Geology and Groundwater

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Can my town support areas of more intense development?

Where are areas of favorable water supply?

Examples - Williston, Brandon, Hinesburg;

What areas should we protect? Example: springs in Dorset

Areas favorable for higher yield shallow aquifers? Ex. PWS Woodstock, Manchester

What are the anticipated depths and yields in my area? Helps with a cost estimate

Are there water quality issues such as arsenic, uranium, manganese?

Other WQ issues such as salt, nitrates or other contaminants and how can we avoid or mitigate these?

Water available for recharge:

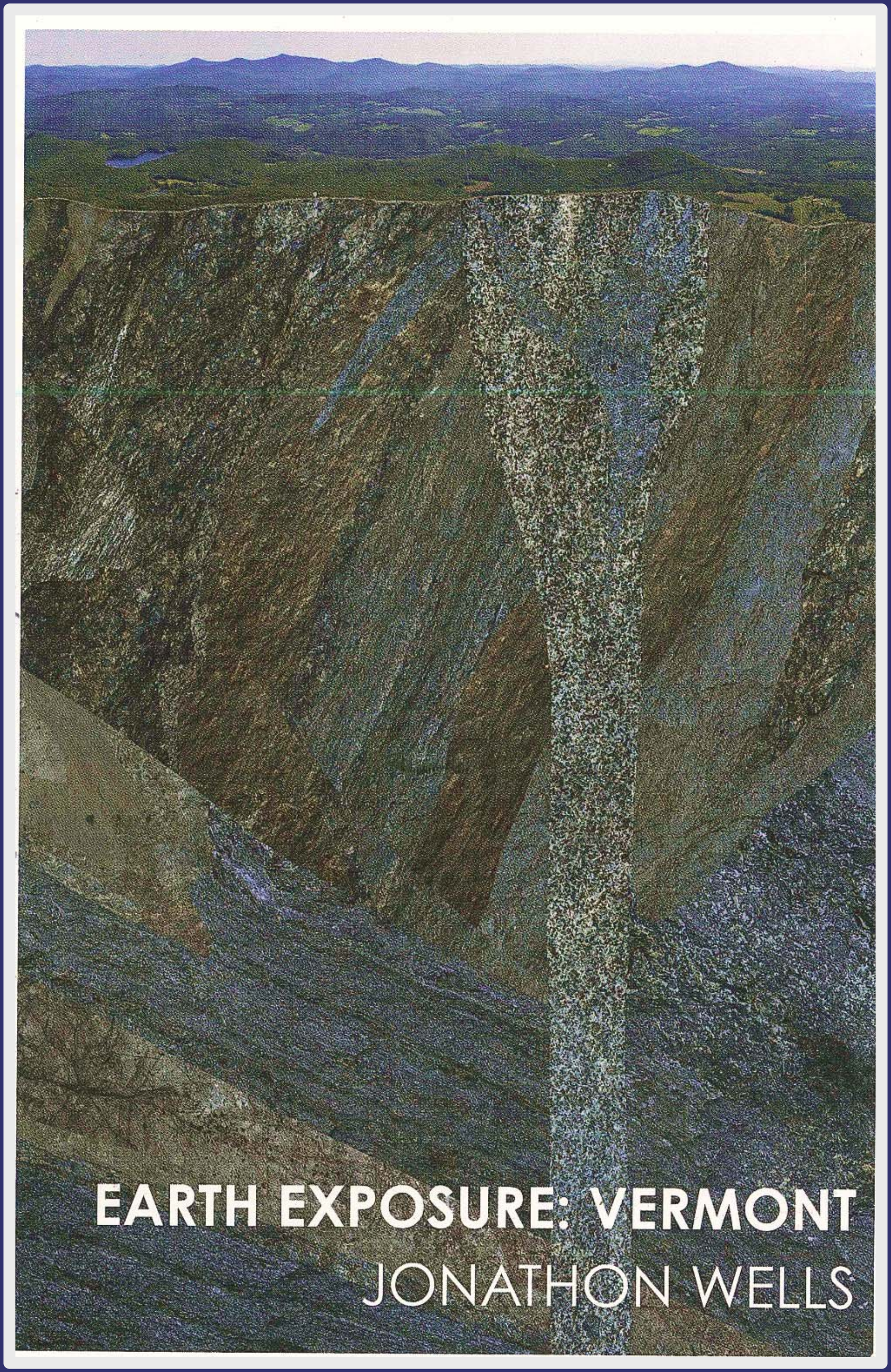
Metcalf and Robbins, 2013, estimated that approximately 20% infiltrated the ground and only 1.95% of that water recharged the fractured bedrock aquifer in Connecticut.

1 inch of rain falling on 12 square feet of ground is roughly 90 gallons of water and only 0.49 gallons recharges the bedrock aquifer.

The system from above

Groundwater flow generally mimics surface water flow –

Recharges in the uplands and discharges to rivers



The System From Below

~1000 feet

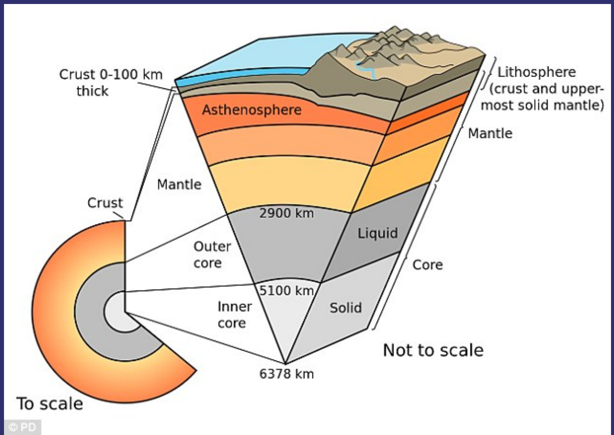
~1 mile

7 km
4.4 miles

~ 36" - Soils
Thin to thick surficial materials (most <50')
Av drinking water well in VT ~290'

GW generally <3000'

Saline water (?)

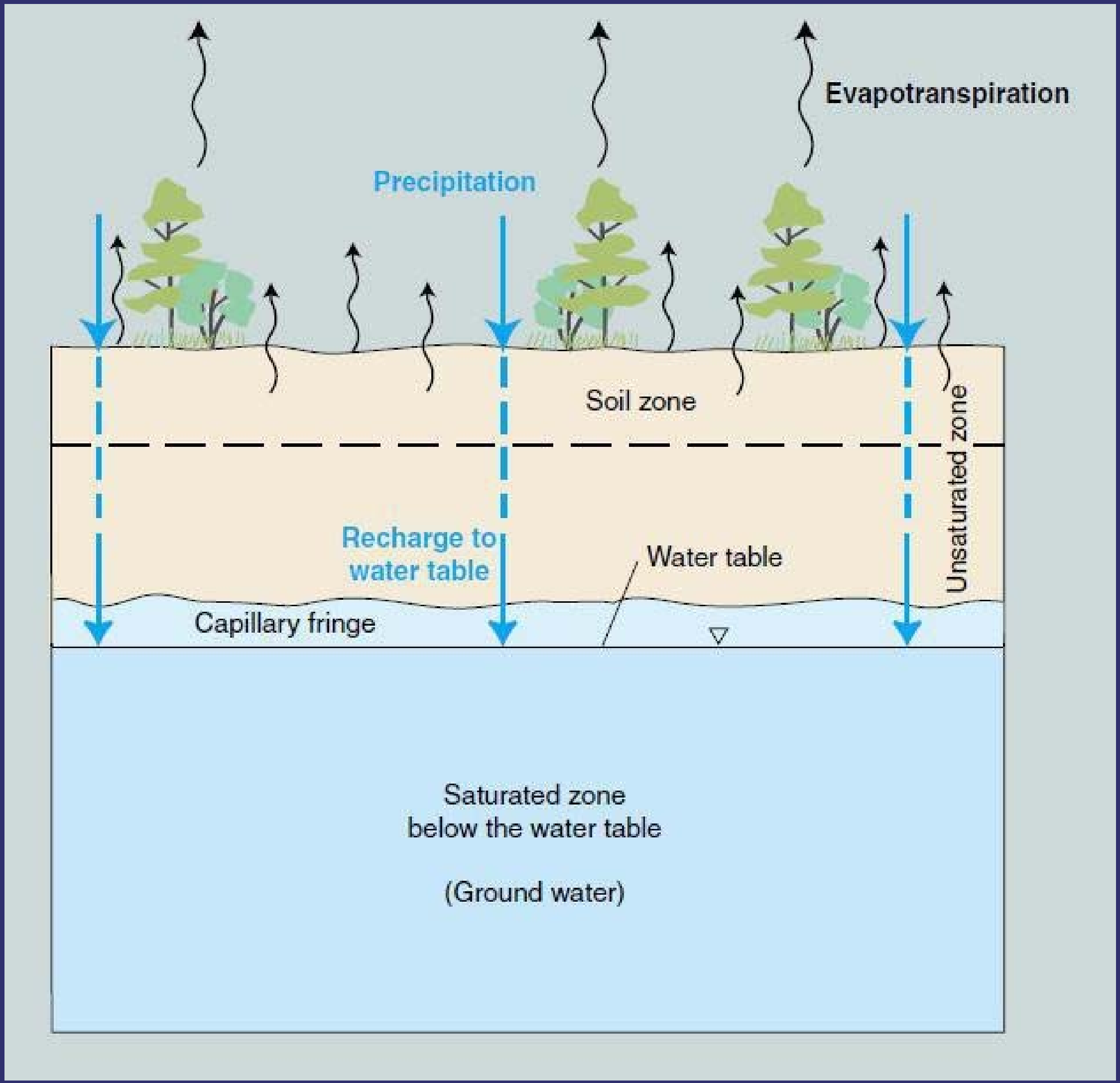


Groundwater is water that flows or seeps downward and saturates soil or rock, supplying springs and wells.

