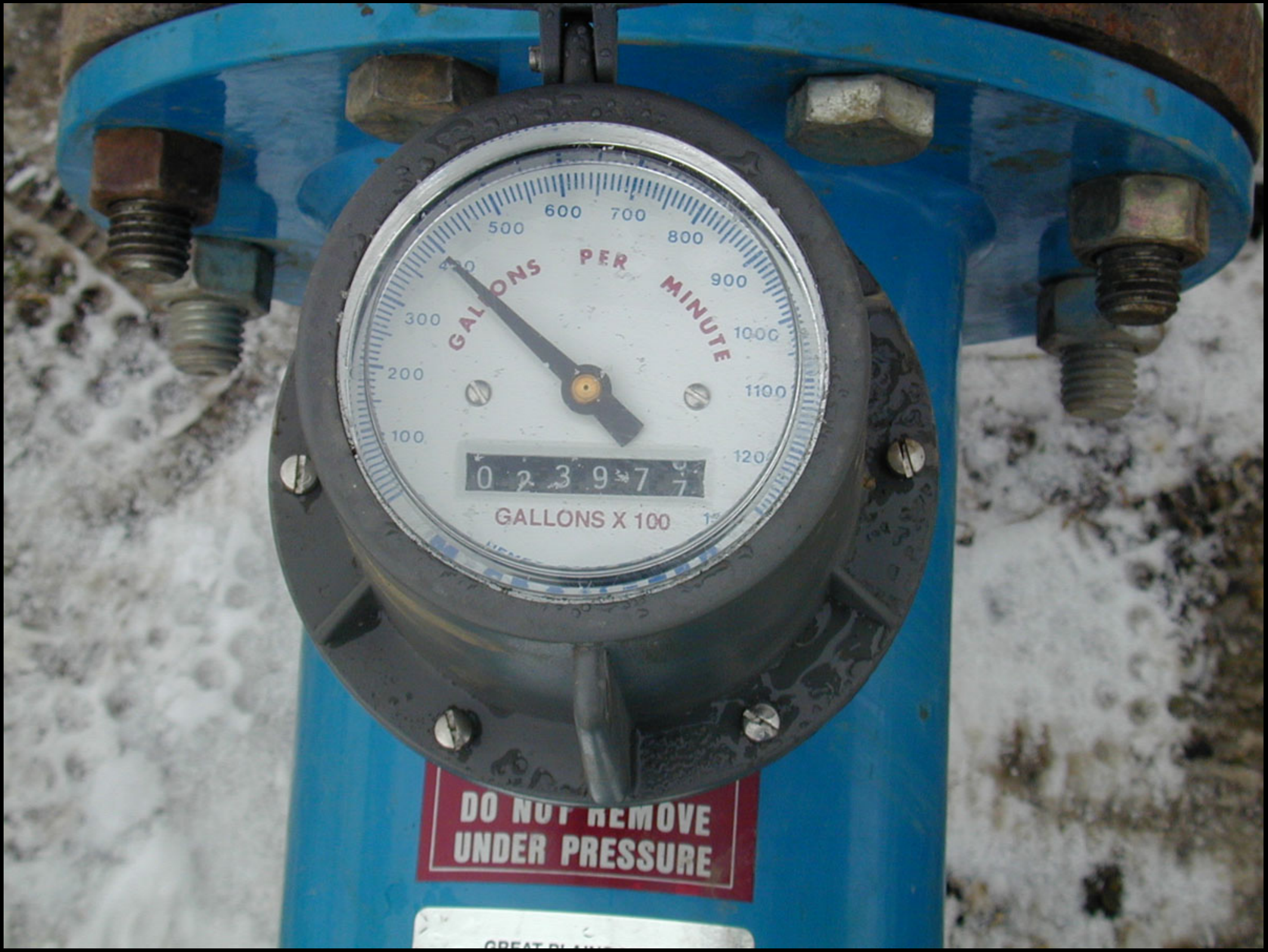


# LOTS AND LOTS OF WATER

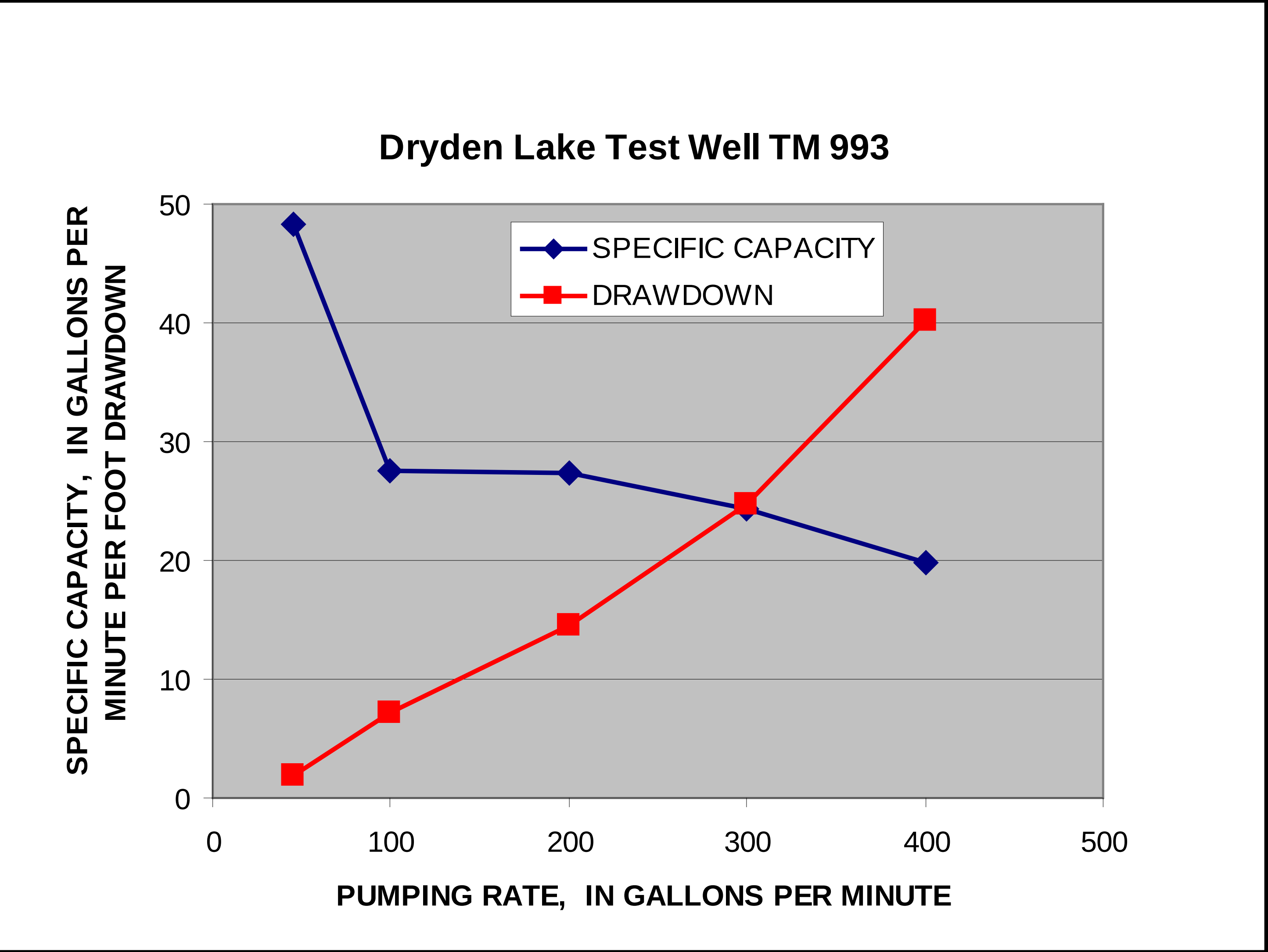
# BRIEF AQUIFER TEST

# BRIEF AQUIFER TEST

# 400 GAL/MIN FROM 6 IN. DIAMETER OPEN-END CASING

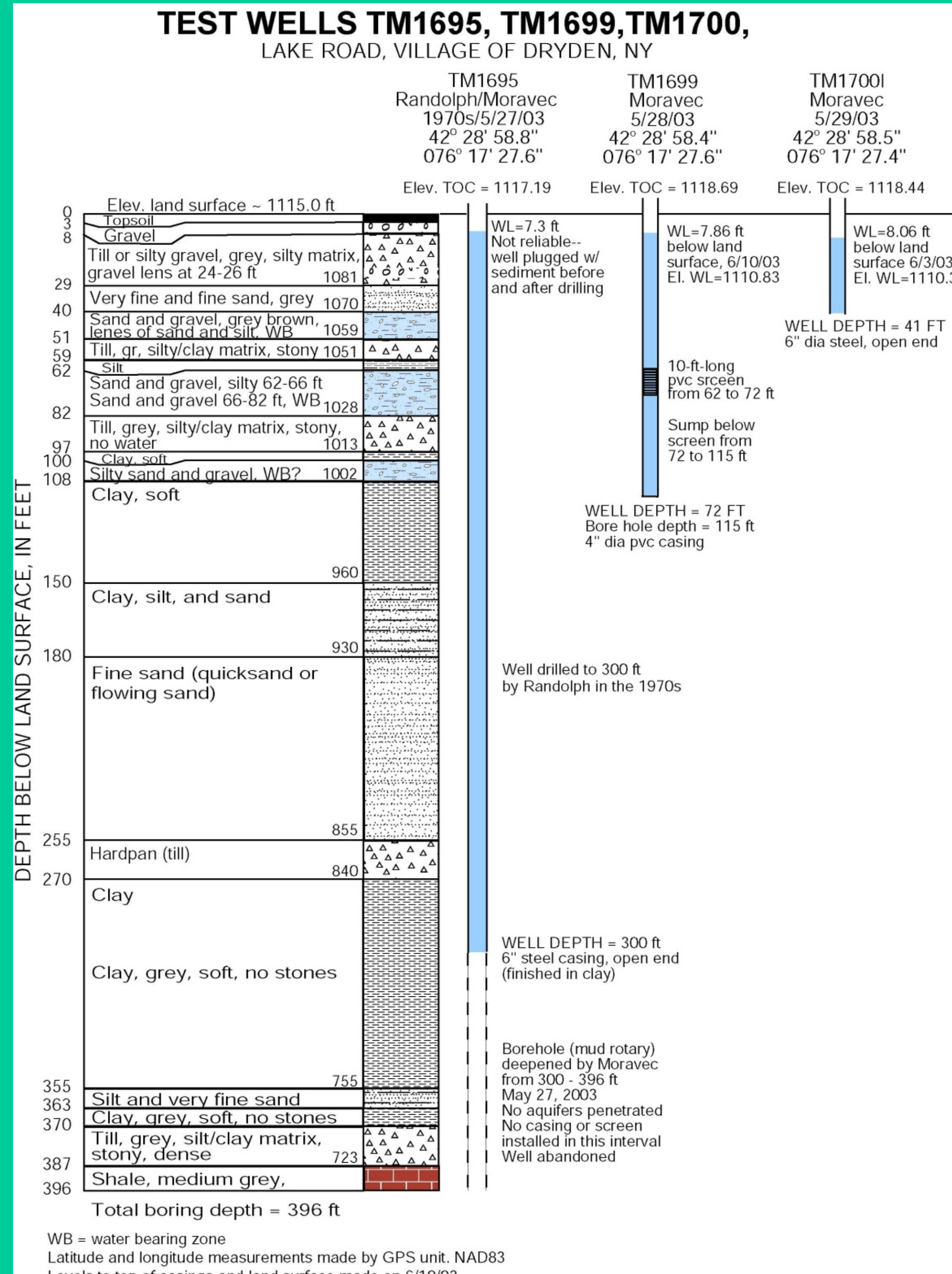


# RESULTS OF BRIEF AQUIFER TEST AT DRYDEN LAKE SITE

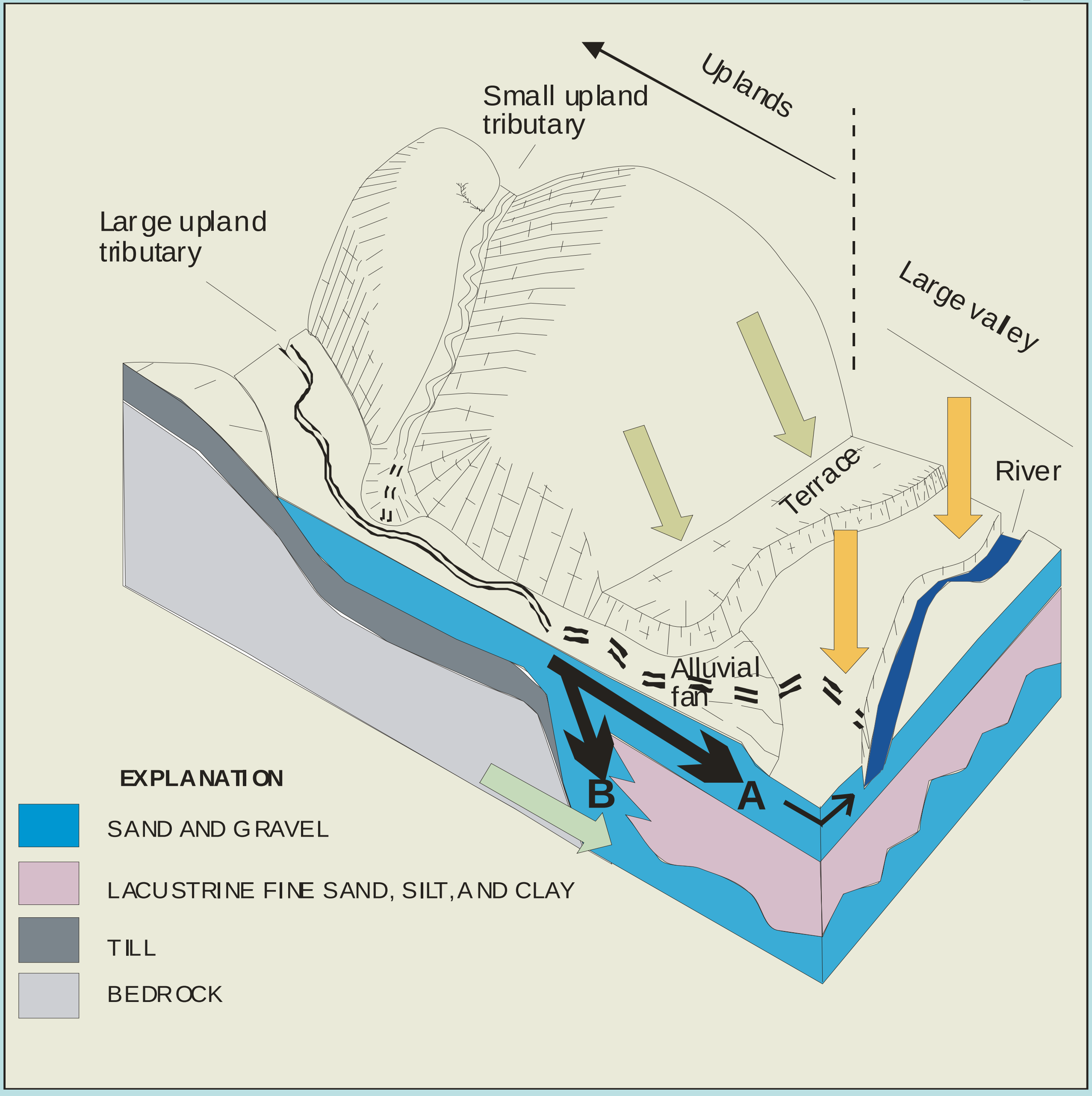


# TEST DRILLING AT LAKE RD WELL FIELD

# TEST DRILLING



# SOURCES OF WATER (RECHARGE)

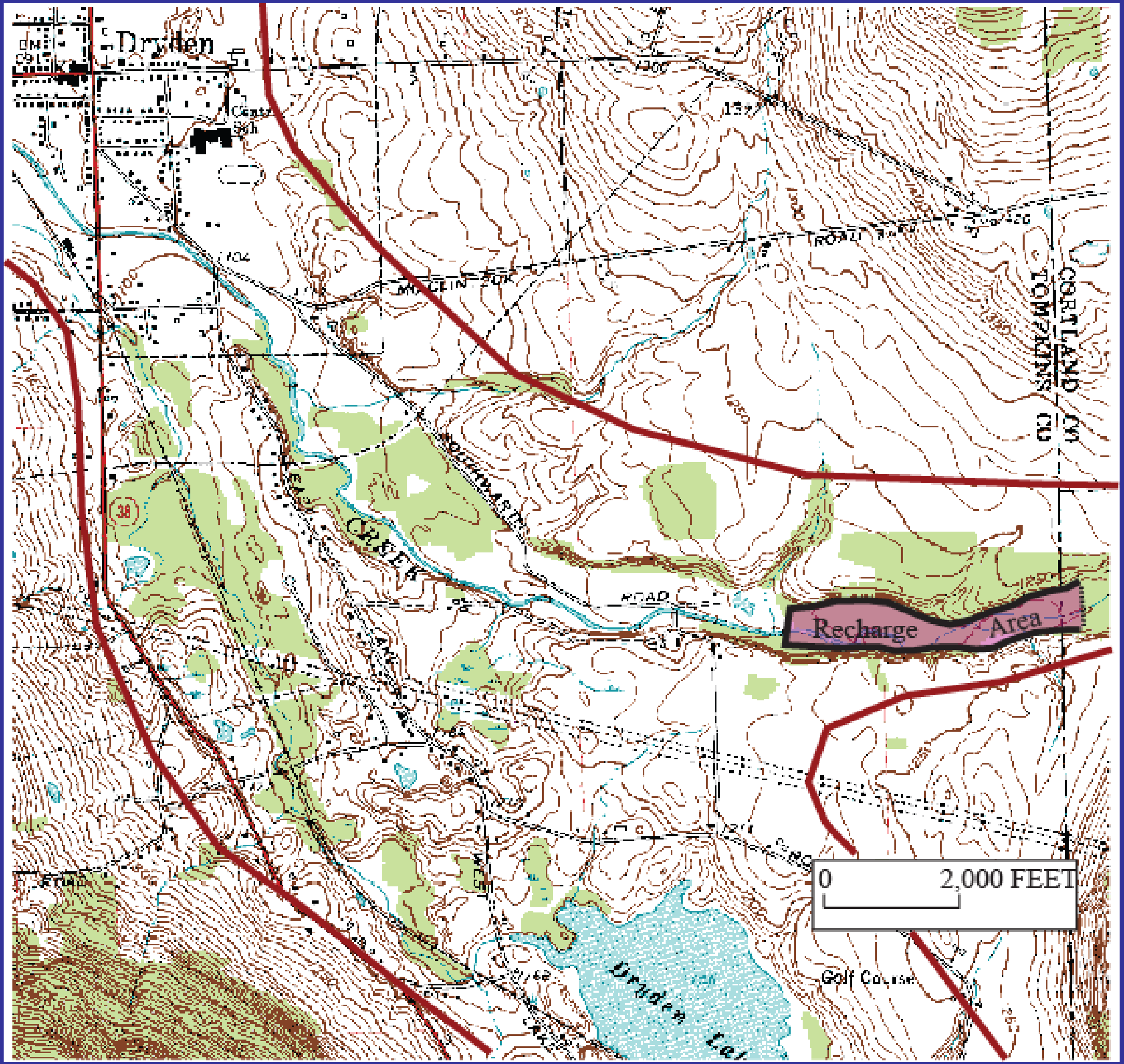



PRECIPITION OVER AQUIFER

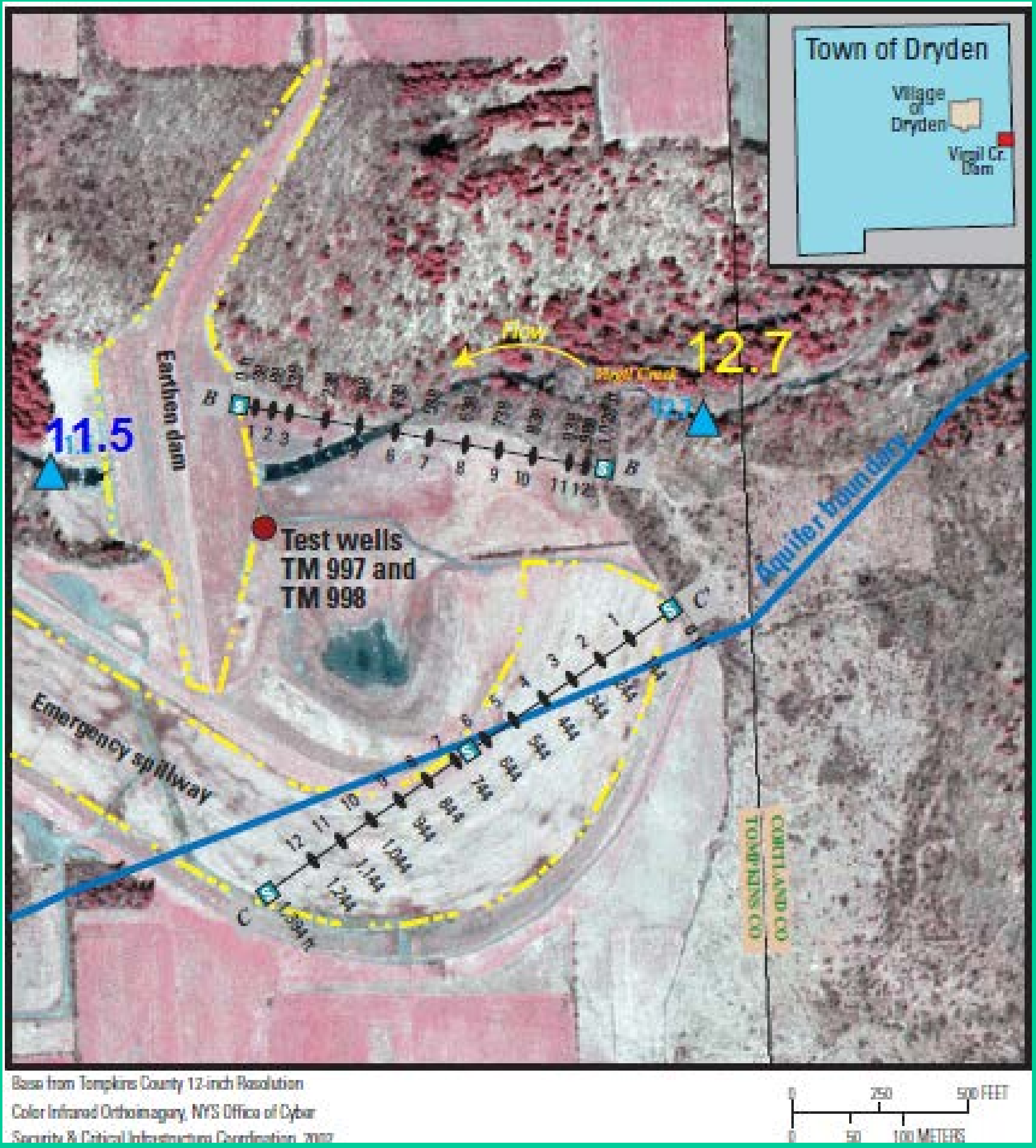
RUNOFF HILLSIDES

LOSING STREAMS

SEEPAGE FROM BEDROCK




RECHARGE AREAS TO CONFINED AQUIFERS ARE DIFFICULT TO LOCATE