The *water table* is at the top of the saturated zone. Below the water table all pores are completely filled with water.

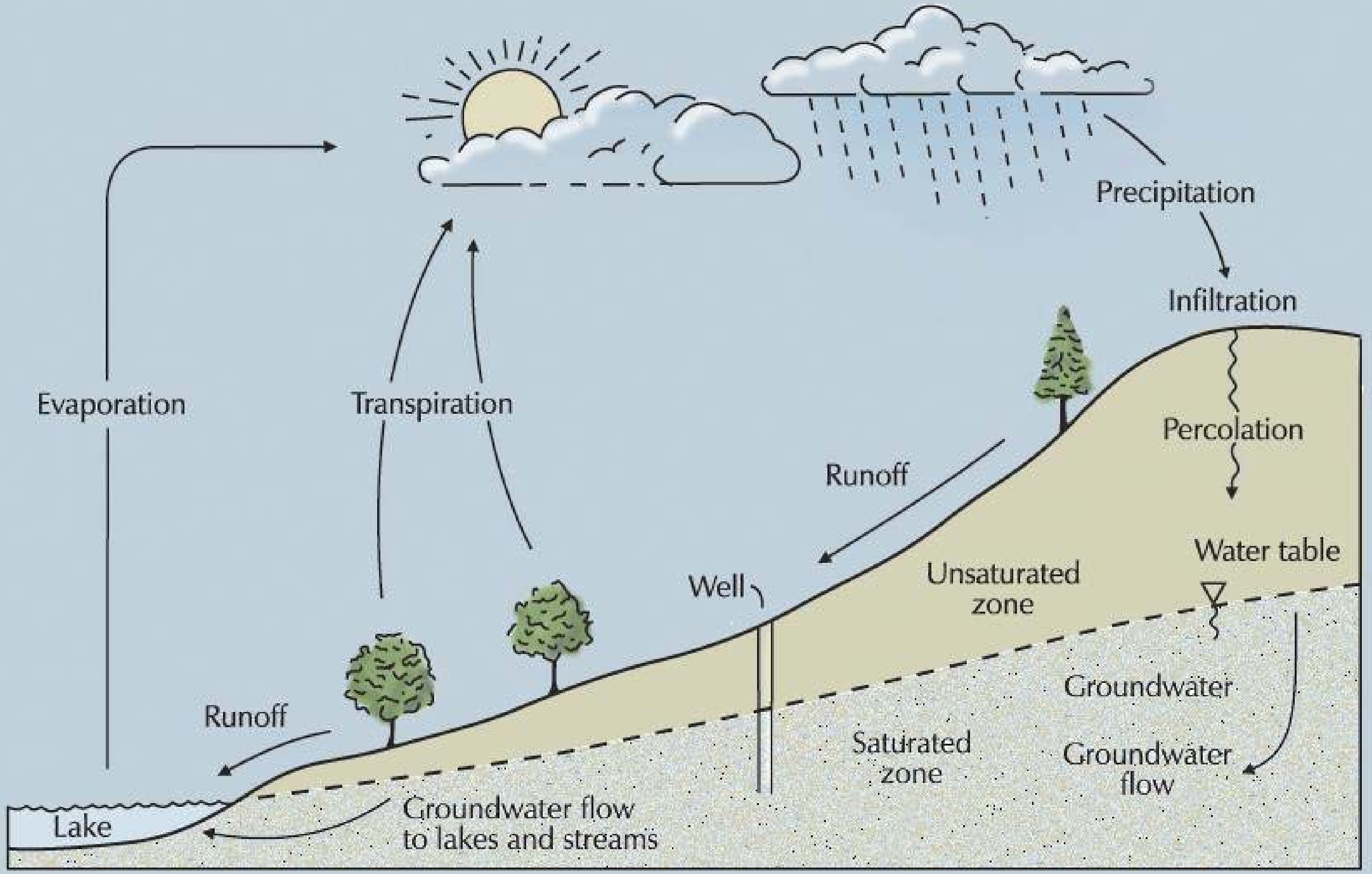
Pressure surface where pore pressure= atmospheric pressure

Above the water table, in the *unsaturated zone*, pores are partly or completely filled with air.



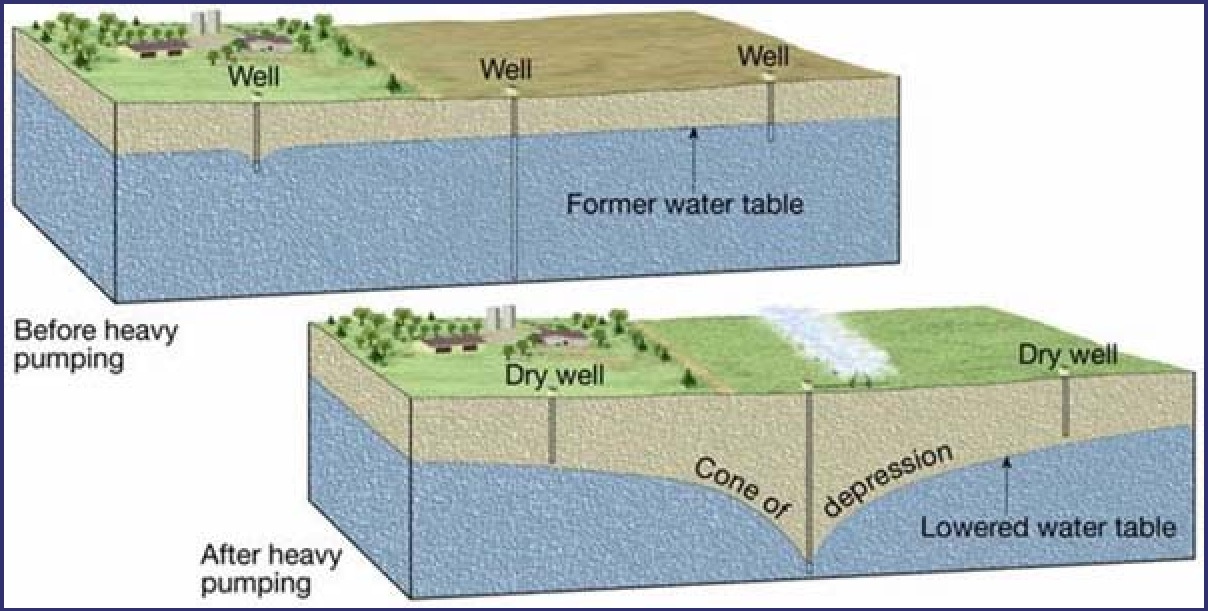
source: K. Bradbury (Wisconsin GS) and USGS

All water is part of the water cycle…



Aquifers are geologic units (sand and gravel, sandstone, etc) that can store and transmit significant quantities of groundwater

A **cone of depression** occurs in an aquifer when groundwater is pumped from a well. In an unconfined aquifer (water table), this is an actual **depression** of the water levels. In confined aquifers (artesian), the **cone of depression** is a reduction in the pressure head surrounding the pumped well.



Properties of surficial materials

Secondary porosity in bedrock provides flow path

Top: Inhomogeneous glacial deposits

Bottom: Fractured bedrock

Surficial Materials

Porous, permeable sand

Less permeable clay and silt, Seaver Brook, Craftsbury

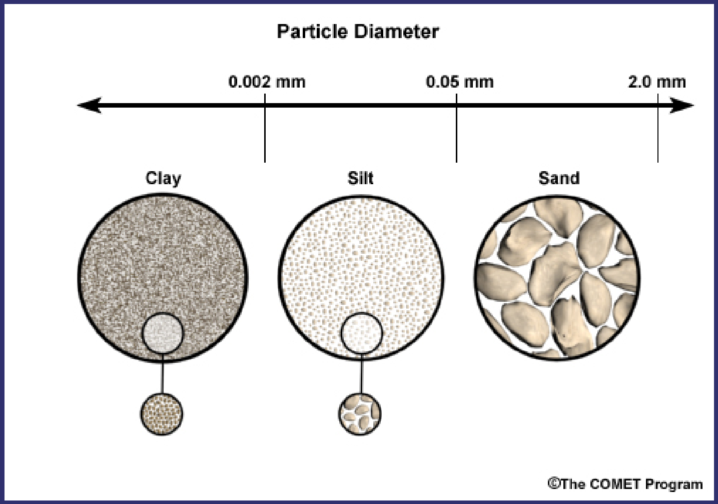
Dense, compacted glacial till;
Note cobbles of red Monkton Quartzite

Less permeable - Silt and clay

Piping – in more porous silts/sands

Surficial materials influence the rate of movement through materials (hydraulic conductivity) and infiltration

Depositional Environment	Material	Horizontal Hydraulic Conductivity
Lake-bottom and deltaic (coarse)		
	Gravel	150 - >250 feet/day
	Coarse sand	60 – 200 feet/day
	Medium to coarse sand	15.9 feet/day
	Medium sand	60 – 175 feet/day
	Fine sand	1 – 30 feet/day
	Sand and silt (deltaic)	1.1 – 56.7 feet/day
Lake Bottom		
	Fine to very fine silty sand	0.2 – 9 feet/day
	Fine sand to silt	0.165 – 5.29 feet/day
	Fine sand, silty sand, silt, minor clay	0.01 – 1.13 feet/day
Lake Bottom (fine)		
	Lacustrine silt to clay	0.002 – 0.029 feet/day
Mixed		
	Lacustrine sand and ablation till	135 feet/day
Till		
	Sandy ablation till	22 feet/day
	Till	1 foot/day
	Hardpan	0.3 feet/day



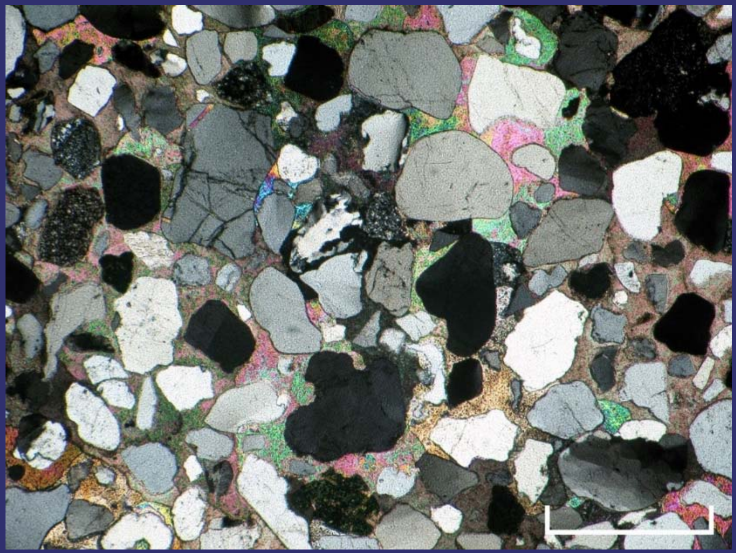
Porosity (open space)

Permeability (connected spaces)

Secondary porosity – bedrock structures

Vermont rocks do not generally have primary porosity

Marble



Calcareous quartzite

Schist

Groundwater flow in bedrock is mainly along planar features such as fractures, bedding and cleavage.

Features are interconnected and flow paths may be complex.

Type of materials influences recharge to shallow and bedrock aquifers.

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Secondary porosity in bedrock may allow water to infiltrate directly –

Fractures vary –
orientation, length, aperture, intersections, depth, rock type.

Hydraulic conductivity in rock is generally much less than in surficial deposits.

Town Resource Maps

- Surficial and Bedrock Geology
- Locate Water Well Data
- Depth to Bedrock
- Flow Directions – Generalized
- Hydrogeologic Units – Bedrock
- Recharge Potential to Bedrock
- Potential Overburden Aquifer with Direct Recharge
- GW – Plan, Map, Test, Protect

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The average person uses 150 gallons of water per day or 600 gallons for a family of 4.

Statewide mean (92,314 bedrock wells): 13.76 GPM; 293 ft

1 GPM is 1440 gallons over a 24 hour period.

FIGURES 2-5. WATER WELL DATA, BEDROCK TYPE, AND IDW ANALYSES

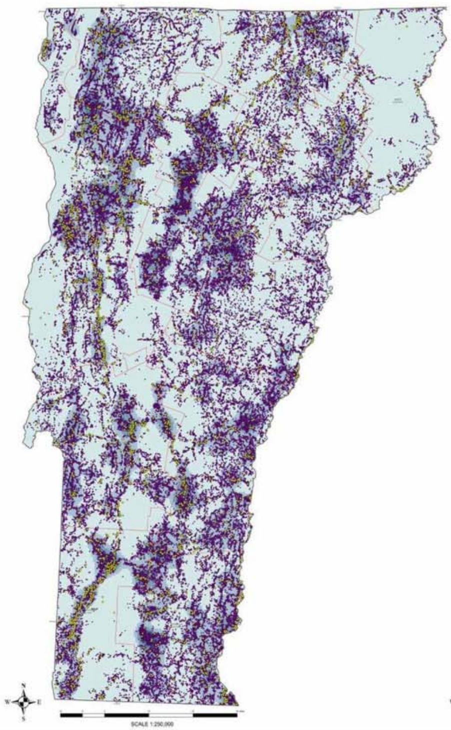

FIGURE 2. Distribution of 93,788 water wells completed in 1966-2006. Database has 76 fields including use, yield, depth, type (gravel or bedrock), and materials at various depths. Locations are suspect; ~11% had E911 or GPS locations in 2006; 17% have updated E911 or GPS locations in 2014.

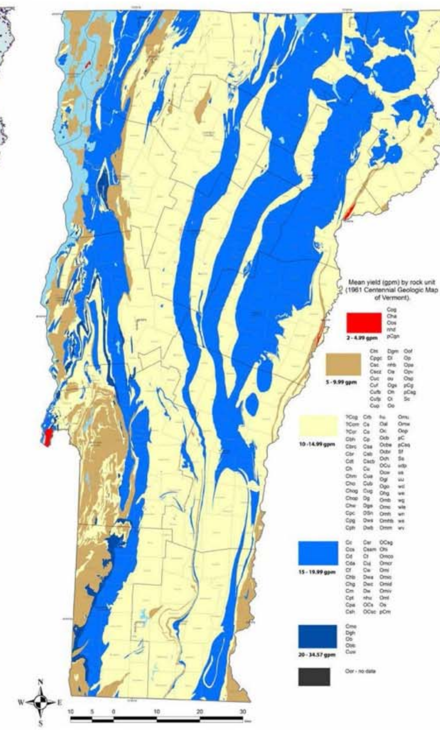

FIGURE 3. Wells were selected and average yields were calculated by bedrock formation (1961 map of Vermont). Formations were then grouped to produce a generalized yield map. Moore and others (2002) discussed factors which correlated negatively and positively with well yield. Among these are year drilled, drilling method, thickness of overburden, depth, elevation, proximity to streams, and type of bedrock.

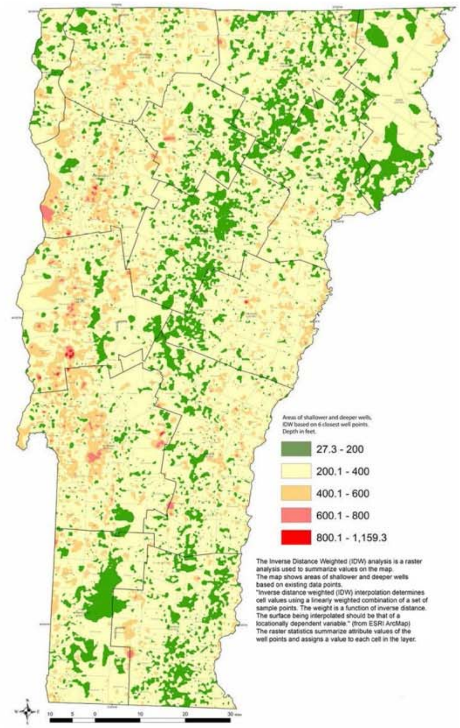

FIGURE 4. Inverse distance weighted (IDW) analyses of well depths based on 6 nearest points. Map indicates some areas where deeper wells could be anticipated. There are large areas of no data (see Fig. 2).

Depth in feet	# of wells	Mean yield in gpm
Well depth ≤ 200'	31340	18.43
Well depth > 200' and ≤ 400'	41179	13.15
Well depth > 400' and ≤ 800'	19142	7.64
Well depth > 800'	654	6.90

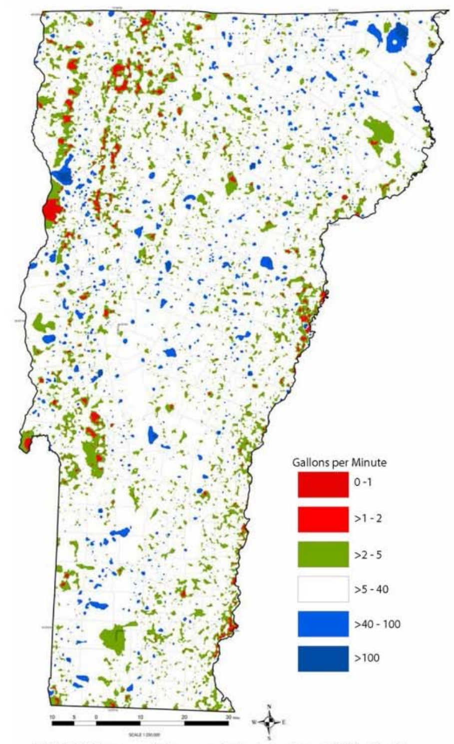

FIGURE 5. Inverse distance weighted analyses (IDW) of well yield based on 6 nearest points. Map indicates some general areas where higher or lower yields could be anticipated. There are large areas of no data (see Fig. 2).

A reported well yield of 1 gpm was selected as the high value for low yield wells; actual yield may be much less. 1 gpm is 1440 gallons per day and the average person uses 75 gallons per day. The percent of low yield wells is 14% and 28% have a yield of >/=20 gpm.