# TO INVESTIGATE RECHARGE AREA AT VIRGIL DAM

1) Seismic-refraction
2) Seepage meas.
3) Test drilling
4) Water-level meas.
5) Surveying

# **TEST DRILLING-** Virgil Cr. Dam


Was the confining layer missing? (eroded Virgil Cr)

Was the aquifer connected to the stream?

What was the water level relationship between stream and aquifer?

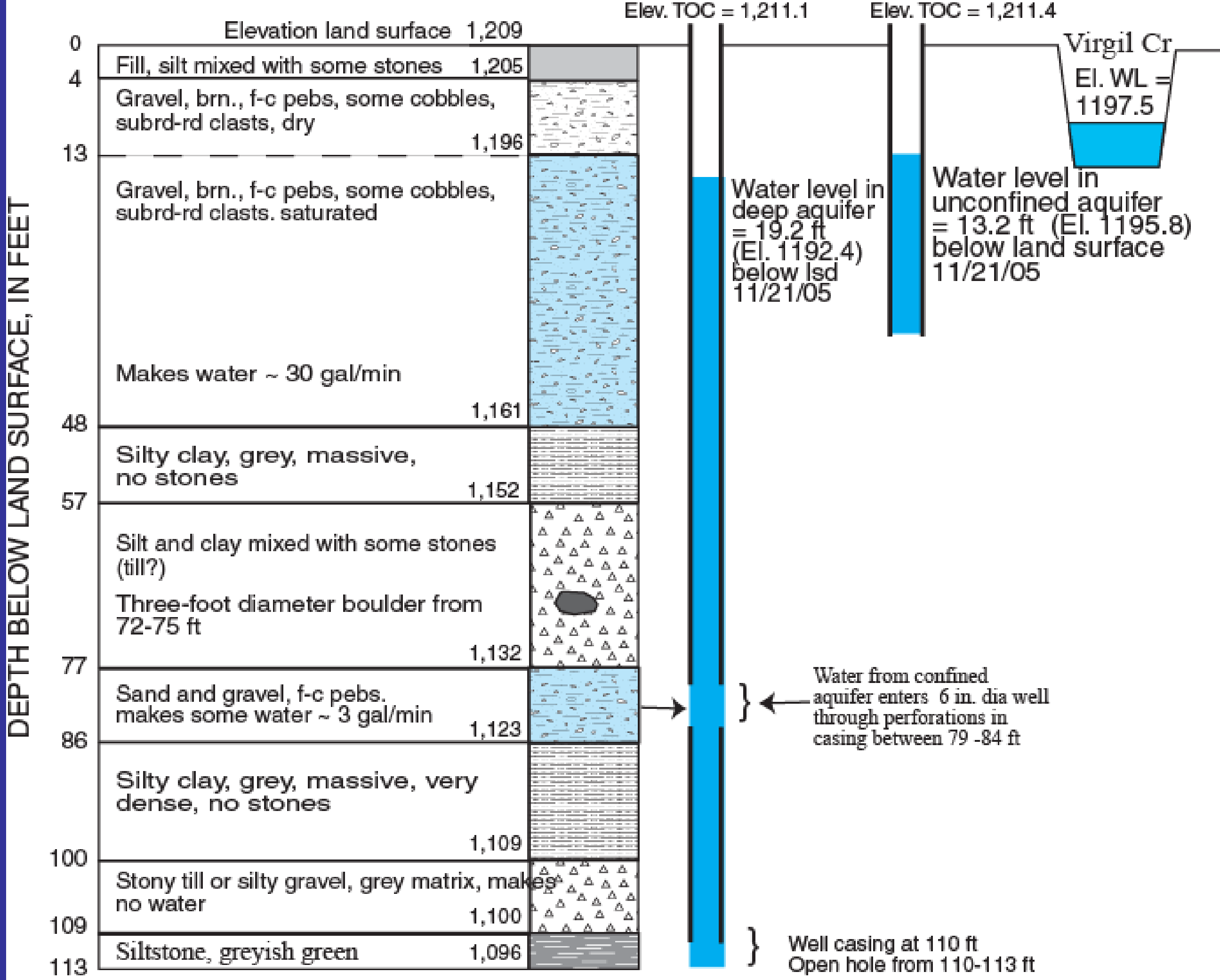
# USGS TEST WELLS TM 997 and TM 998

**Virgil Creek Dam, Town of Dryden, NY**

Site name: TM 997 (84 ft well)
Site ID: 422824076154501
Latitude: 42° 28' 23.58"
Longitude: 076° 15' 45.23"
Date completed: 11/17/05

Site name: TM 998 (37 ft deep well)
Site ID: 422823076154501
Latitude: 42° 28' 23.49"
Longitude: 076° 15' 45.26"
Date completed: 11/18/05