Water Well Data and Analysis

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FIGURE 13. FAVORABILITY MAP

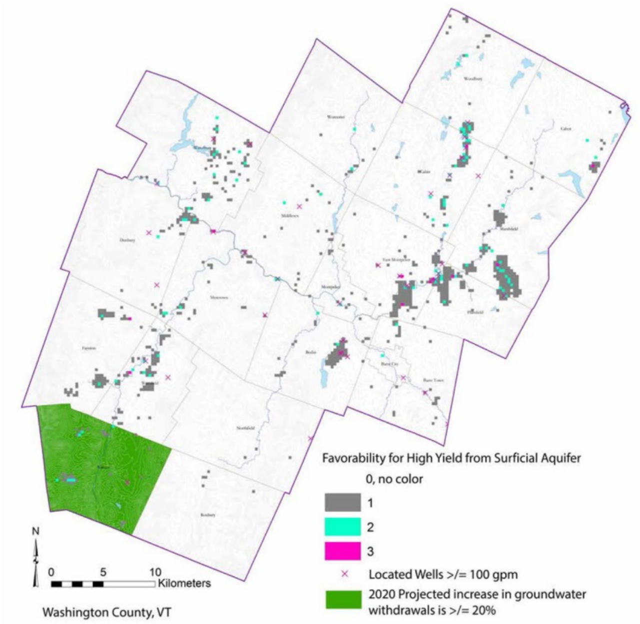


Figure 13 (above). The favorability map for higher yield surficial aquifers is based on summing together three integer rasters derived from yields of surficial wells, depth of overburden, and the hydrogeologic classification. Breaks for the three rasters are:
Yield of surficial wells: 0 = less than 20 gpm, 1 = greater than or equal to 20 gpm.
Depth of overburden: 0 = less than 50 feet, 1 = greater than or equal to 50 feet.
Hydrogeologic classification: 0 = Class 6 through 13, 1 = Class 0 through 5.
Hydrogeologic Class 6 was excluded from the more favorable category as such wells might be susceptible to contamination.

The three rasters are summed together and then ranked as follows:
0: Areas with a raster score of 0 are ranked low favorability
1 - 2: Areas with raster sums of 1 or 2 are ranked progressively higher
3: Areas with a score of 3 are highest favorability

ck

om
as

Figure 14 (right) . The statewide map shows the 5 counties where well location projects and assignment of hydrogeologic class have been completed. Well data for 11,994 wells was reviewed for the project. Water well location projects need to be conducted in the remaining 9 counties (~55,000 wells) and hydrogeologic classes could then be assigned to located wells (~ 30%). The raster analysis of thickness could be refined based on the new data and the aquifer favorability maps would be developed by county.

Groundwater use data by town is available for the state and the highlighted areas show towns where growth or increase in use is projected. The map focuses attention on areas where new projects could assist in locating future water supply. The more detailed census block analysis can also be constructed for these towns.

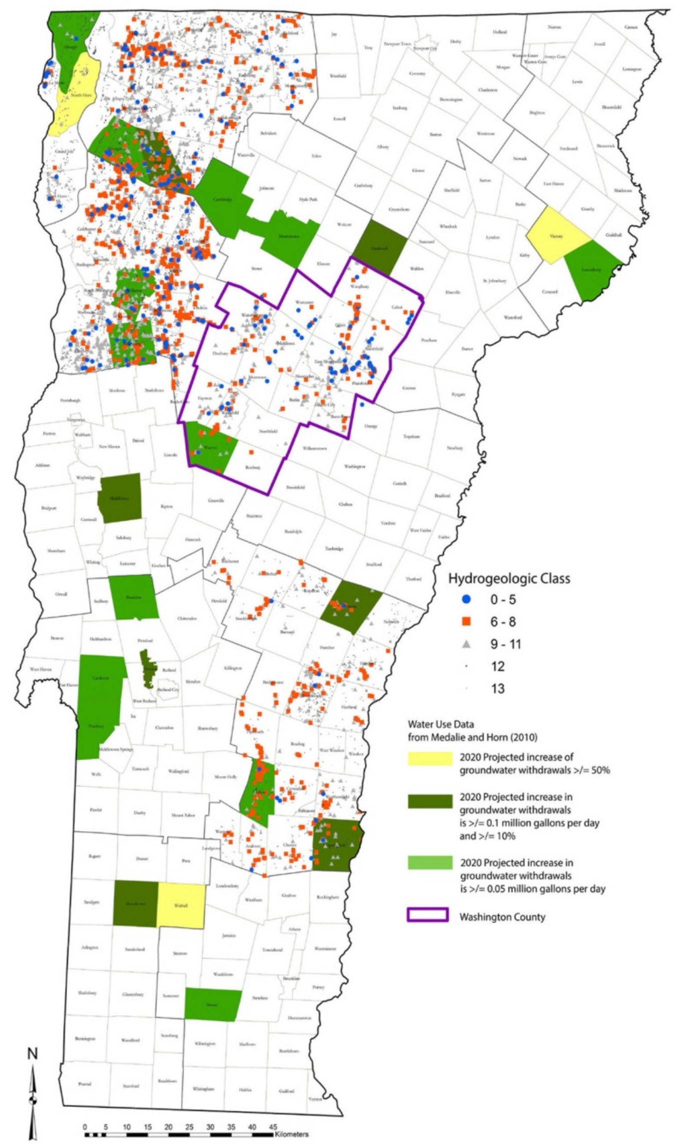
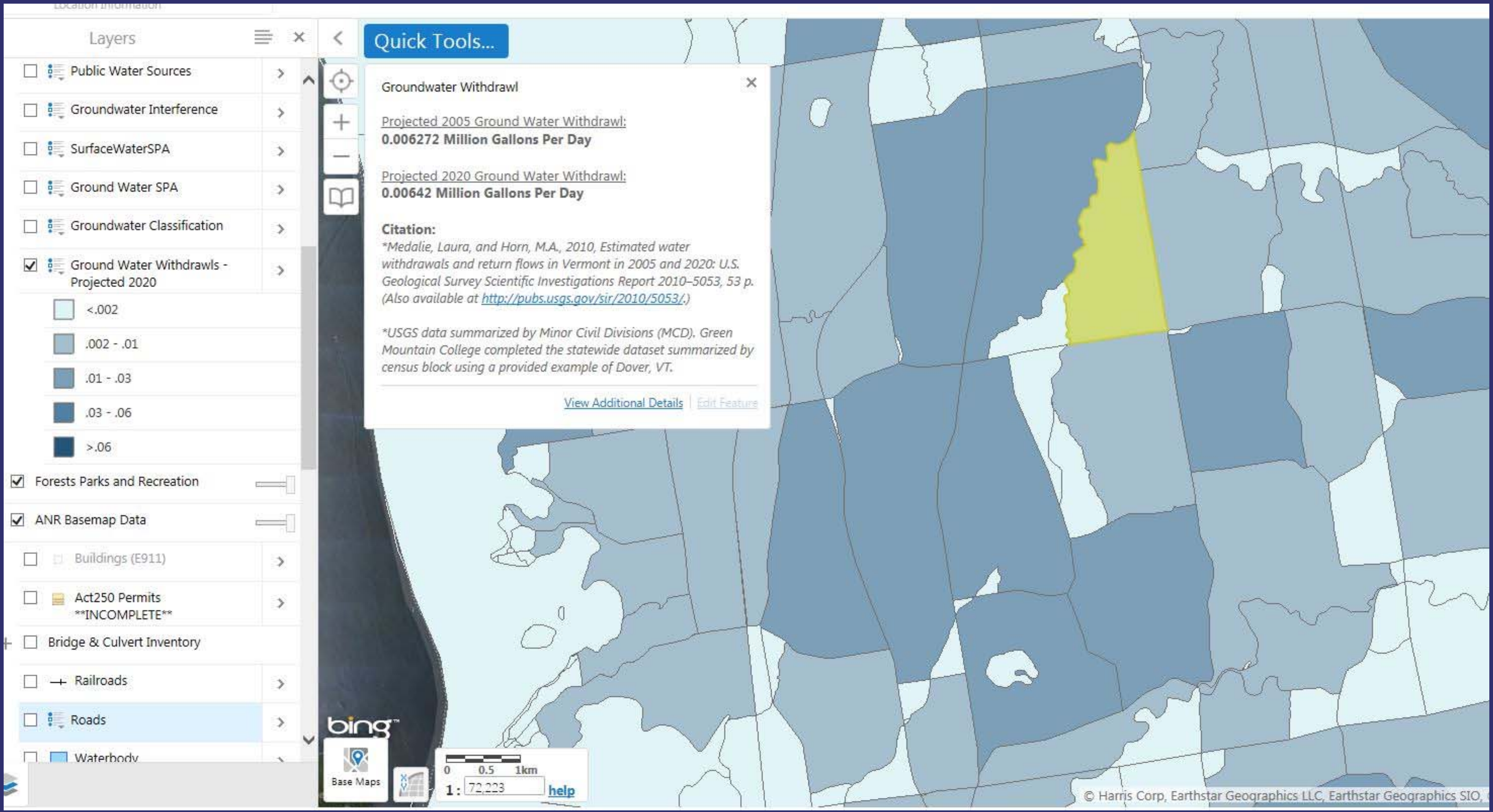


FIGURE 14. STATEWIDE FOCUS

ANR Atlas- Well data, SPA, Water Use Data Projected to 2020 in million gallons/day



Plus maps of materials, well data, structure, and water chemistry lead to favorable/unfavorable areas

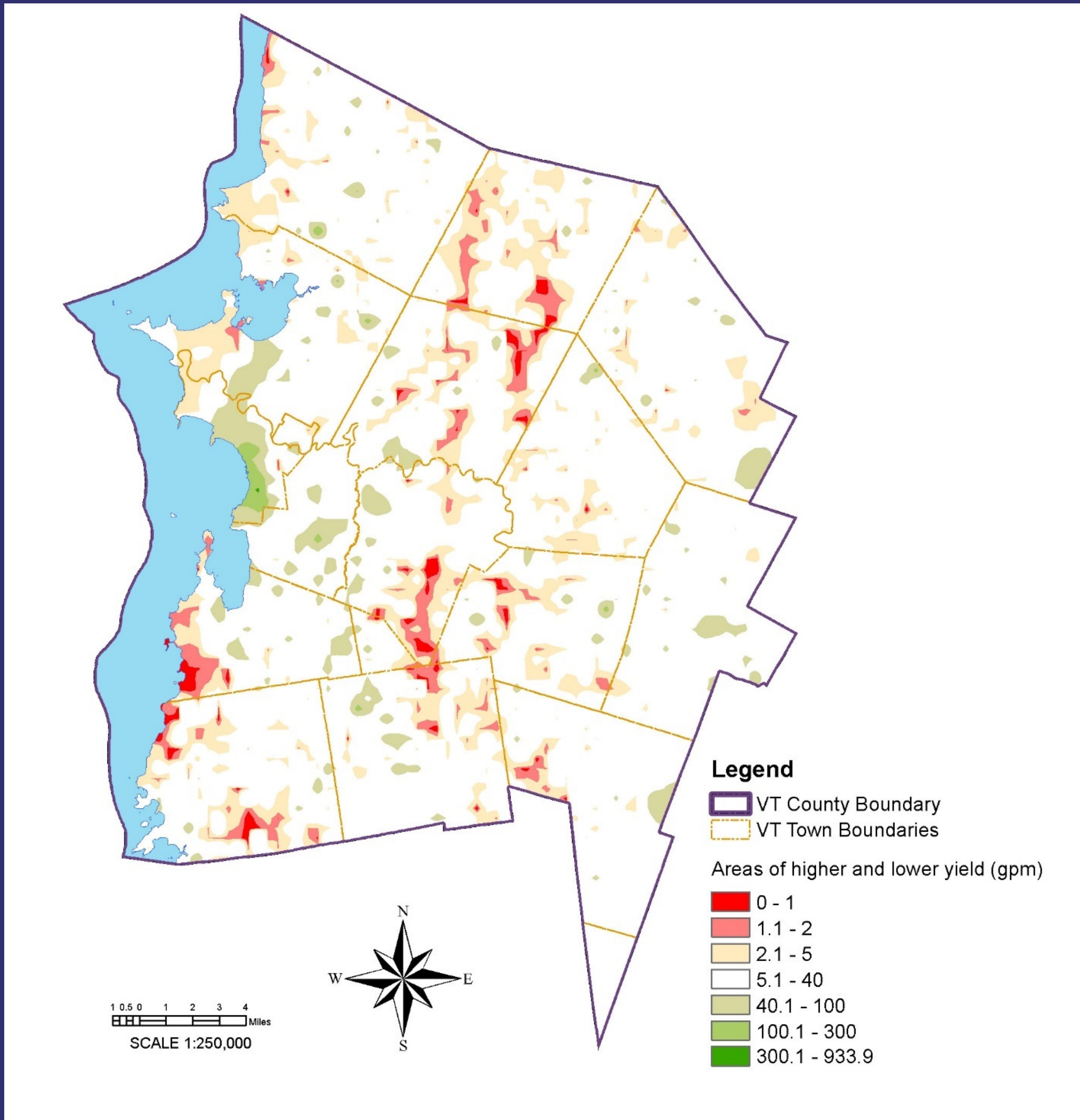


Figure 2. Areas of higher and lower yield based on an inverse distance weighted analysis of 92,315 well points

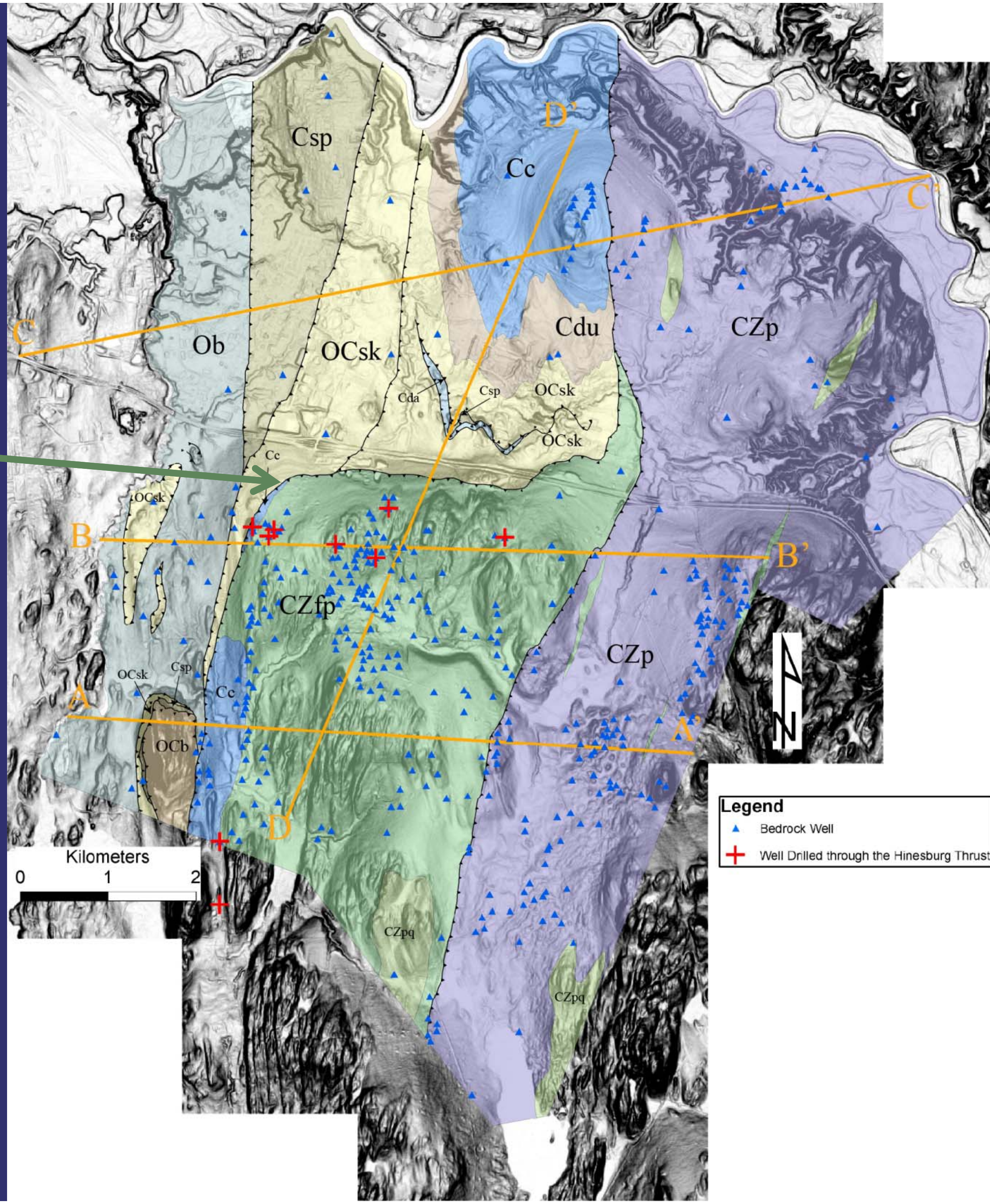
Identify geographic
Areas of concern

Williston area
Town planning

(Derman, Kim, and Klepeis, 2008)