Drilling contractor: Barber & DeLine, Tully, NY




# TEST DRILLING BEHIND DAM

Recharge area confirmed

# Hydrogeologic section at Virgil Creek Dam

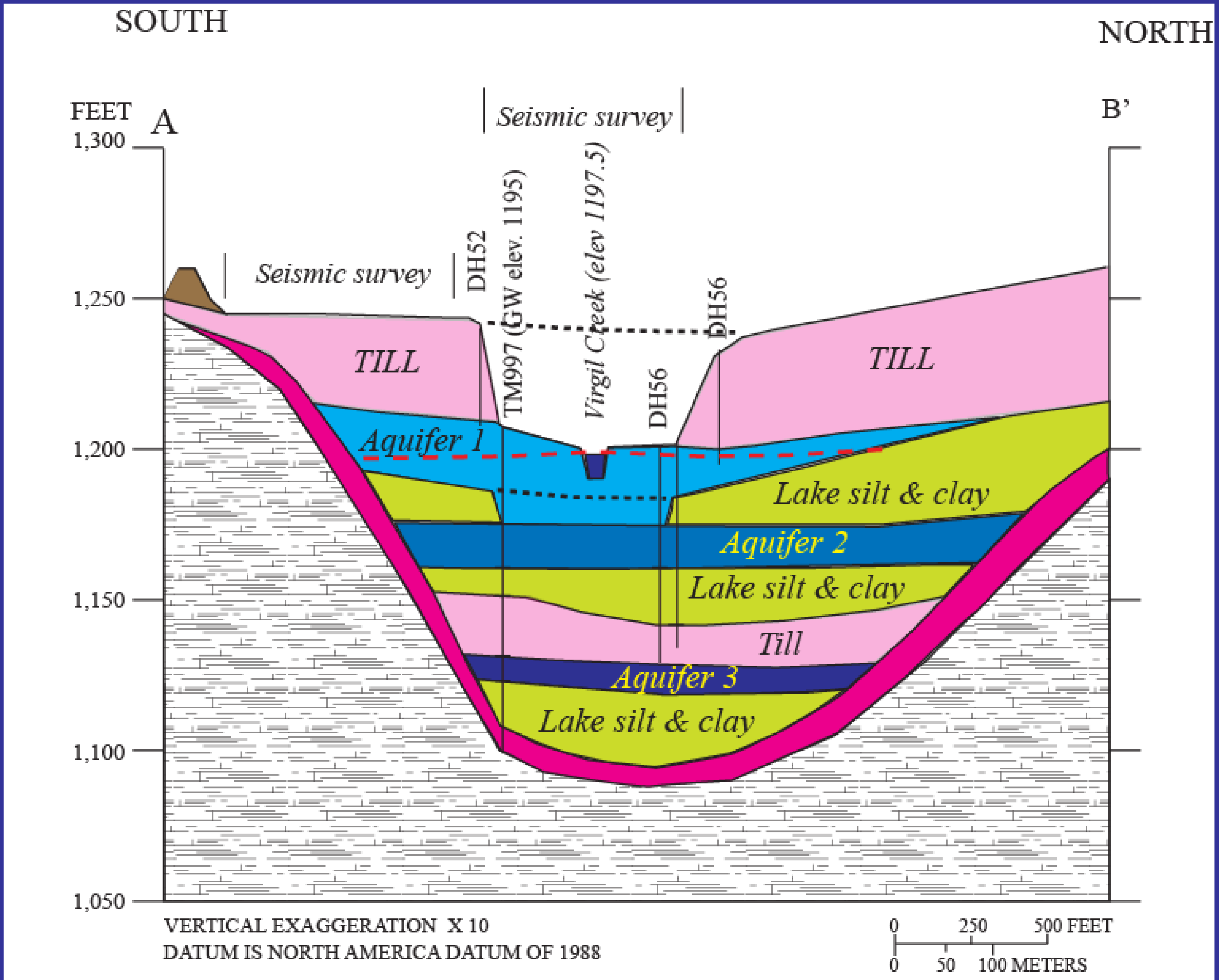
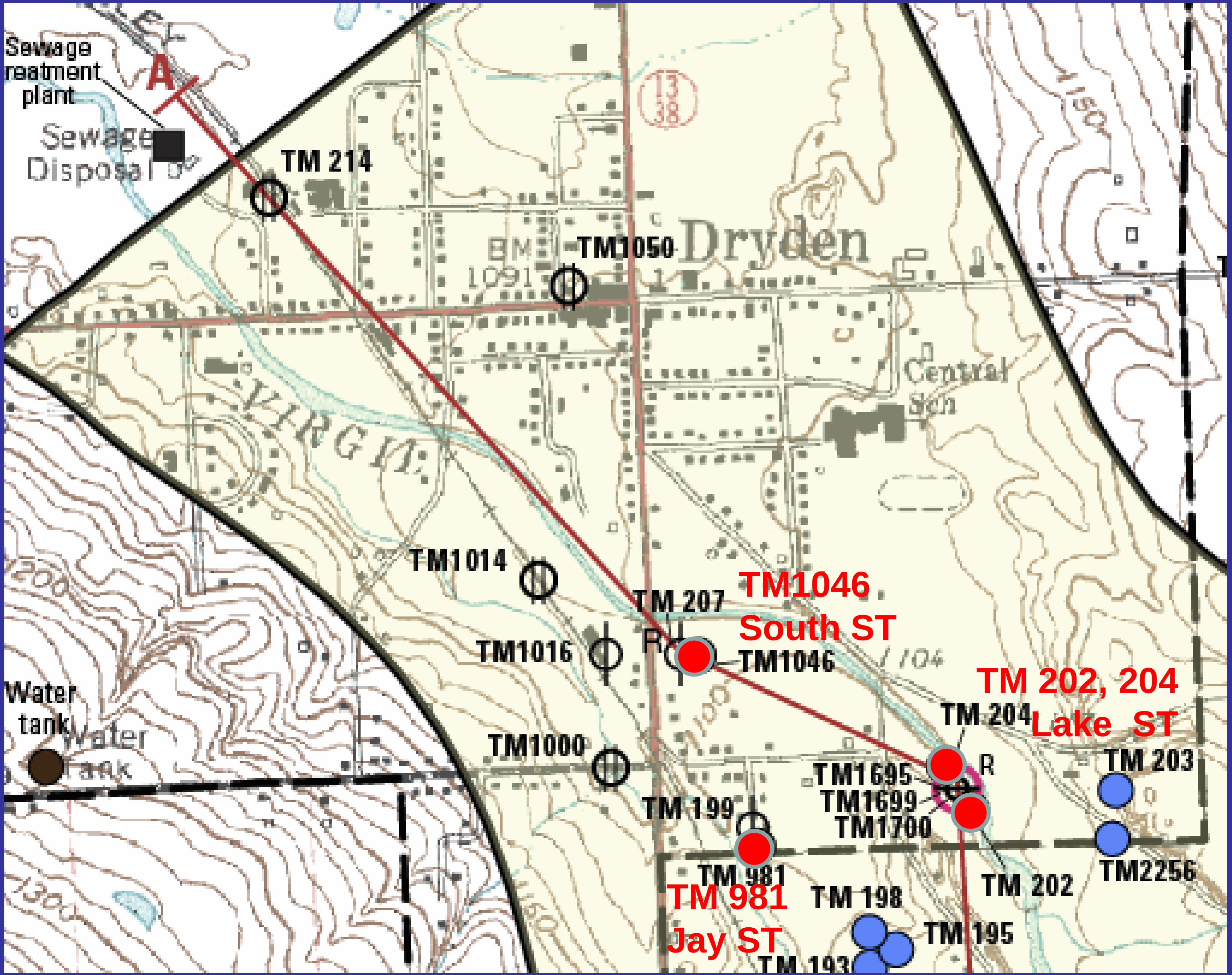
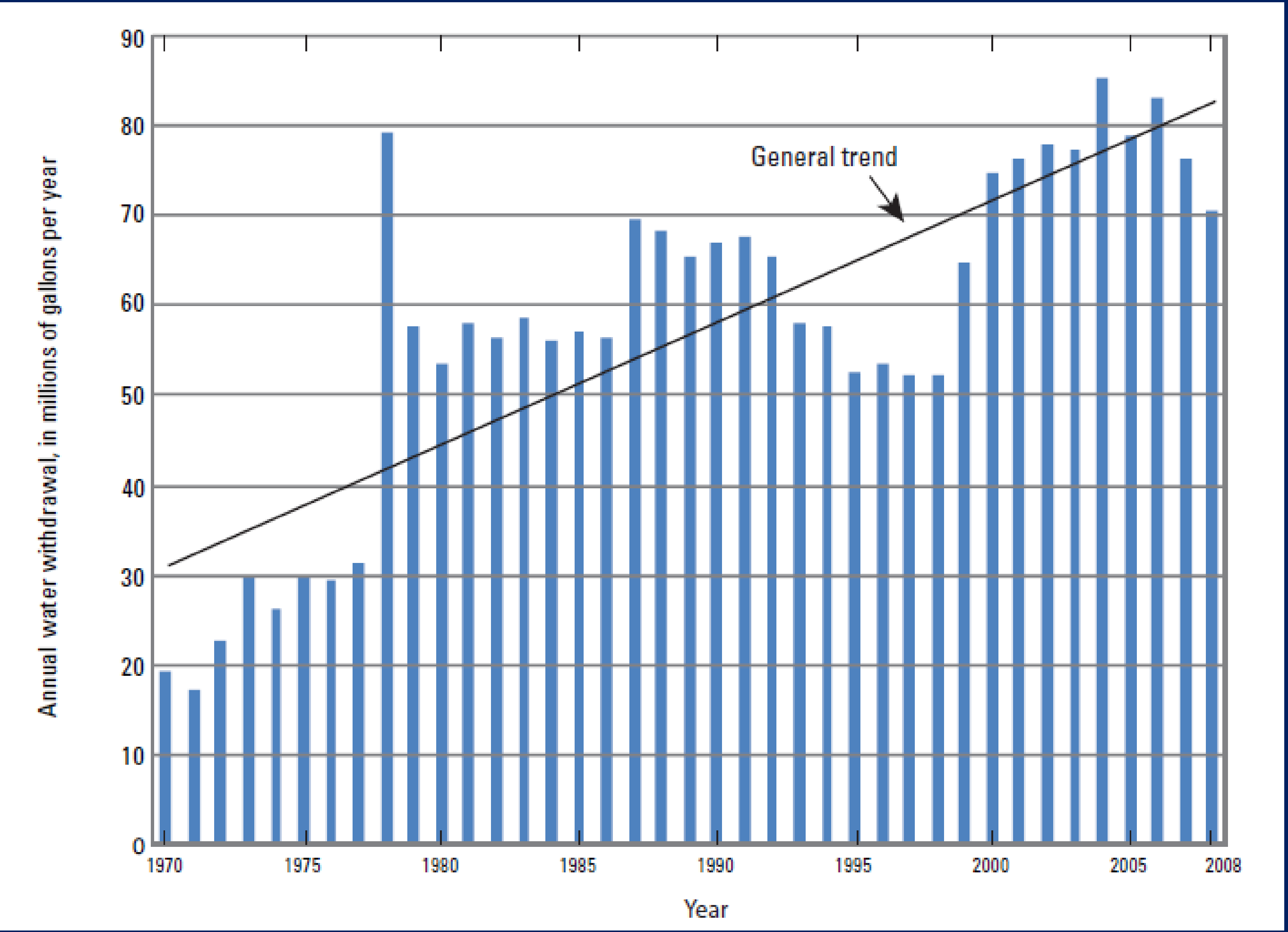



Figure __.-- Seismic refraction profile B--B' at the Virgil Creek Dam, Town of Dryden, New York

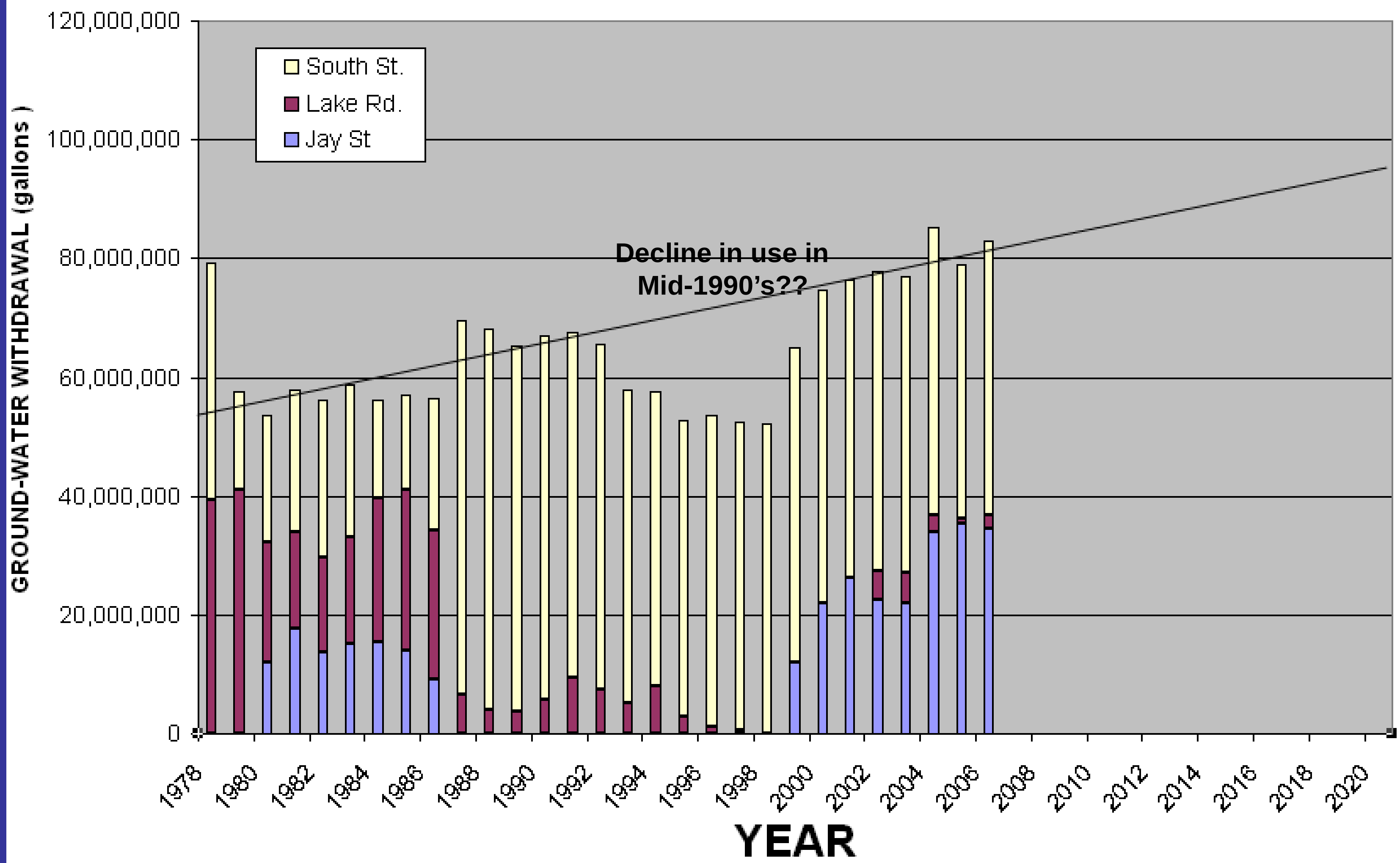
# WATER USE OF MUNICIPAL WELLS



# Annual withdrawals from the Village of Dryden, 1970 - 2008



# VILLAGE OF DRYDEN GROUND-WATER WITHDRAWAL
## 1978 through May 2007
## (includes yearly totals for all wells)



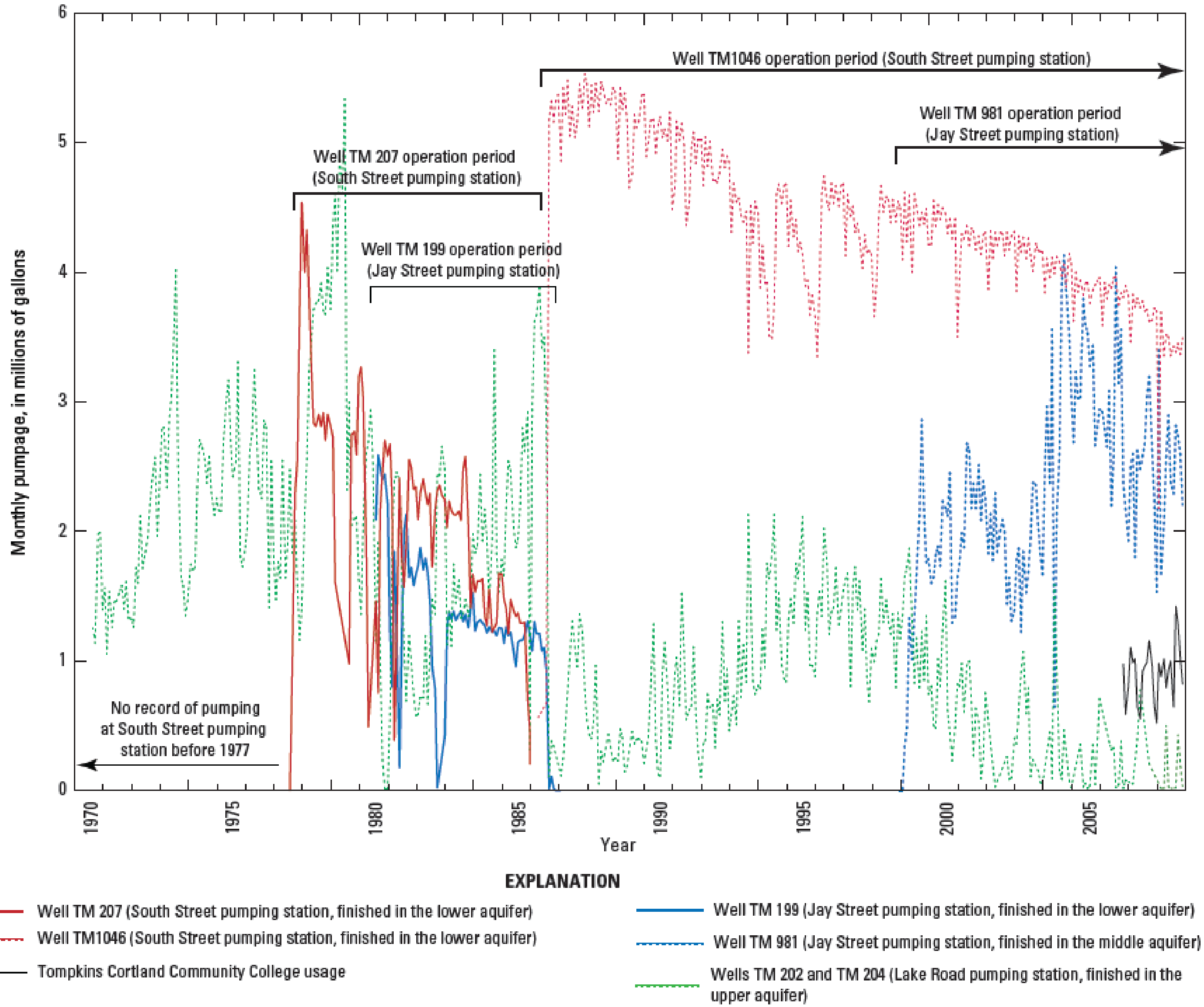
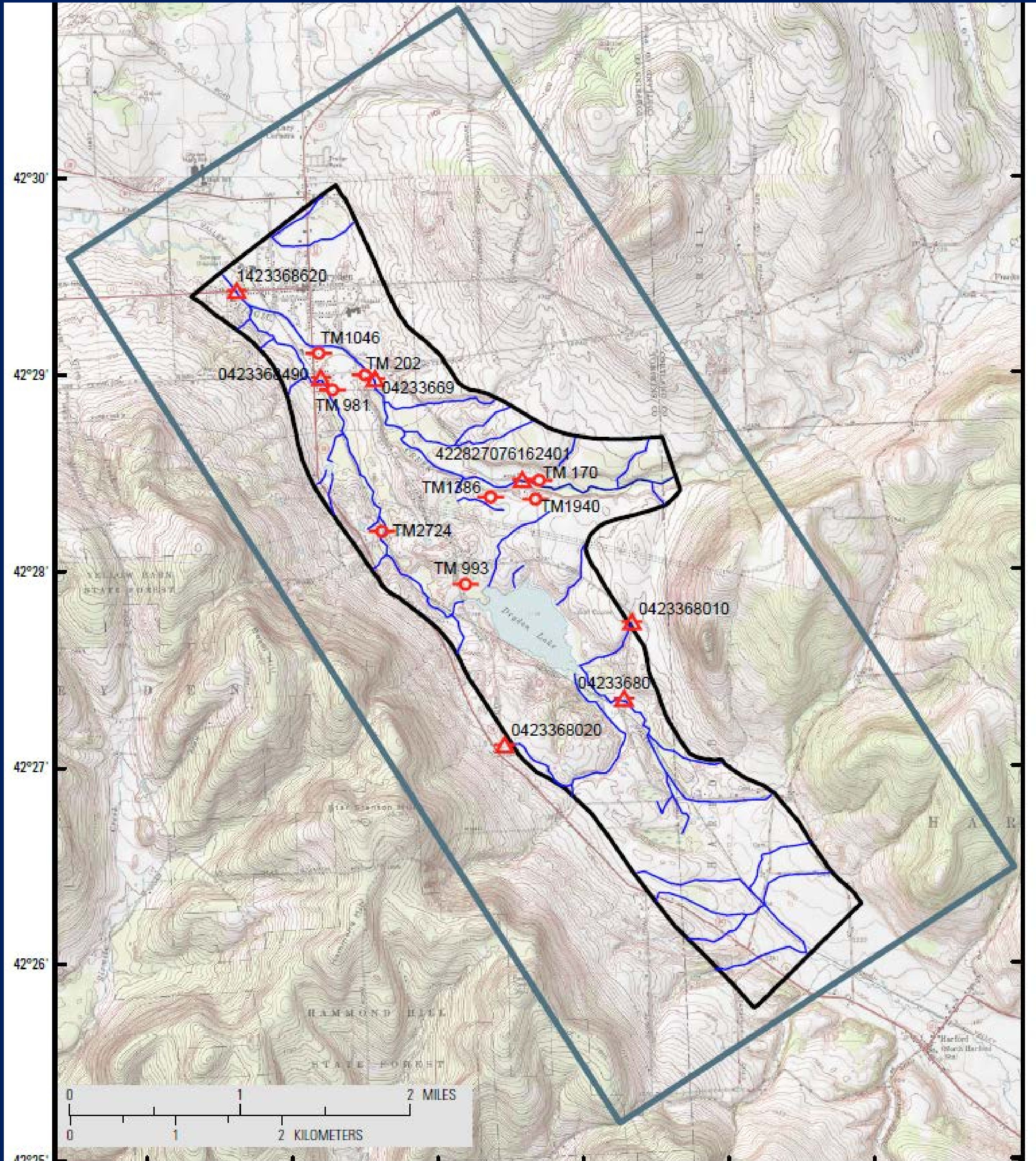