Hinesburg Thrust

Williston VT



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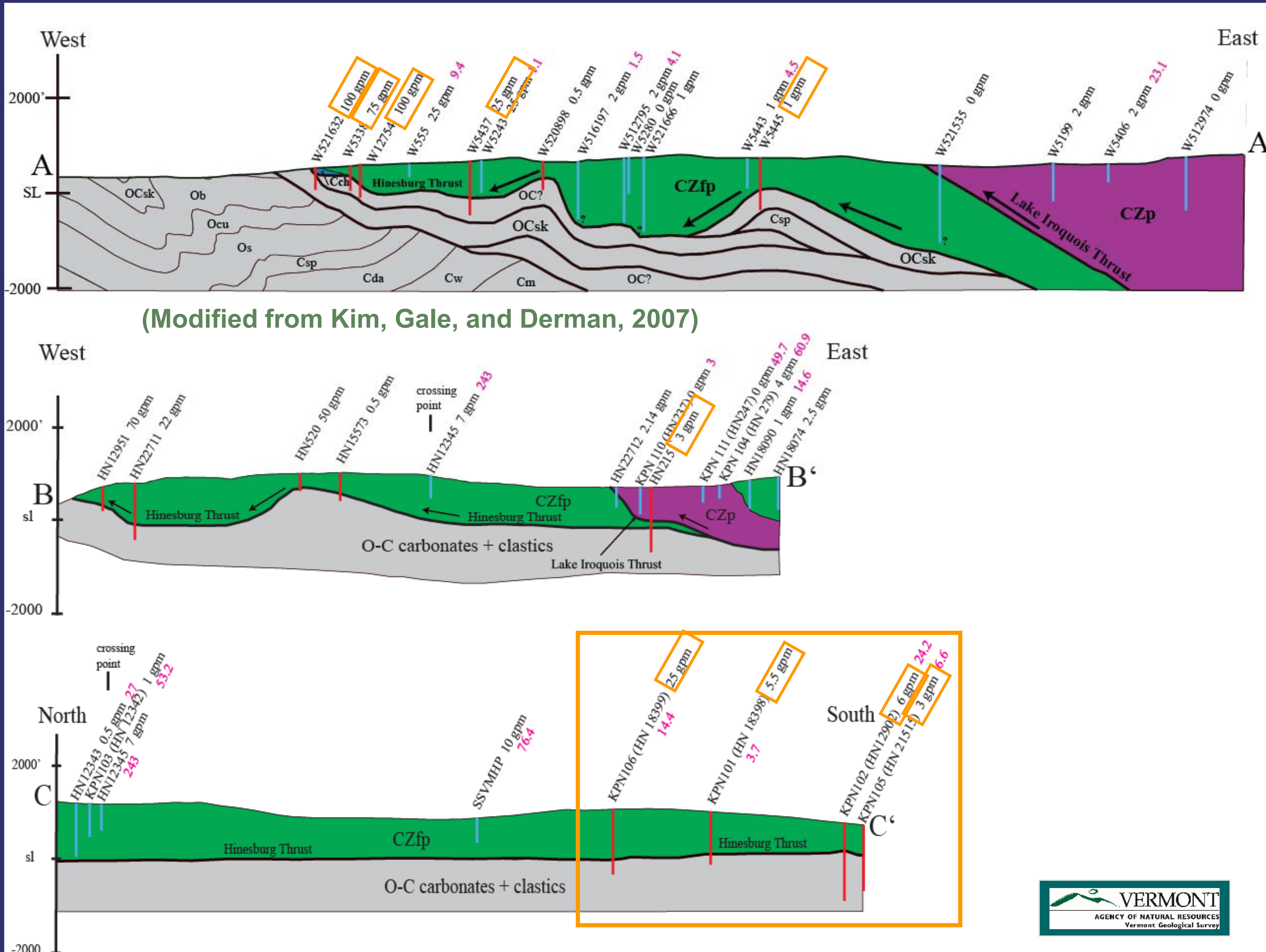
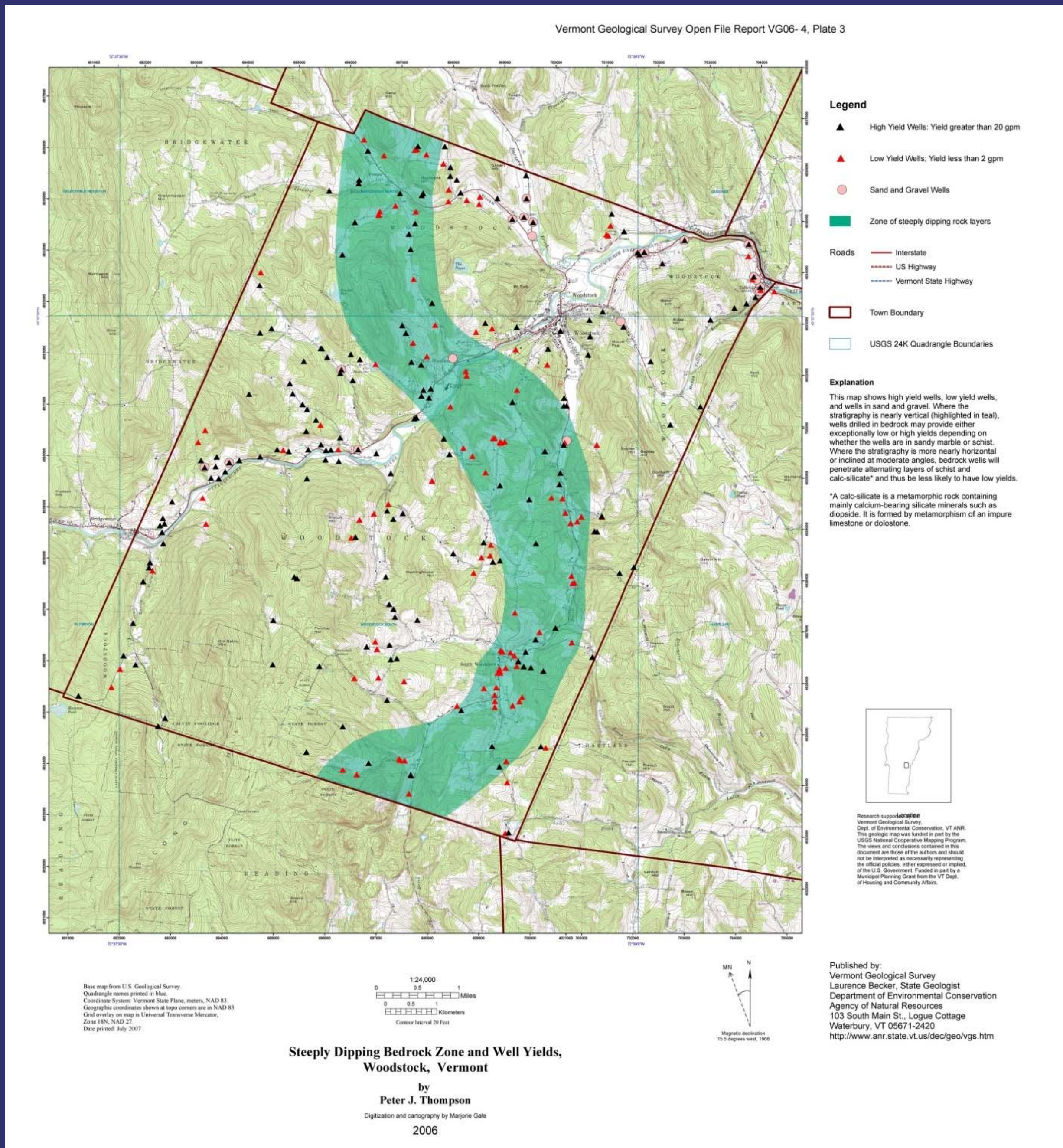


(Modified from Kim, Gale, and Derman, 2007)

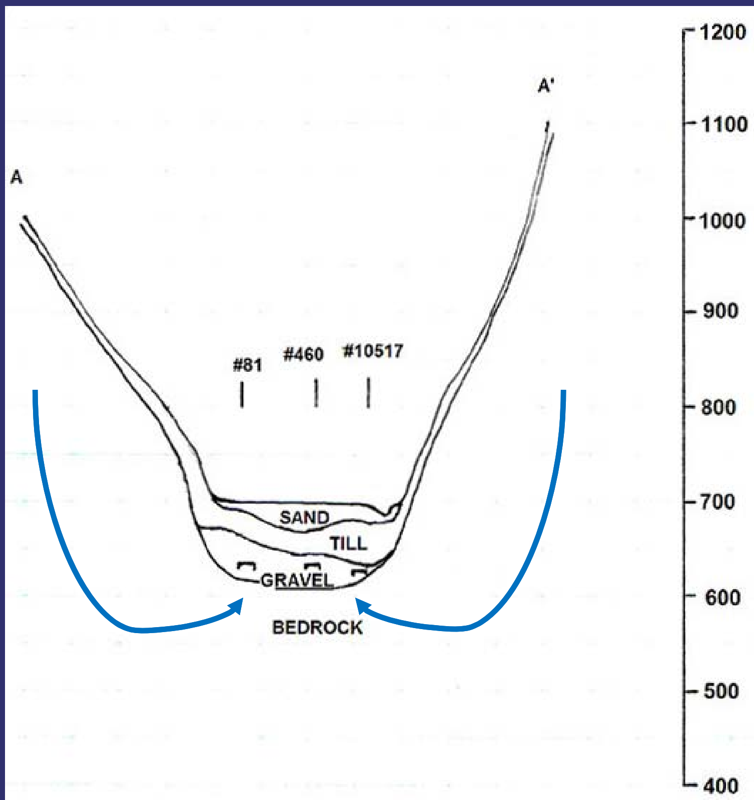
WOODSTOCK

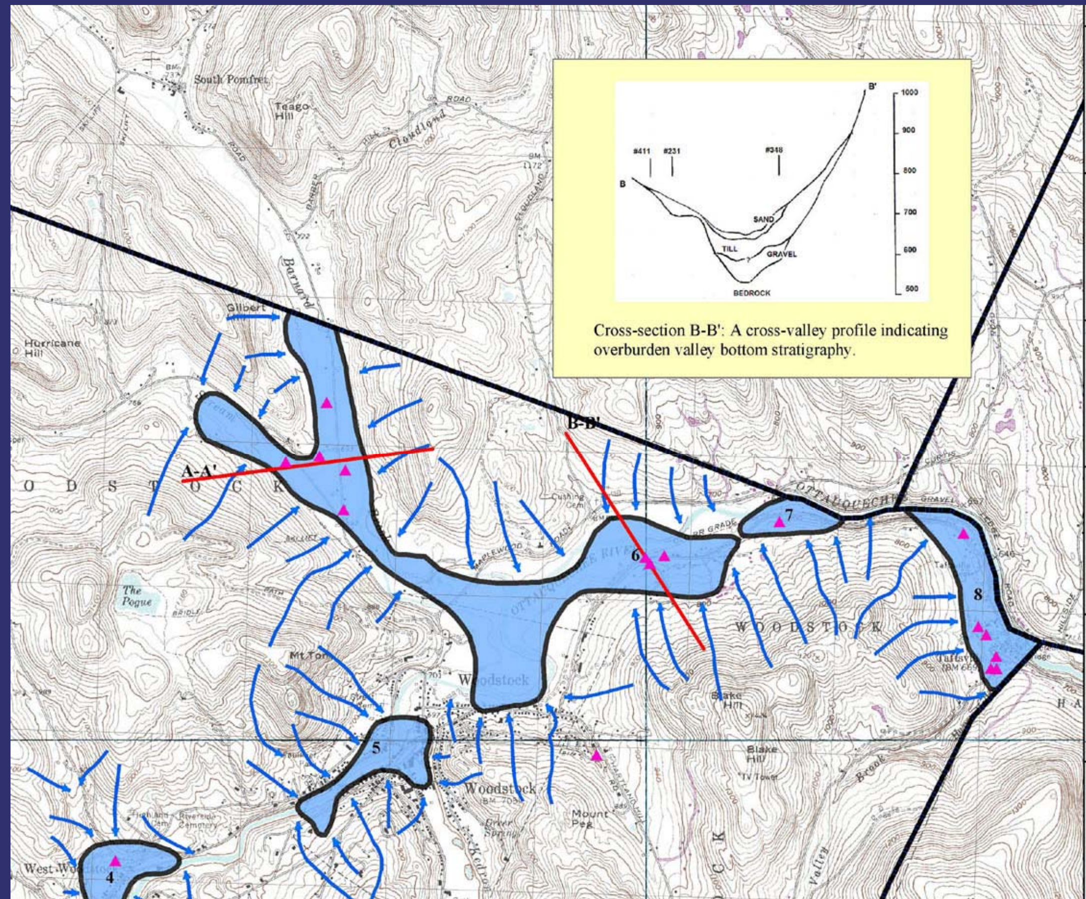
Steeply Dipping Bedrock Zone and Well Yields



Thompson, 2006

Woodstock





Potential Buried and Shallow Aquifers

Potential Recharge to Buried Aquifer

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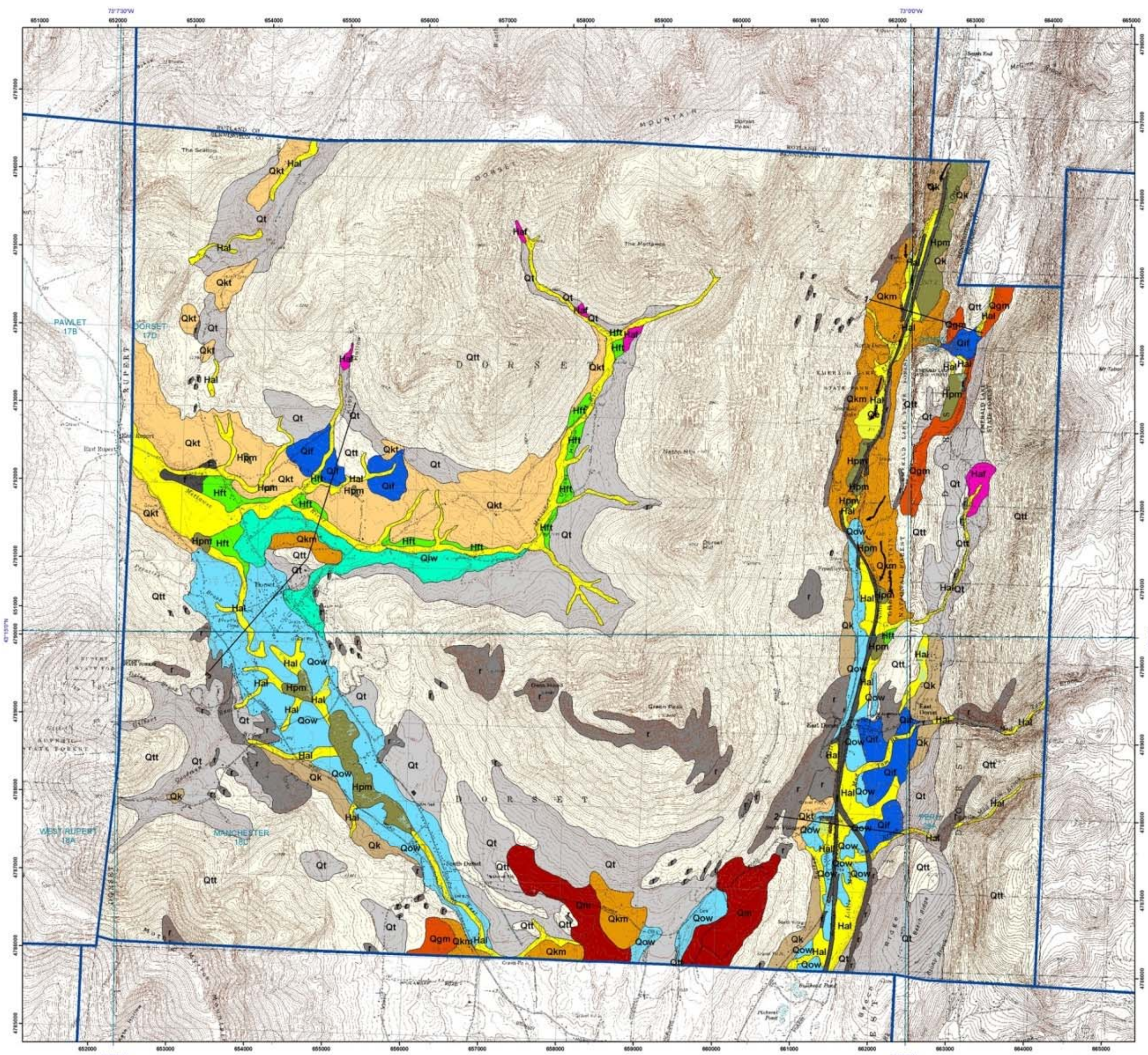


Base map from U.S. Geological Survey.
Quadrangle names printed in blue.
Coordinate System: Vermont State Plane, meters, NAD 83.
Geographic coordinates shown at topo corners are in NAD 83.
Grid overlay on map is Universal Transverse Mercator,
Zone 18N, NAD 27.

Digitization and Cartography by Marjorie Gale
Date: February 2009

1:24,000
0 0.5 1 2 Miles
0 0.5 1 2 Kilometers
Contour Interval 20 Feet

MN N
Magnetic declination
15.5 degrees west, 1968

SURFICIAL GEOLOGIC MAP OF THE TOWN OF DORSET, VERMONT

by
David De Simone
2009

Research supported by the Vermont Geological Survey, Dept. of Environmental Conservation, VT ANR.
This geologic map was funded in part by the USGS National Cooperative Mapping Program.
The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Government.
The map was funded in part by the Town of Dorset and by the Bennington County Regional Planning Commission.

Legend

DESCRIPTION OF MAP UNITS

RECENT

- **f** — Fill; variable materials used as artificial fill along rail beds, road beds, embankments and low lying areas.
- **Hpm** — Peat & Muck; organic sediment, mostly silt and clay in wetlands and swamps; low lying lands prone to flooding.
- **Hal** — Alluvium; stream flood plains; fine sand, silt and gravel of river channel, bar, and bank areas; river bottom lands; variable permeability but usually intermediate to low; often wet sites and prone to flooding; can be good aquifer if sufficiently thick.
- **Haf** — Alluvial Fan; tributary stream deposits; gravel, silt and sand, often poorly sorted; gently to moderately sloping lands located at the base of steep slopes and at stream junctions; variable permeability but usually intermediate to low; fair aquifer if sufficiently thick and permeable.
- **Hft** — Fluvial Terrace; old flood plains; fine sand, silt, and gravel generally less than 5 meters thick; flat to gently sloping lands; variable permeability, usually intermediate; old stream terrace deposits above the flood plain; soils are often deep, well drained loams suitable for agriculture; water table may be sufficiently deep to allow for conventional septic systems; percolation rates may be locally variable and wet areas are not uncommon; banks above streams may be prone to failure; fair aquifer. Some terraces may be latest Pleistocene and related to lowering of glacial lake levels.

PLEISTOCENE

- **Qif** — Inwash Fan; see Qiw description.
- **Qiw** — Inwash; stratified fluvial sand, sand and gravel, or gravel deposited where uplands transition to lowlands and associated with other ice contact sediment or accumulated against an ice margin and having one ice contact side, typically the distal side; well drained and, if thick, a good aquifer.
- **Qow** — Outwash; glacial melt water deposits of well sorted gravel and sand typically greater than 5 meters thick; gently sloping to flat lands which may be pitted due to melted ice blocks; intermediate to high permeability; high gravel-sand resource potential.
- **Qe** — Esker; subglacial/englacial melt water stream deposits of moderately well sorted gravel and sand with boulders; prominent elongated and curving narrow ridges with steep sides and heights reaching 60+ feet; intermediate to high permeability; high gravel-sand resource potential; steep slopes may pose a slope stability problem.
- **Qk** — Kame, undifferentiated hummocky terrain; glacial deposits from streams, slumps and deposition by ice; stratified and unstratified sand, gravel and boulders with variable silt; rolling, hilly lands to individual hills; intermediate to high permeability; high gravel-sand resource potential; fair to good aquifer limited by variable thickness and aerial extent.
- **Qkt** — Kame terrace, sand with gravel; ice contact melt water and sediment flow deposits of stratified and unstratified gravel, sand, boulders and some silt; nearly flat lands; intermediate to high permeability; high gravel-sand resource potential; slopes at edges of these areas may pose a stability problem; variable sediment thickness typically exceeds 10 meters; percolation rates are generally satisfactory for conventional septic systems; aquifer recharge areas may be prone to contamination from infiltration.
- **Qkm** — Kame Moraine, sand and gravel; ice contact melt water and sediment flow deposits of stratified and unstratified gravel and sand with silt and boulders; rolling, hilly ridged land with local flat areas; intermediate to high permeability; high gravel-sand resource potential; local steep slopes may pose a stability problem.
- **Qgm** — Ground Moraine, hummocky till with sand and gravel; ice contact sediment flow, melt water and ice deposited sediments of variable texture ranging from stratified and well sorted gravel and sand to unstratified and poorly sorted silt, sand, gravel and boulders; thickness is variable and rock outcrops may portrude; low to high permeability; limited local slope stability problems; gently rolling hills and elongate smooth hills are possible.
- **Qm** — Moraine, ridged till; ice contact ice deposited, sediment flow, and melt water materials of unstratified and stratified silt, sand, gravel and boulders; broad ridges and swales with rolling low hills; variable permeability; local slopes may pose a stability problem.
- **Qt** — Till, thick or blanket; ice derived deposits of hardpan, silt, boulders, gravel and sand which are unsorted and unstratified and deposited beneath the glacier; may contain deformed stratified units that may be re-deposited diamictons from subaqueous or subglacial flows; thickness greater than 3 meters but rock outcrops may be common; surface boulders or erratics are common; smoothed and streamlined hills in the valley and gently undulating slopes on the lower mountain flanks to nearly flat plains dotted with erratics; low permeability; unstable slopes in excavations; may be prone to slope failures along stream banks.
- **Qtt** — Till, thin or veneer; ice derived deposits of hardpan, silt, boulders, gravel and sand which are unsorted and unstratified and deposited beneath the glacier; thickness less than 3 meters with rock outcrops common; surface boulders or erratics are common; moderate to steep mountain slopes and summit areas; low permeability where thicker than 3'; moderately permeable where thin, weathered soils are less than 3' thick.