**Figure 20.** Monthly withdrawals from Village of Dryden, New York municipal production wells, September 1970 through December 2008 and water usage by Tompkins Cortland Community College from 2005 to 2008.




Topographic basemap from TOPO! and used with

# Water Quality sampling sites

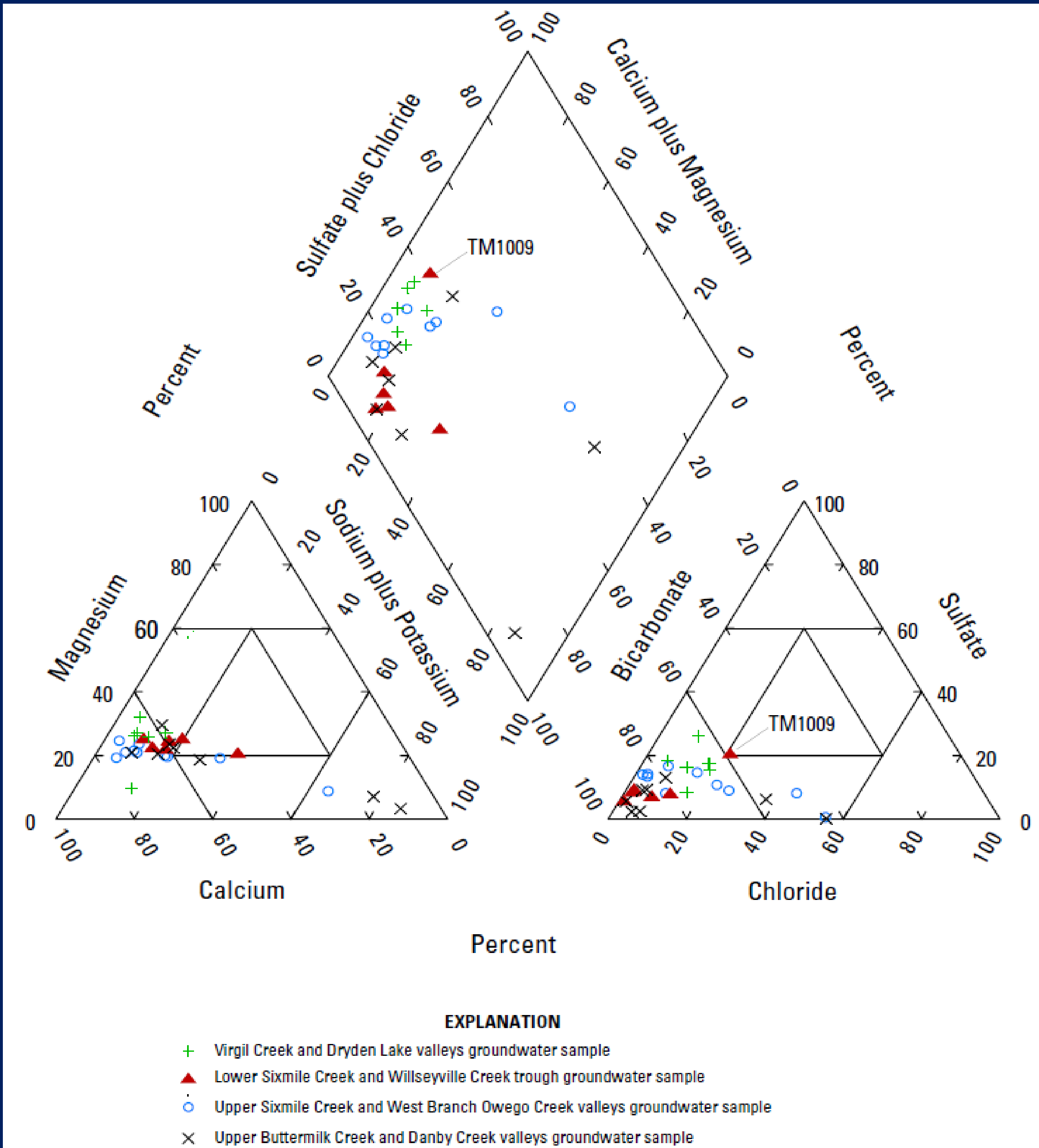
# WATER CHEMISTRY--Common Ions

| | | | Middle aquifer (Intermediate) | | Lower aquifer (Deep) | |
|---|---|---|---|---|---|---|
| Local Name | | | Lake St well 2 | Jay St well | South St. well | Dryden Lake |
| USGS Station Name | | | TM 202 | TM 981 | TM 207 | TM 993 |
| Date sampled | | | 7/28/2003 | 7/28/2003 | 7/28/2003 | 12/13/2004 |
| - **Station ID Number** | | | 422857 076172701 | 422854 076174201 | 422905 076144901 | 422755 076164801 |
| Common ions | Parm. Code | Units | Concentrations of chemical constituents | | | |
| Dissolved solids, at 180 C | 70300 | mg/L | 280 | 292 | 198 | 200 |
| Fluoride, dis | 00950 | mg/L | <0.17 | <0.17 | 0.24 | 0.11 |
| pH (field) | 00400 | pH | 8.1 | 8.2 | 8.1 | 7.9 |
| Sp. conductance (field) | 00095 | uS/cm | 475 | 487 | 328 | 337 |
| Iron, dis | 01046 | ug/L | 70.5 | 43 | 92.1 | 105 |
| Manganese, dis | 01056 | ug/L | 156 | 161 | 149 | 114 |
| Calcium, dis | 00915 | mg/L | 75.2 | 70.0 | 48.0 | 39.6 |
| Magnesium, dis | 00925 | mg/L | 16.9 | 17.2 | 11.9 | 11.2 |
| Silica, dis | 00955 | mg/L | 10.3 | 13.1 | 13.7 | 11.0 |
| Sodium, dis | 00930 | mg/L | 8.61 | 12.2 | 8.78 | 10.8 |
| Chlorides, dis | 00940 | mg/L | 16.7 | 31.7 | 5.71 | 19.3 |
| Sulfate, dis | 00945 | mg/L | 32.9 | 45.4 | 26.6 | 27.5 |
| Alkalinity, dis, (field) | 39086 | mg/L | | | 115 | 106 |
| Potassium, dis | 00935 | mg/L | 0.73 | 0.60 | 0.71 | 0.86 |

# WATER CHEMISTRY--Nutrients

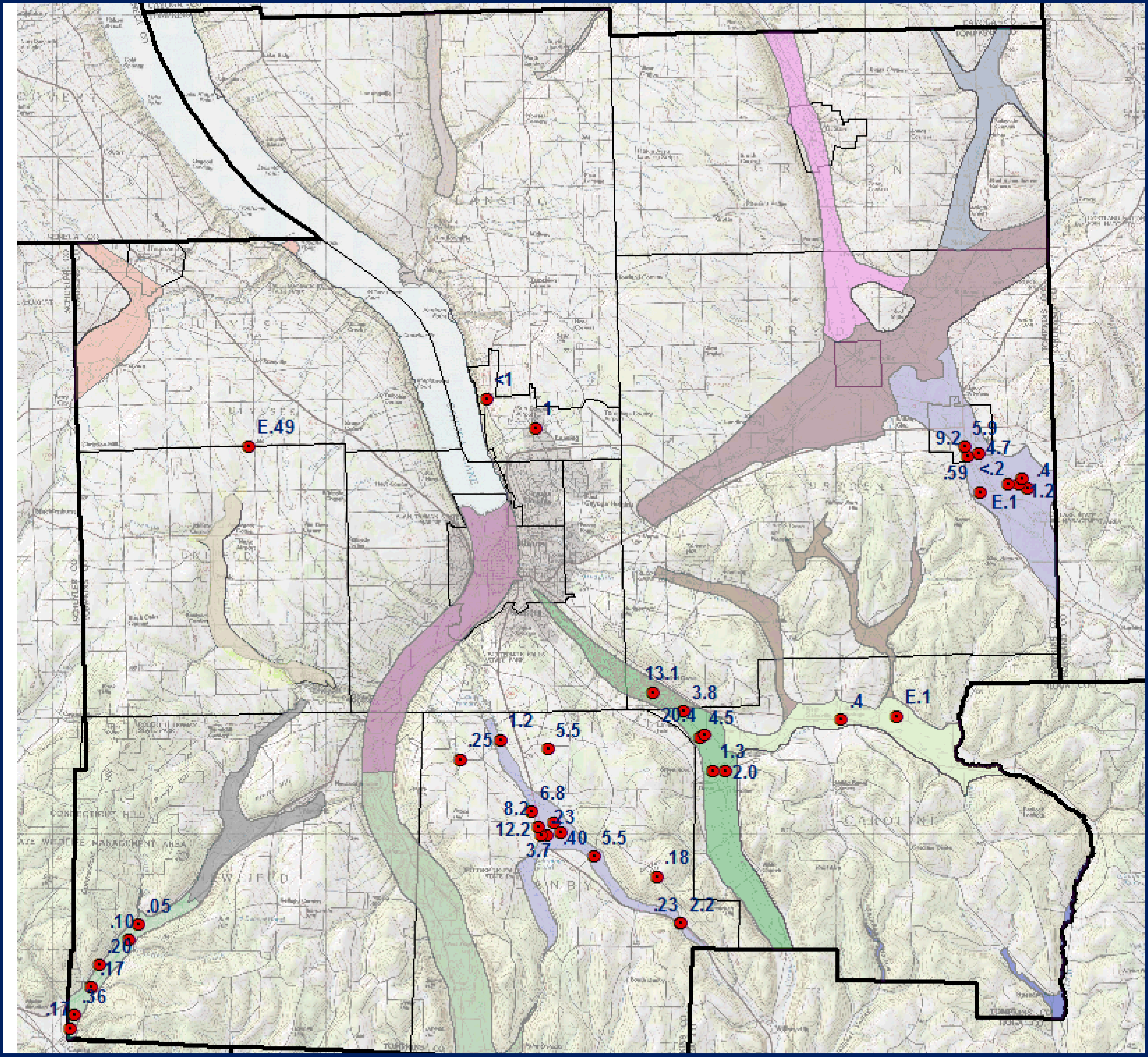
## Nitrates were found above the detection limit

| | | Local Name | Lake St well 2 | Jay St well | South St. well | Dryden Lake |
|---|---|---|---|---|---|---|
| | | USGS Station Name | TM 202 | TM 981 | TM 207 | TM 993 |
| | | Date sampled | 7/28/2003 | 7/28/2003 | 7/28/2003 | 12/13/2004 |
| - Station ID Number | | | 422857 076172701 | 422854 076174201 | 422905 076144901 | 422755 076164801 |
| Common ions | Parm. Code | Units | Concentrations of chemical constituents | | | |
| Nutrients | | | | | | |
| N, Nitrite | 00613 | mg/L | <0.008 | <0.008 | <0.008 | <0.008 |
| P, ortho-phosphate | 00671 | mg/L | <0.02 | <0.02 | <0.02 | <0.02 |
| N as nitrate, no2+no3 | 00631 | mg/L | <0.060 | <0.060 | <0.060 | <0.060 |
| N, ammonia | 00608 | mg/L | E0.03 | 0.05 | 0.12 | <0.04 |
| N, organic+ammonia, fil | 00623 | mg/L | E0.06 | E0.08 | 0.1 | <0.1 |
| N, organic+ammonia, wca | 00625 | mg/L | E0.09 | 0.1 | 0.2 | <0.1 |
| Low-level phosphorus, fil | 00666 | mg/L | E0.003 | 0.006 | 0.011 | 0.004 |
| Low-level phosphorus, wca | 00665 | mg/L | E0.003 | 0.006 | 0.011 | 0.007 |
| Physical properties | | | Values of physical properties | | | |
| Depth of well | | ft | 53 | 72 | 176 | 234 |
| Aquifer type | | | S&G, conf | S&G, conf | S&G, conf | S&G, conf |
| Water temperature | | Celcius | 10.0 | 10.2 | 10.7 | 10.1 |



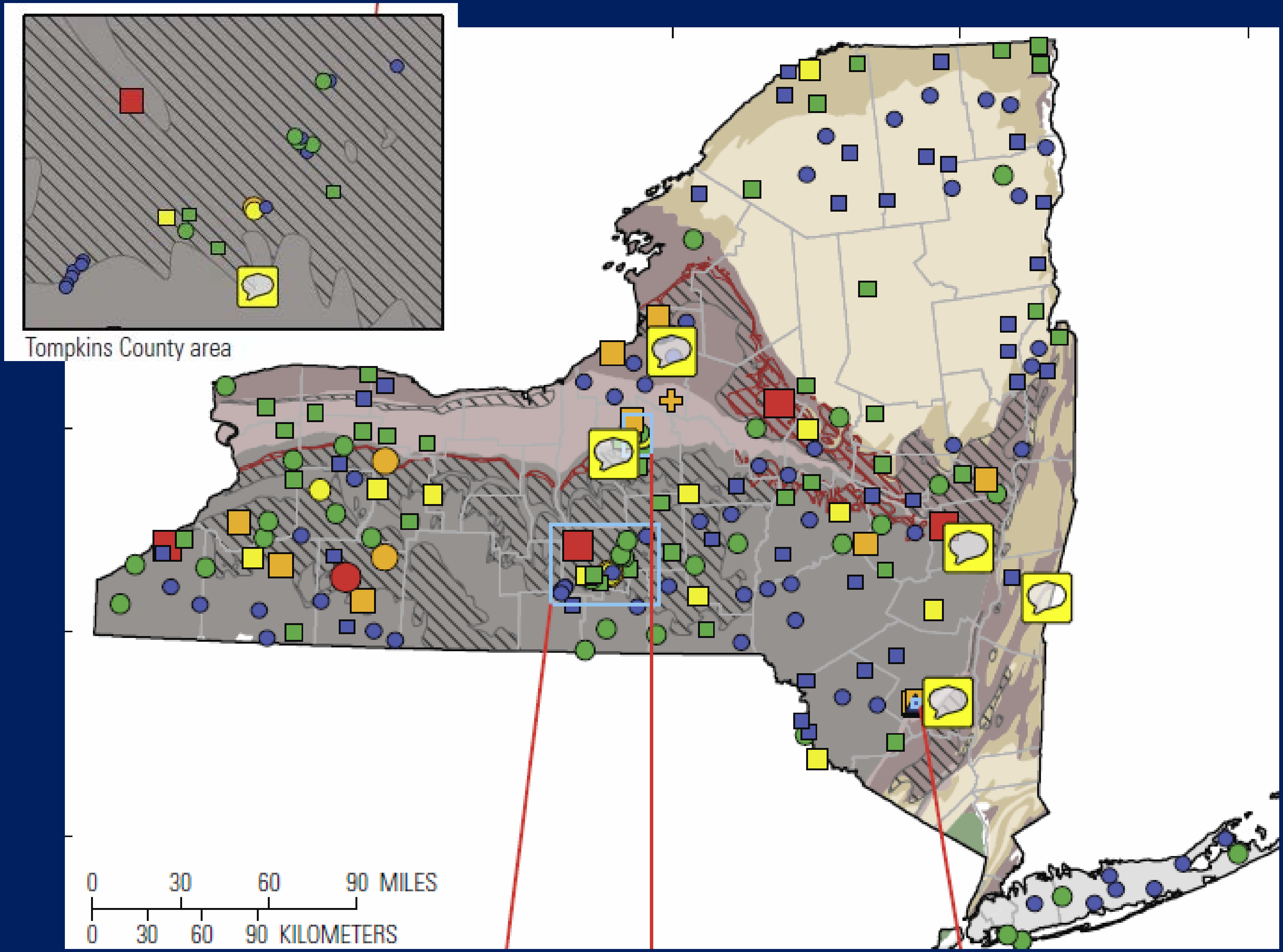

# Variability in major ion composition of groundwater in four valley-fill aquifers in Tompkins County

Groundwater was predominantly a calcium bicarbonate type except for a few samples




About 10% of samples in central NY have arsenic above the drinking-water standard

# Methane in Groundwater



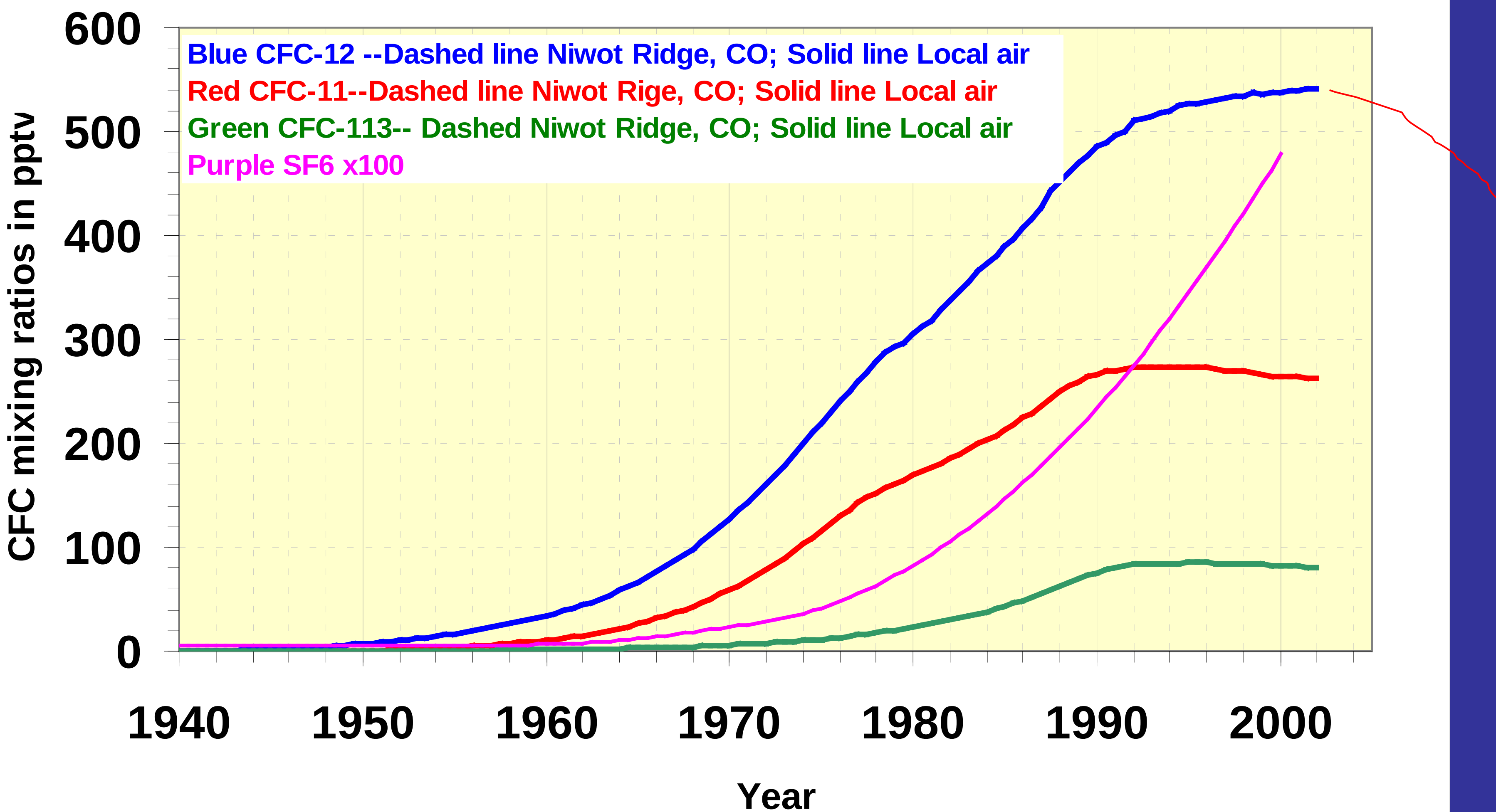
# DATING YOUNG GROUNDWATER

Every drop tells a story

## Chlorofluorocarbons CFCs)

- Determine ground-water age
- Improve understanding of hydrology
- Refine ground-water models
- Assess aquifer susceptibility to anthropogenic inputs (SWAP)
- Trace movement of water
- Locate recharge and discharge areas

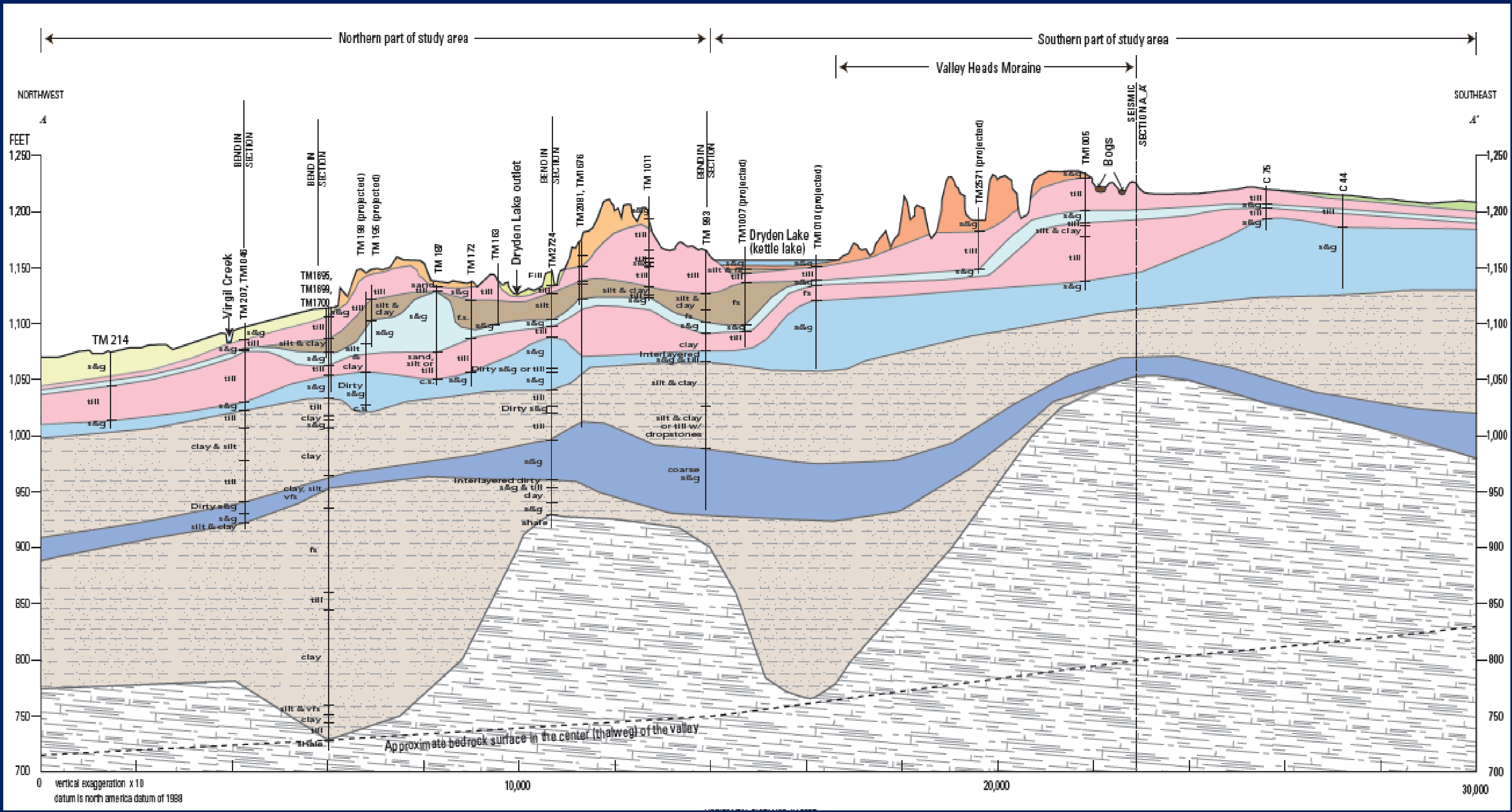
# CFCs IN ATMOSPHERE



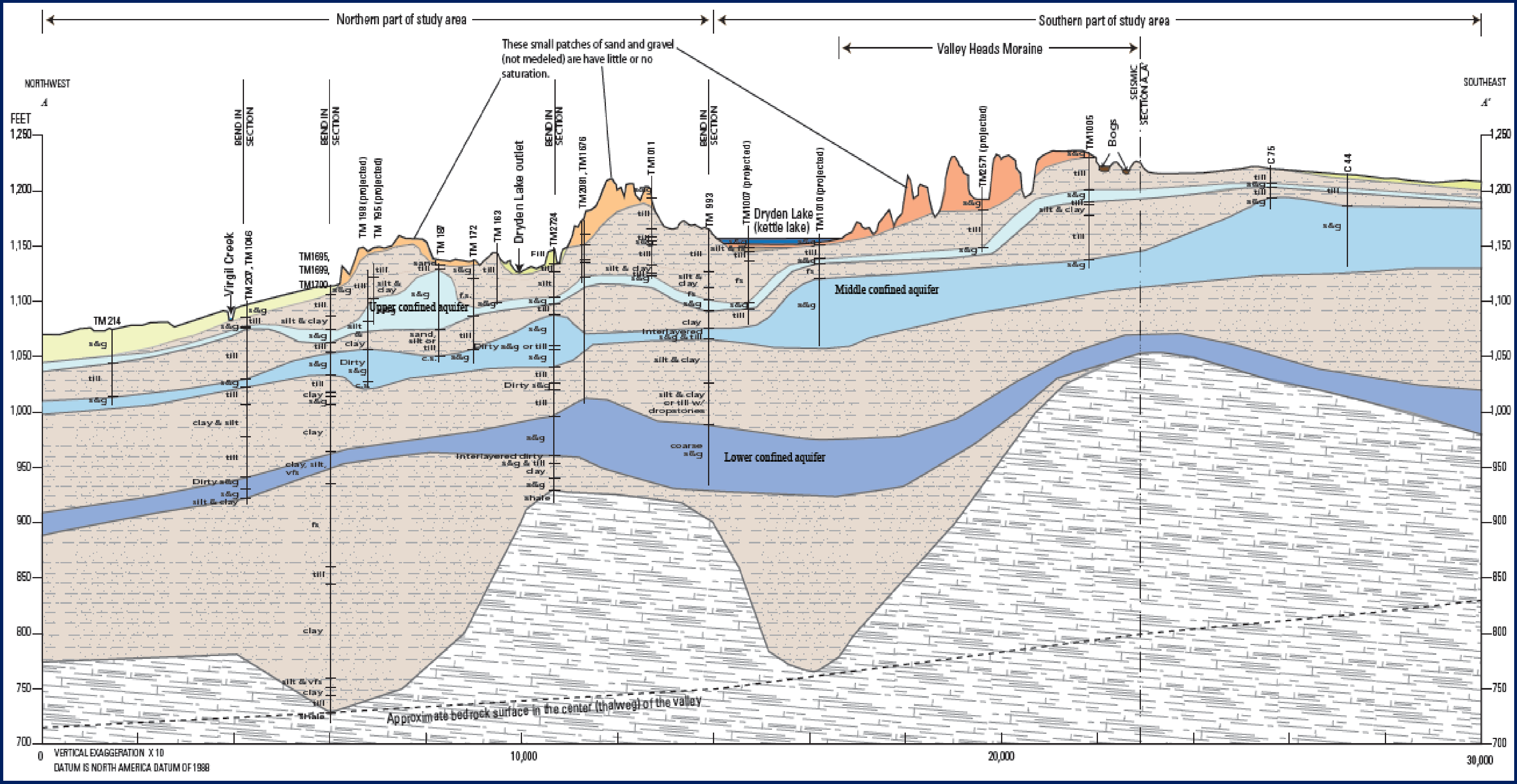
# RESULTS OF CFCs DATING

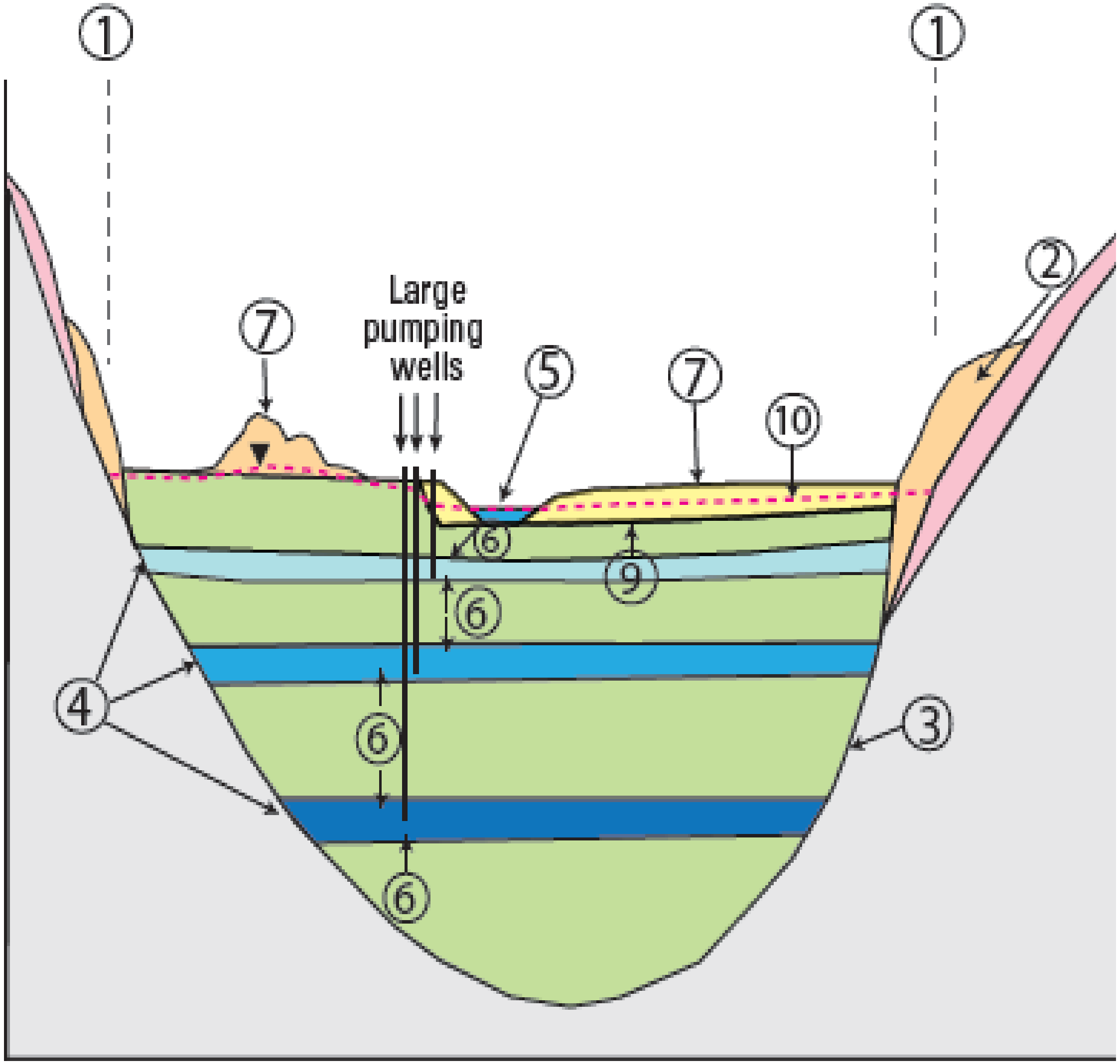
| Sample Site number | Rech temp C | Conc. In solution CFC-11 pg/kg | CFC-12 pg/kg | CFC-113 pg/kg | Recom. Age based on | Comments |
|---|---|---|---|---|---|---|
| TM 207 South St. Well | 1.9 | 65.61601 | 0.0 | 0 | CFC12 | |
| | 1.9 | 47.84833 | 0.0 | 0 | CFC113 | Greater than 40 years and |
| | 1.9 | 29.62258 | 0.0 | 0 | | probably older than 1940 |
| TM 980 Jay St. Well | 4.8 | 107.1986 | 1.1 | 0 | CFC12 | |
| | 4.8 | 12.51112 | 0.0 | 0 | CFC113 | Greater than 40 years and |
| | 4.8 | 89.04419 | 0.8 | 0 | | probably older than 1940 |
| TM 202 Lake St. Well | 5.6 | 23.64433 | 0.0 | 0 | CFC12 | |
| | 5.6 | 74.45091 | 0.6 | 0 | CFC113 | Greater than 40 years and |
| | 5.6 | 71.58162 | 0.8 | 0 | | probably older than 1940 |
| TM993 Dryden Lake Well | 4.0 | 2.194039 | 0.197961 | 0.16707 | All | Early to mid 1970's. |
| | 4.0 | 2.238679 | 0.849187 | 0.26485 | | |
| | 4.0 | 1.298937 | 0.119095 | 0.05203 | | |
| Well TM170 Pleasant View | 8.8 | 0.014 | 3.767 | 0.008 | All | Mid 1940's or older water |
| | 8.8 | 0.007 | 1.918 | 0 | | |
| | 8.8 | 0.013 | 0.441 | 0 | | |

# Glacial Stratigraphy



# Hydrostratigraphy (geology simplified)

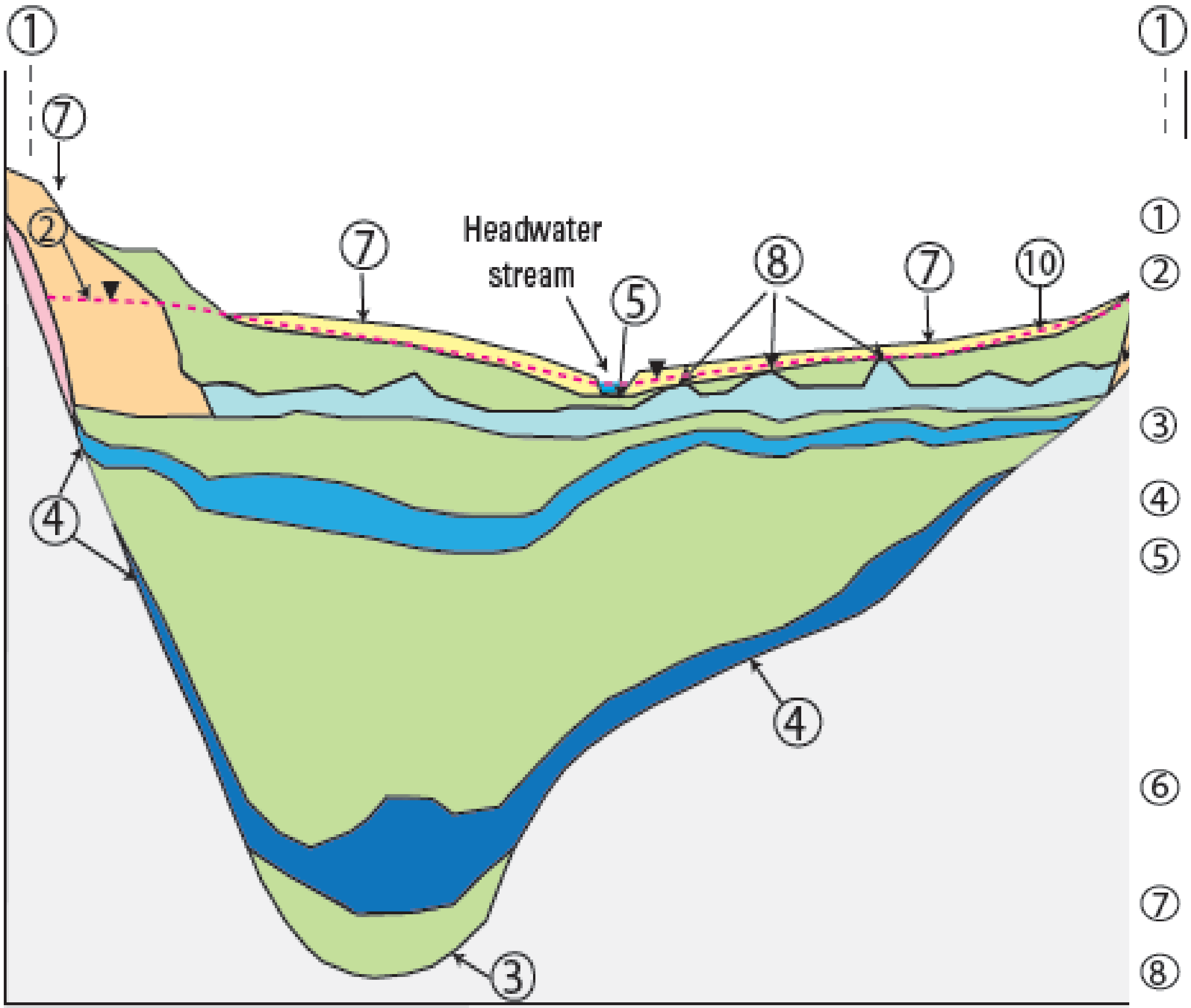





A. Northern part of the study area—thin alluvial and small kame unconfined units and three extensive and continuous confined aquifers

**EXPLANATION**

1. Edge of valley-fill deposits.
2. Recharge along edge of valley-fill deposits from infiltration of precipitation; and groundwater inflow and runoff from upland areas, recharing the confined aquifers where they crop outat land surface or is in contact with coarse-grained kame deposits.
3. Lateral contact between fine-grained stratified drift and till or bedrock. Flow across this contact is small.
4. Some leakage from till and bedrock along the valley walls valley bottom recharges the confined aquifers.
5. In most places, little or no water recharges the confined aquifer from streams flowing across the fine-grained deposits in the main valley except in the vicinity of the Village of Dryden municipal well (TM 204) that taps the upper aquifer and is near Virgil Creek—withdrawals from this shallow aquifer lowers the water levels enough to induce recharge from the overlying confining unit and, subsequently, from the overlying stream.
6. Some recharge reaches confined aquifer from overlying and underlying sources through the over- and underlying confining units, especially where large withdrawals increase the vertical gradient into the aquifer.
7. Recharge from precipitation that falls directly over valley-fill sediments.
8. Confining units may be locally interrupted by "windows" of permeable sediment that can readily transmit recharge from precipitation and tributaries that lose water as they flow over the valley floor.
9. In areas where the hydraulic head in the units underlying the surficial alluvium is greater than that in the alluvium, some water from below recharges the surficial alluvium.
10. Water table in the valley-fill deposits.




B. Southern part of study area—thin alluvial unit and three extensive and continuous confined aquifers

**EXPLANATION**

① Edge of valley-fill deposits.

② Recharge along edge of valley-fill deposits from infiltration of precipitation; and groundwater inflow and runoff from upland areas, recharing the confined aquifers where they crop outat land surface or is in contact with coarse-grained kame deposits.

③ Lateral contact between fine-grained stratified drift and till or bedrock. Flow across this contact is small.

④ Some leakage from till and bedrock along the valley walls valley bottom recharges the confined aquifers.

⑤ In most places, little or no water recharges the confined aquifer from streams flowing across the fine-grained deposits in the main valley except in the vicinity of the Village of Dryden municipal well (TM 204) that taps the upper aquifer and is near Virgil Creek—withdrawals from this shallow aquifer lowers the water levels enough to induce recharge from the overlying confining unit and, subsequently, from the overlying stream.

⑥ Some recharge reaches confined aquifer from overlying and underlying sources through the over- and underlying confining units, especially where large withdrawals increase the vertical gradient into the aquifer.

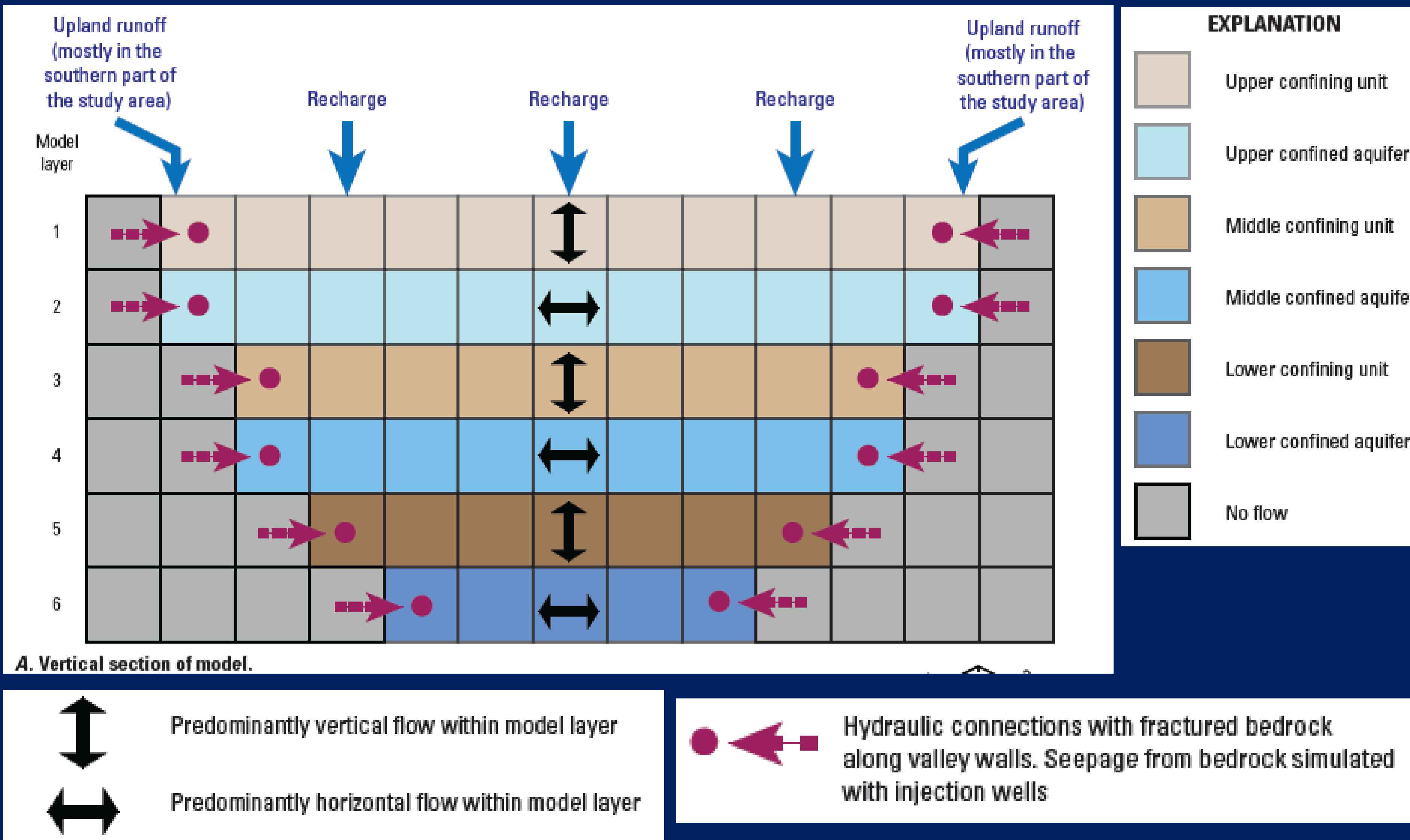
⑦ Recharge from precipitation that falls directly over valley-fill sediments.

⑧ Confining units may be locally interrupted by "windows" of permeable sediment that can readily transmit recharge from precipitation and tributaries that lose water as they flow over the valley floor.

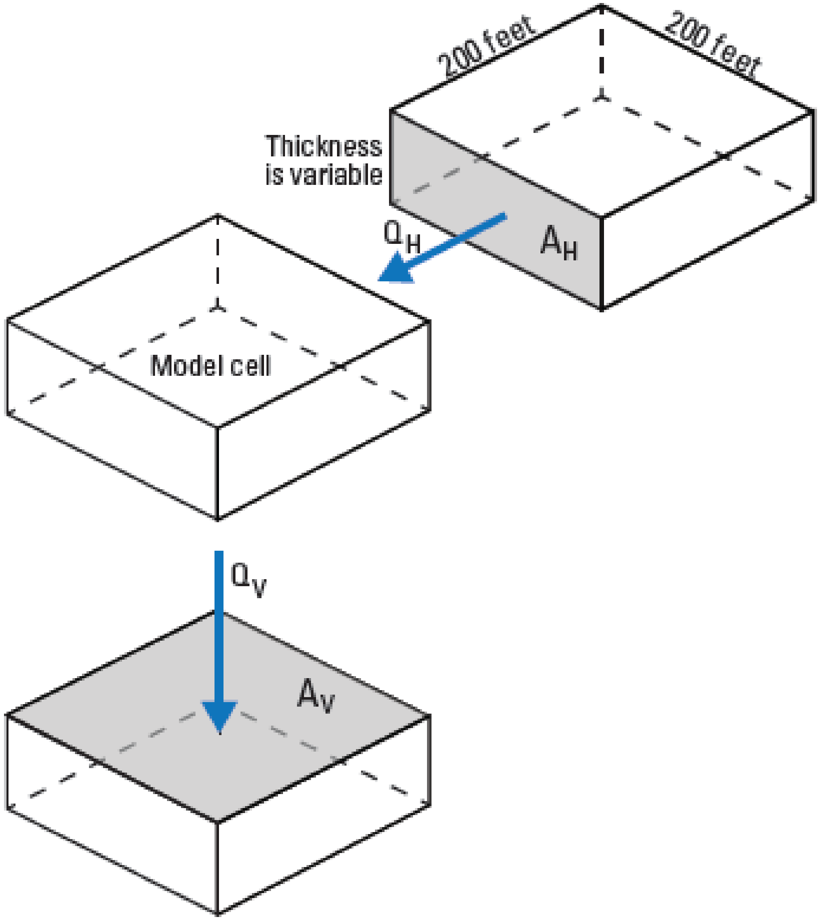
⑨ In areas where the hydraulic head in the units underlying the surficial alluvium is greater than that in the alluvium, some water from below recharges the surficial alluvium.

⑩ Water table in the valley-fill deposits.

# Simulation of GW flow using a numerical model (MODFLOW)




*A.* Vertical section of model.



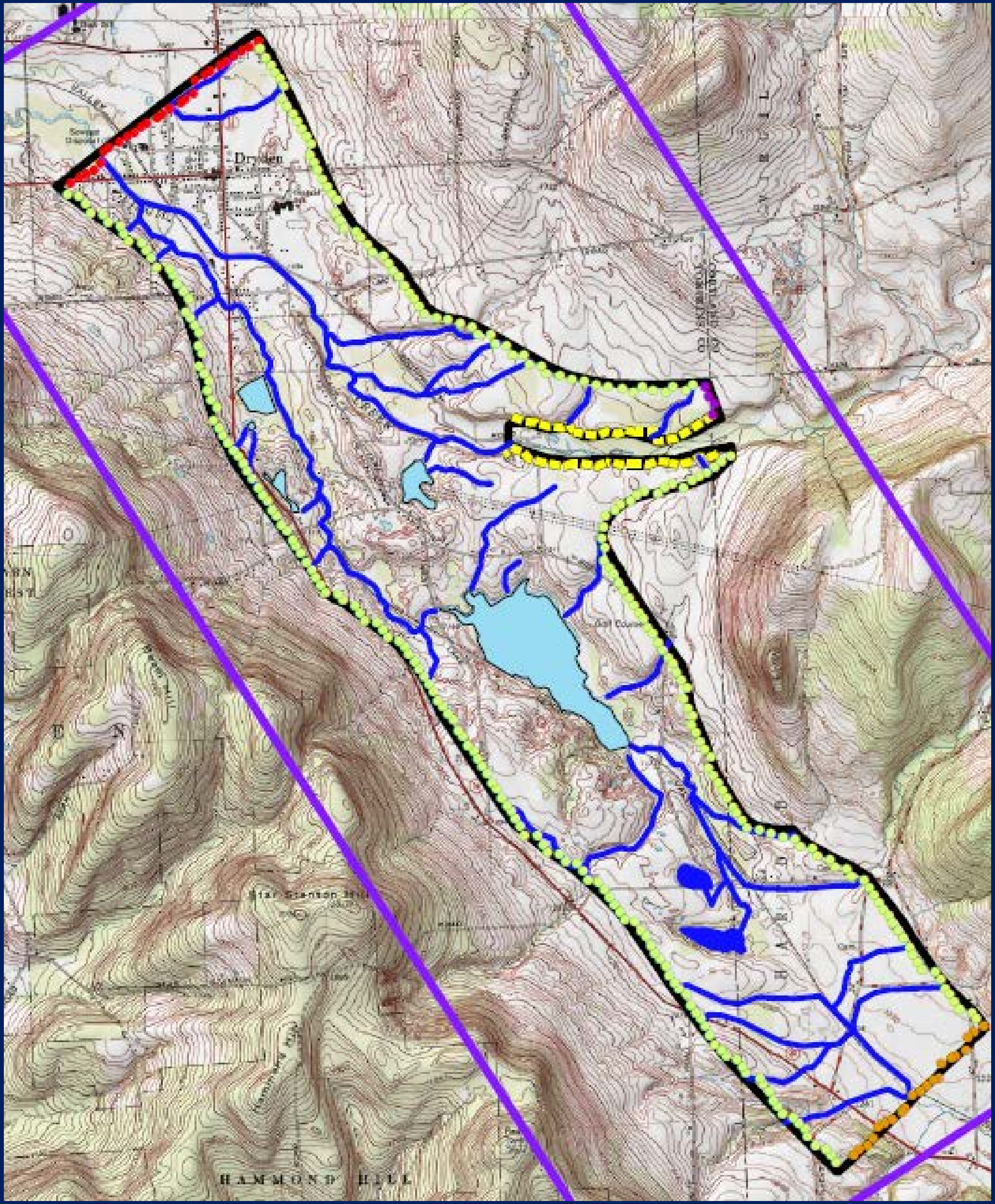

***B*. Cell dimensions and variables used in computation of flow rates.**

**EXPLANATION**

| | |
|---|---|
| $Q_H$ | Horizontal flow |
| $Q_V$ | Vertical flow |
| $A_H$ | Cross-sectional area, horizontal flow |
| $A_V$ | Cross-sectional area, vertical flow |
| ← | Direction of flow |

Modflow computes the water level for each active cell which then could be used to determine the horizontal and vertical components of GW flow

# Boundary conditions in groundwater flow model




General head cells (lakes, ponds, and wetlands)

River cells (streams and bogs)

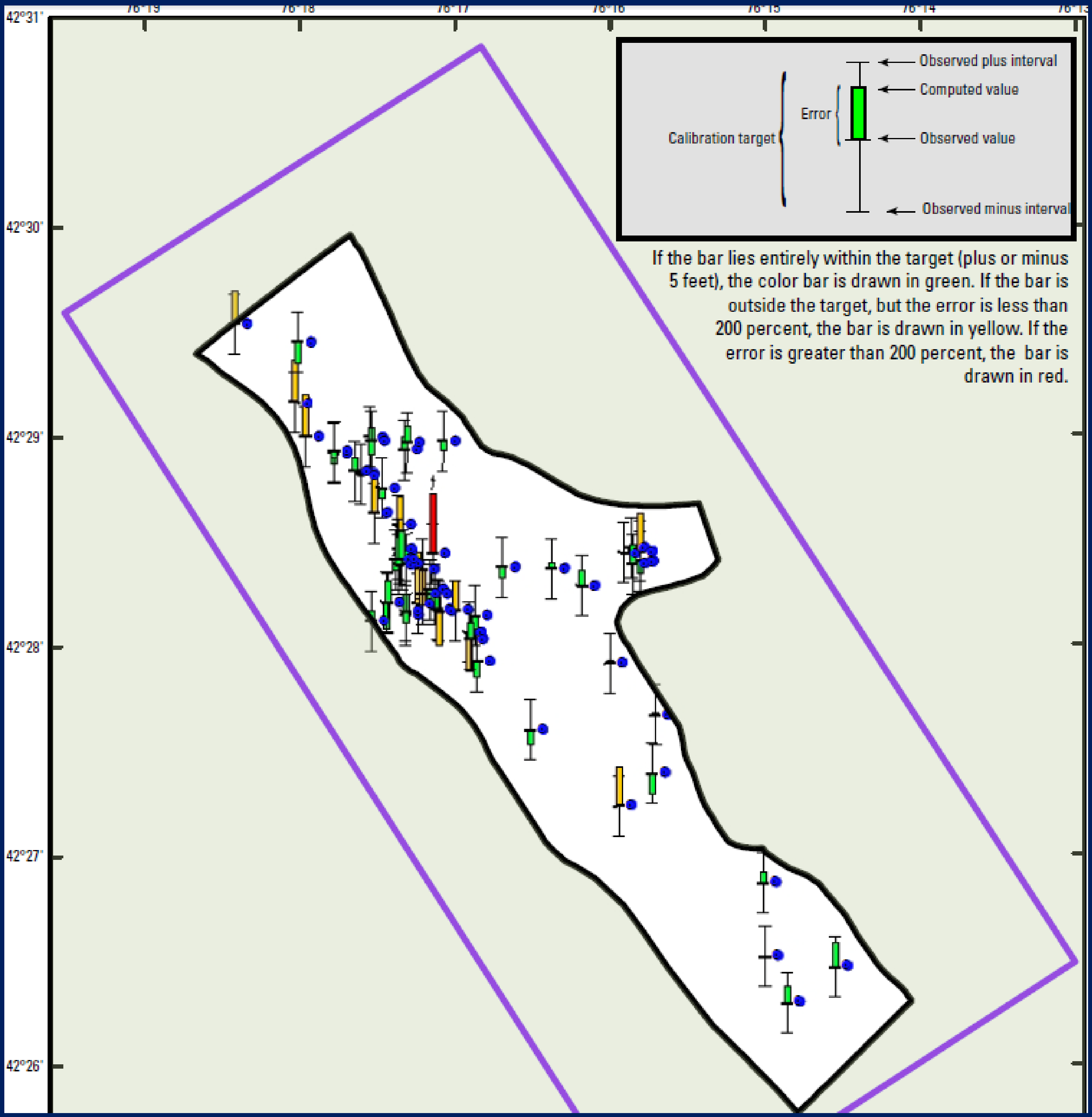
Drain cells (bluffs along eroded stream gorge)

Well cell that simulates groundwater outflow through the northern end of the model

Well cell that simulates groundwater inflow through the eastern end of the model

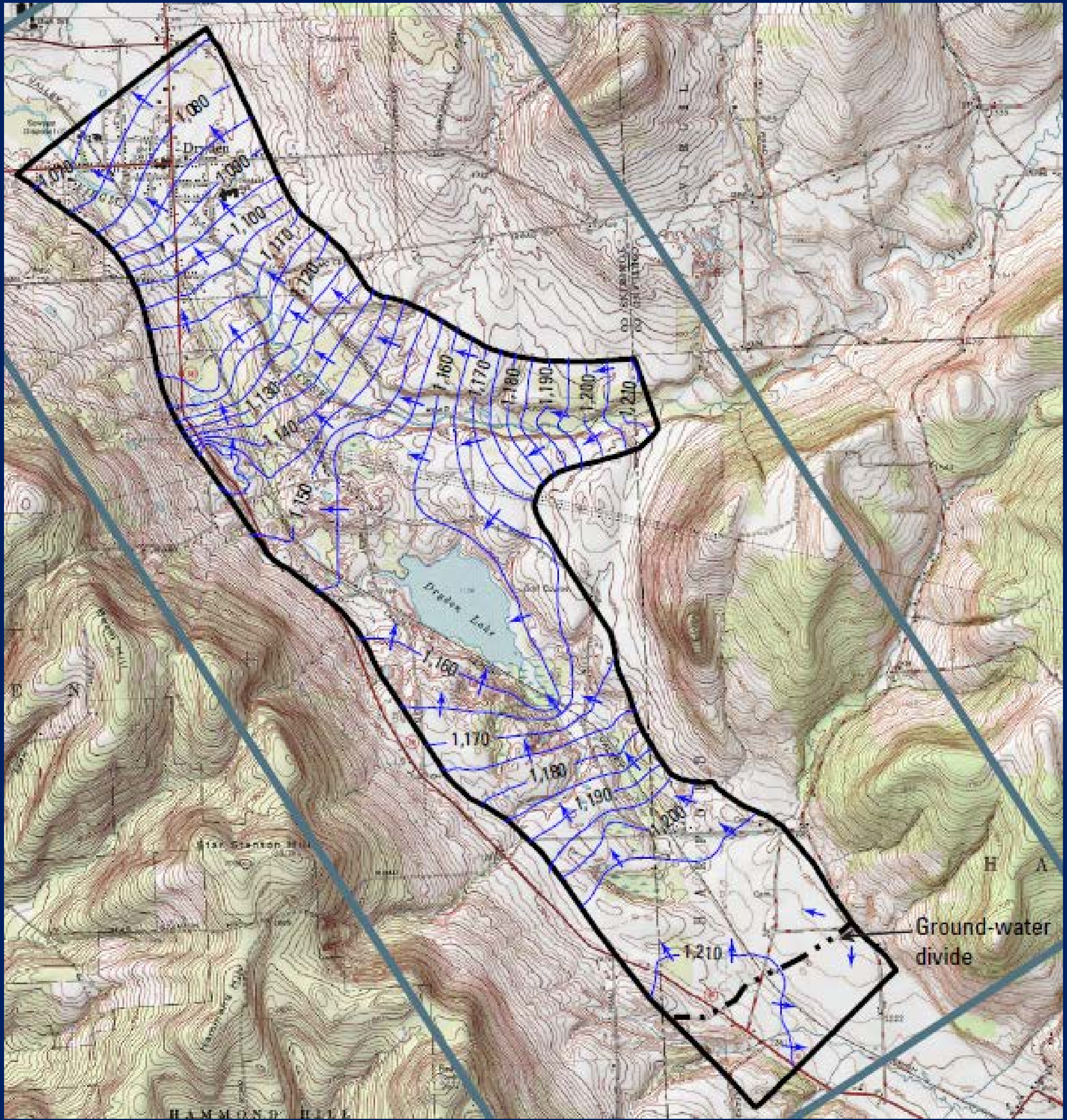
Well cell that simulates groundwater outflow through the southern end of the model

Well well that simulates recharge from groundwater inflow from bedrock along the valley walls and runoff and from unchannel uplands



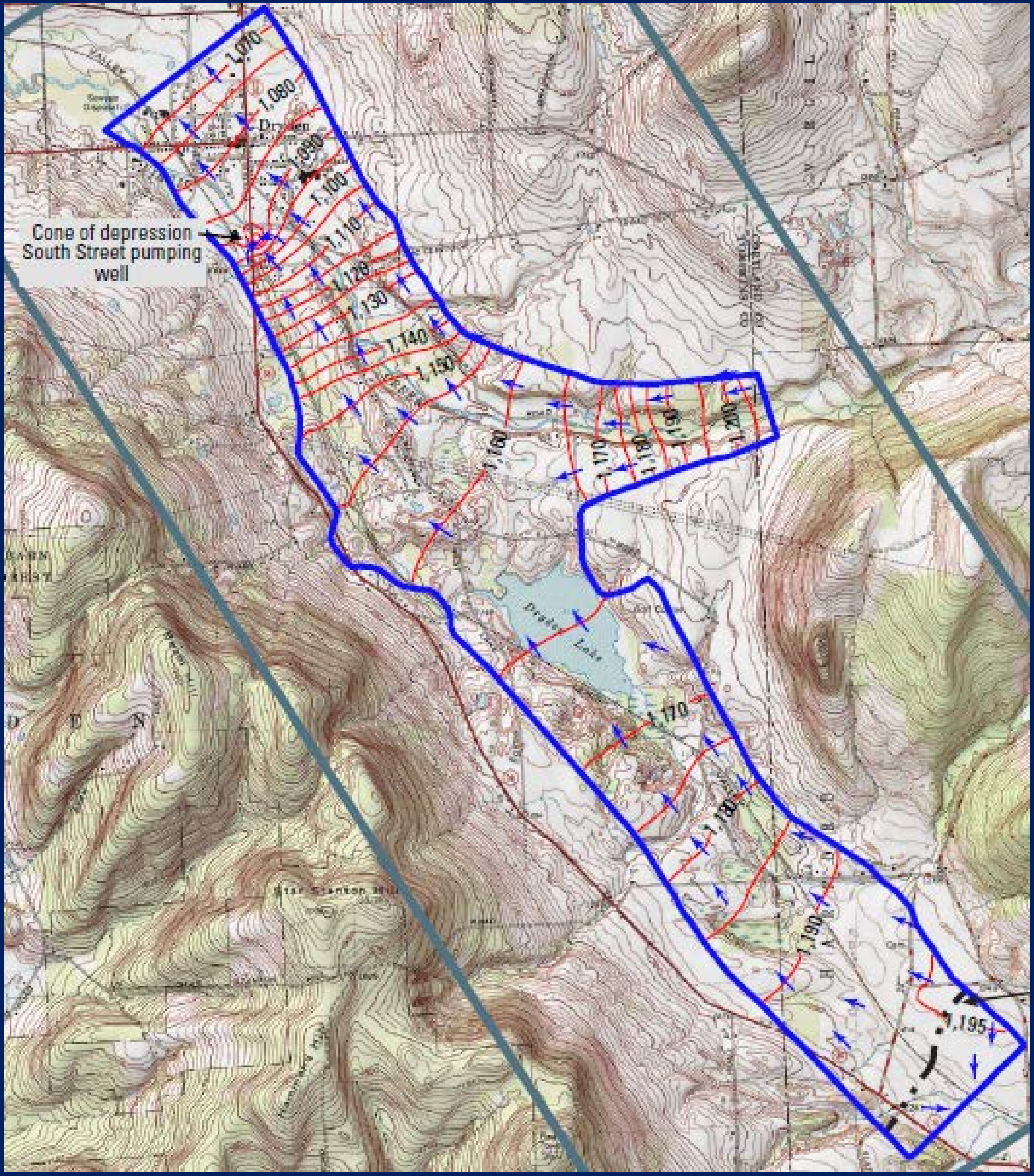

# CALIBRATION

## Groundwater-level residuals for the numerical groundwater-flow model



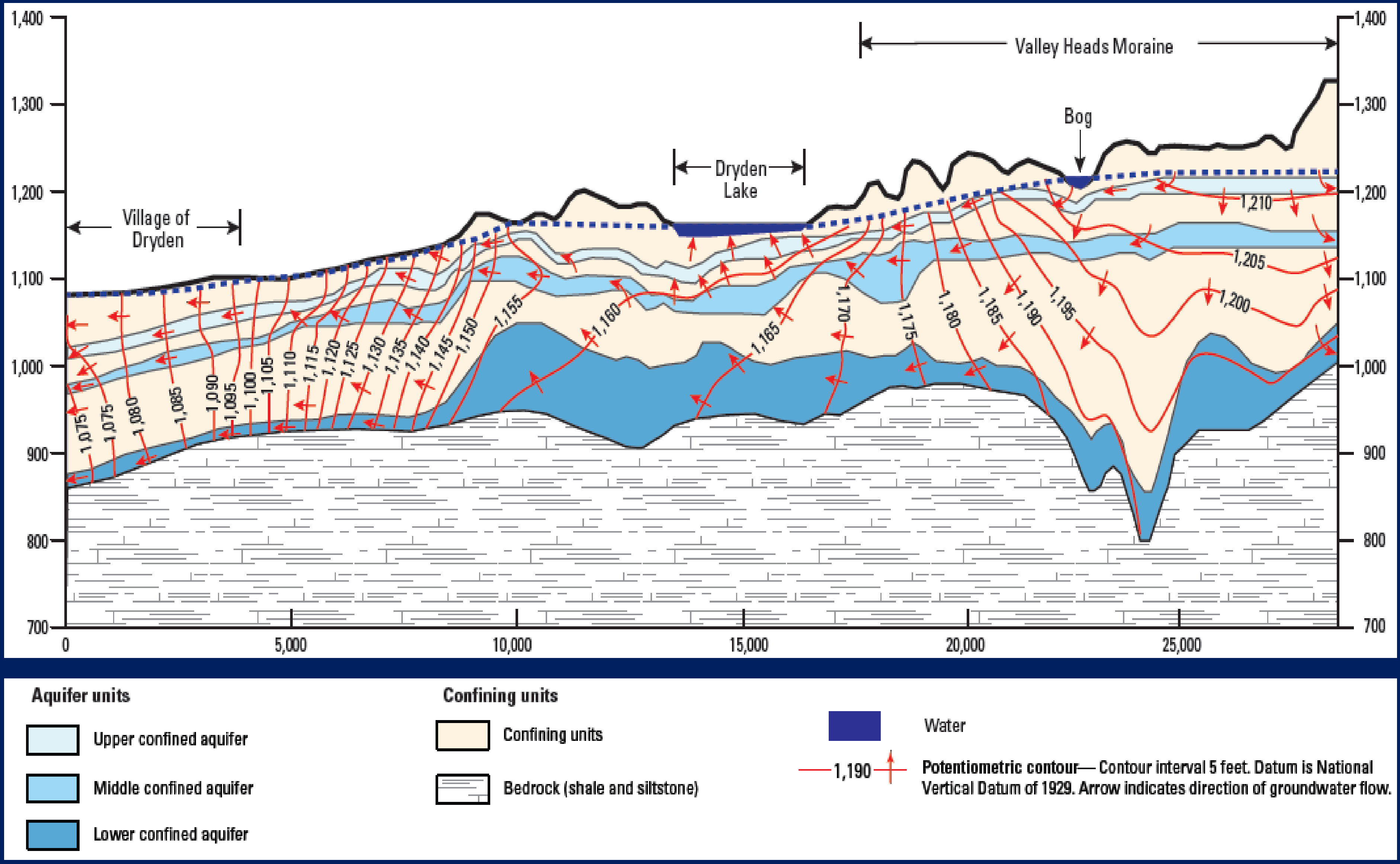

Head computed by steady-state simulation

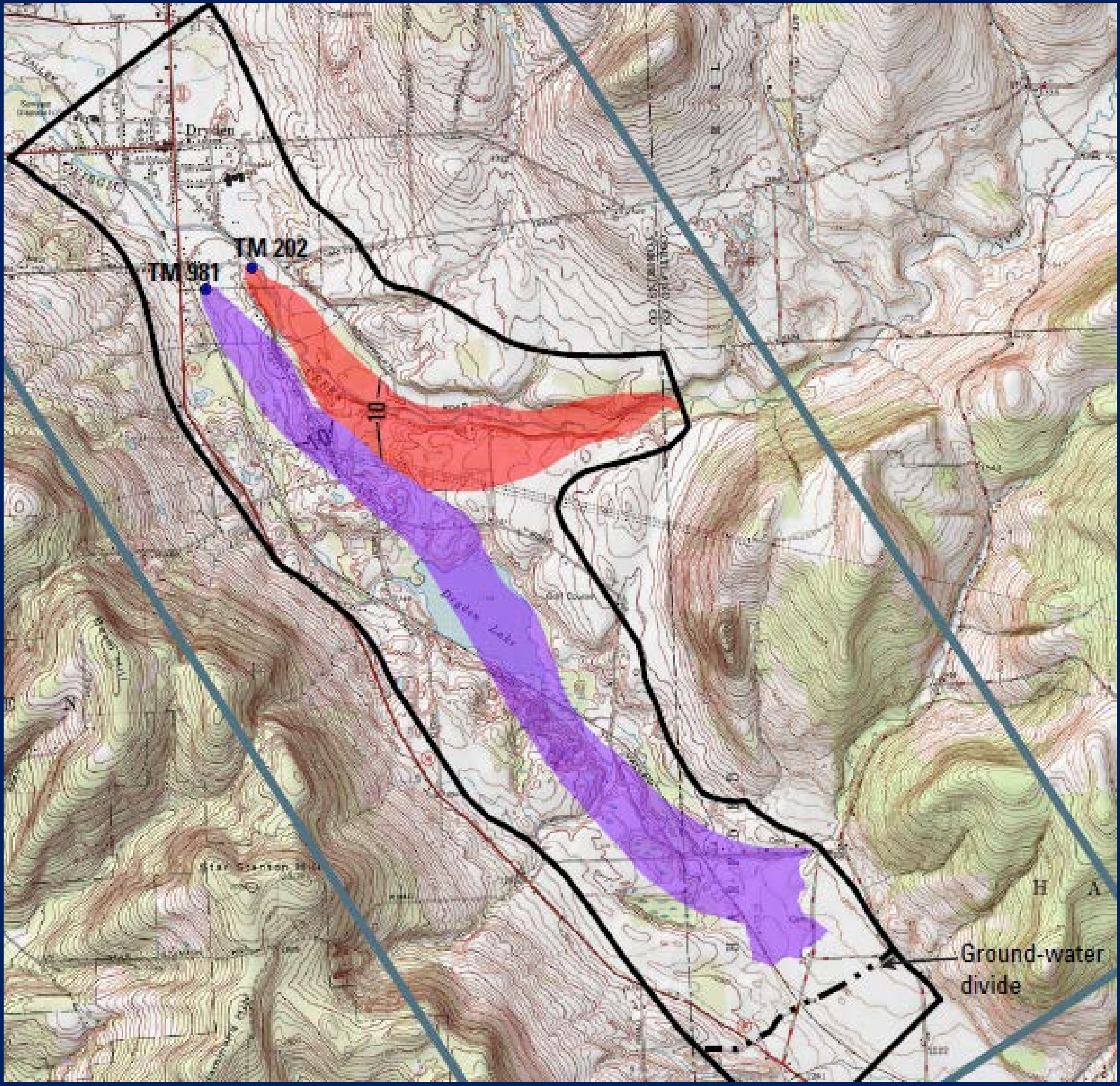
Upper confined aquifer (model layer 2).



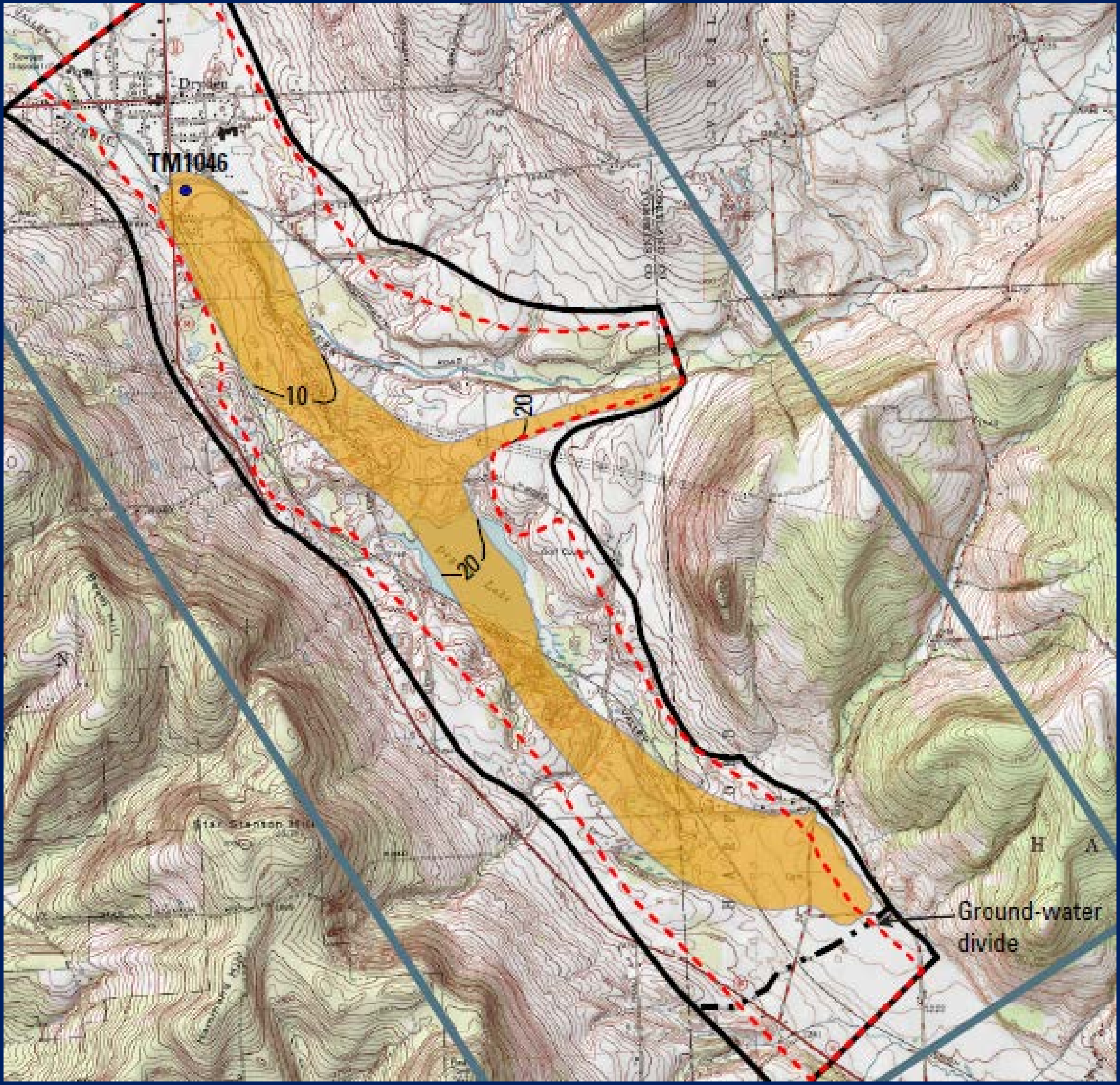

Lower confined aquifer (model layer 6).

# GW flow in a longitudinal section in the central part of the Virgil Creek and Dryden Lake valleys

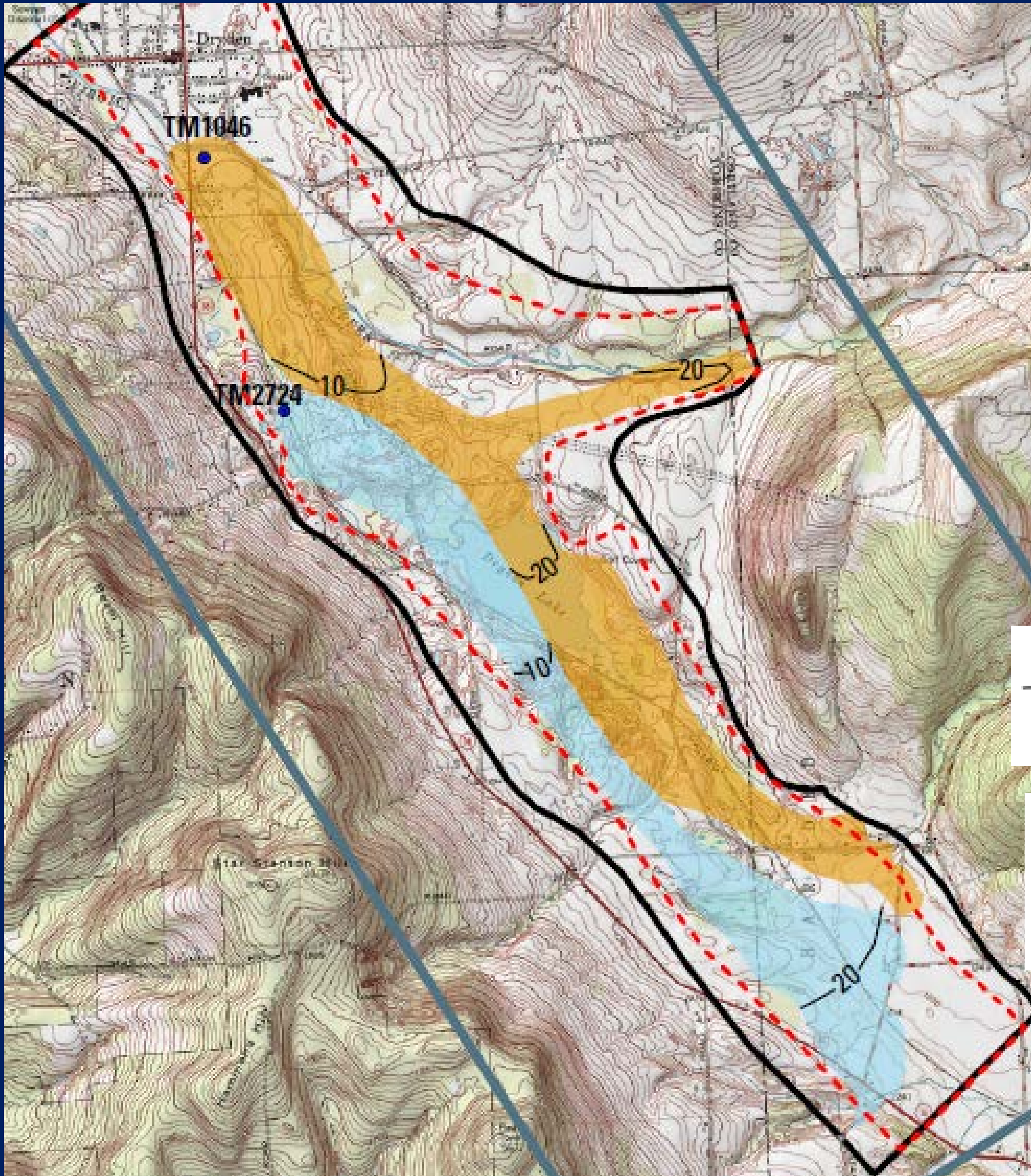





Estimation of contributing areas and time of travel to Village of Dryden production wells TM 202 that is finished in the upper confined aquifer (model layer 2) and TM 981 that is finished in the middle confined aquifer (model layer 4)




Contributing area and time of travel to Village of Dryden production well TM1046 finished in the lower confined aquifer (model layer 6)




Contributing areas and time of travel to Village of Dryden production wells TM1046 that is finished in the lower confined aquifer (model layer 6) and to a hypothetical well at test well site TM2724 near Keith Lane

10

**Contributing area to Village of Dryden production well TM1046**— Contour interval is the time, in years, for groundwater to travel to the wells.

10

**Contributing area to hypothetical well at test well site TM2724 near Keith Lane**— Contour interval is the time, in years, for groundwater to travel to the wells.

# HIGHLIGHTS OF THE DRYDEN AQUIFER STUDY

- The discovery of the highly productive aquifer at depth 177 – 245 ft at Dryden Lake
- CFC dating was fairly successful and indicated that the water is generally old (1940s or older at Village wells, 1970s at Dryden Lake)
- Identifying one of the major recharge areas to the upper confined aquifer(s)
- Virgil Creek is losing at least 450 gal/min to the upper aquifers in the vicinity of the dam