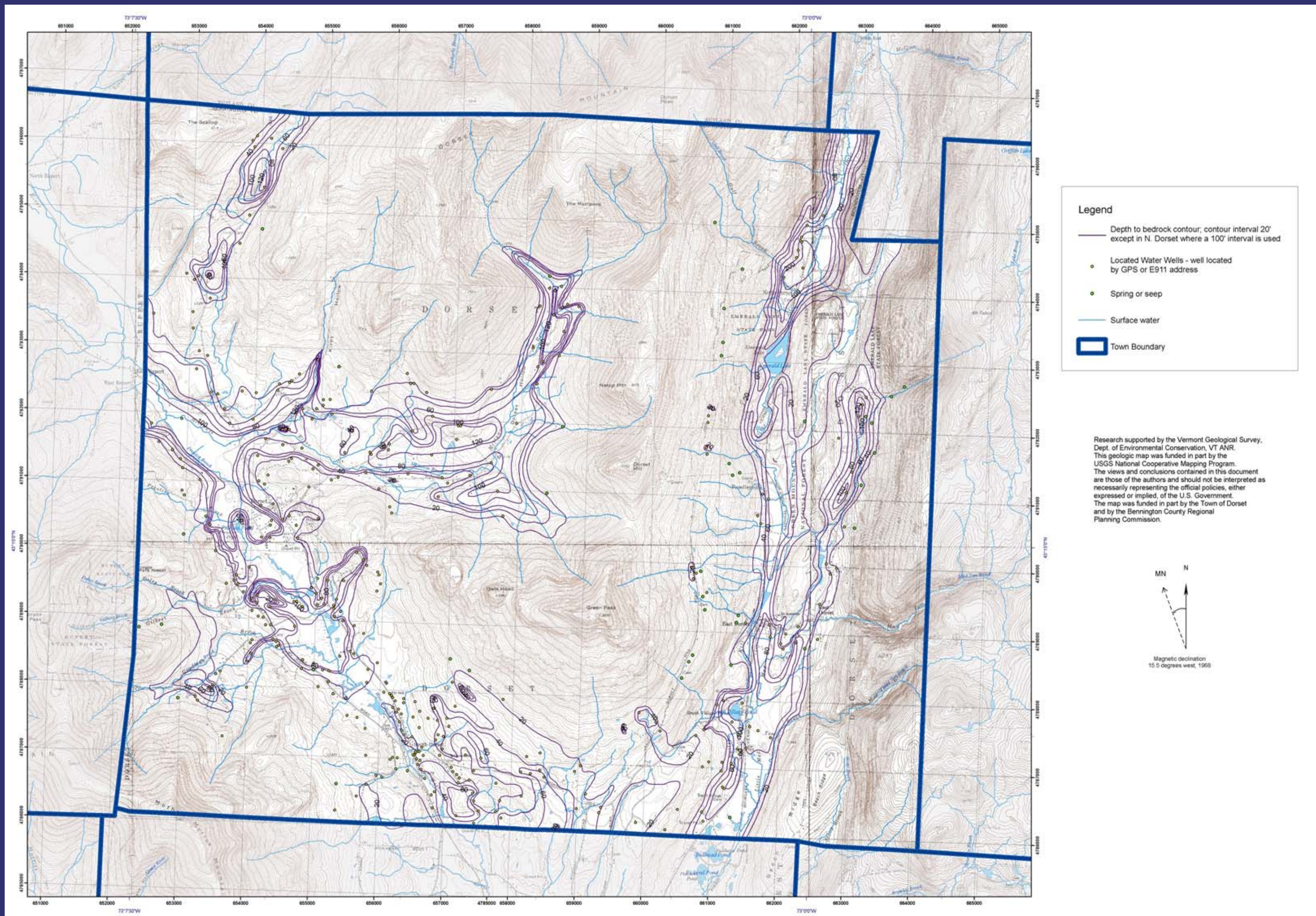
PALEOZOIC AND PRECAMBRIAN

- **r** — Rock Outcrop; includes areas of predominantly outcrop with patches of till; outcrop areas serve to recharge bedrock units with groundwater; poor sites for septic systems; rock types are mainly marble, quartzite, schist and phyllite.

VT Town Boundaries

USGS 24K Quadrangle Boundaries

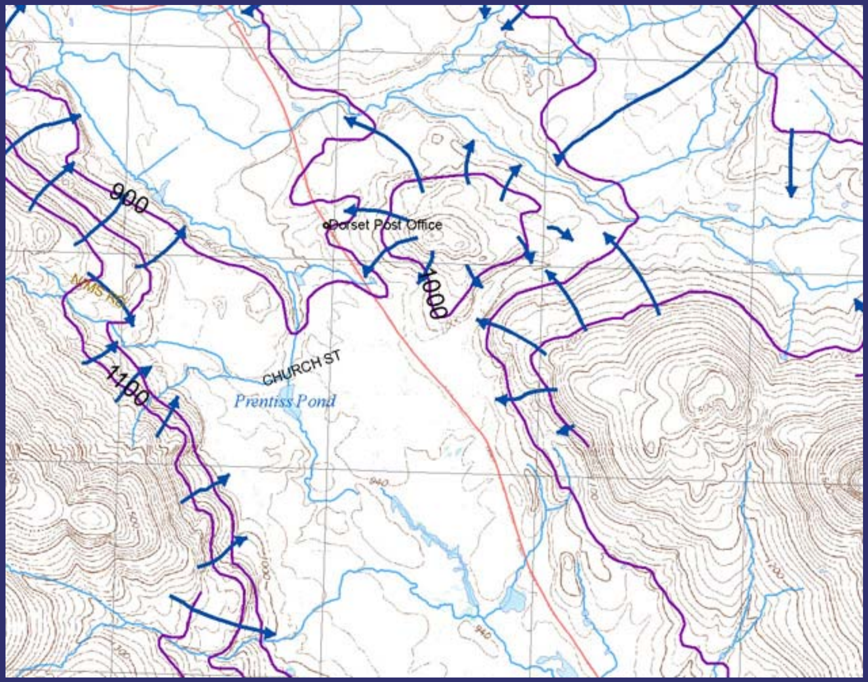
Line of Cross-Section

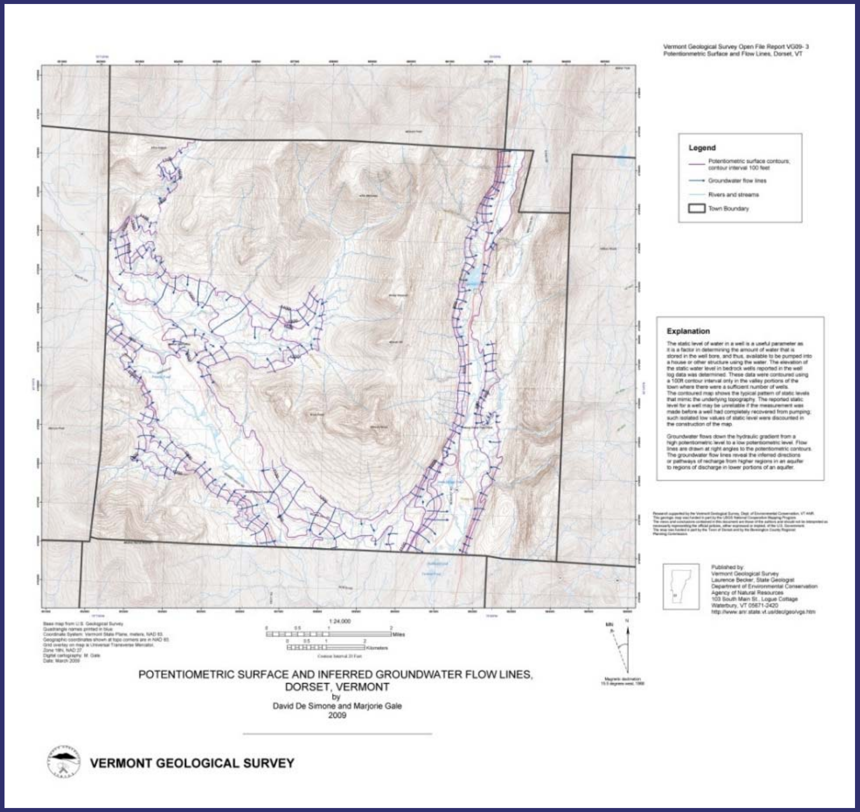


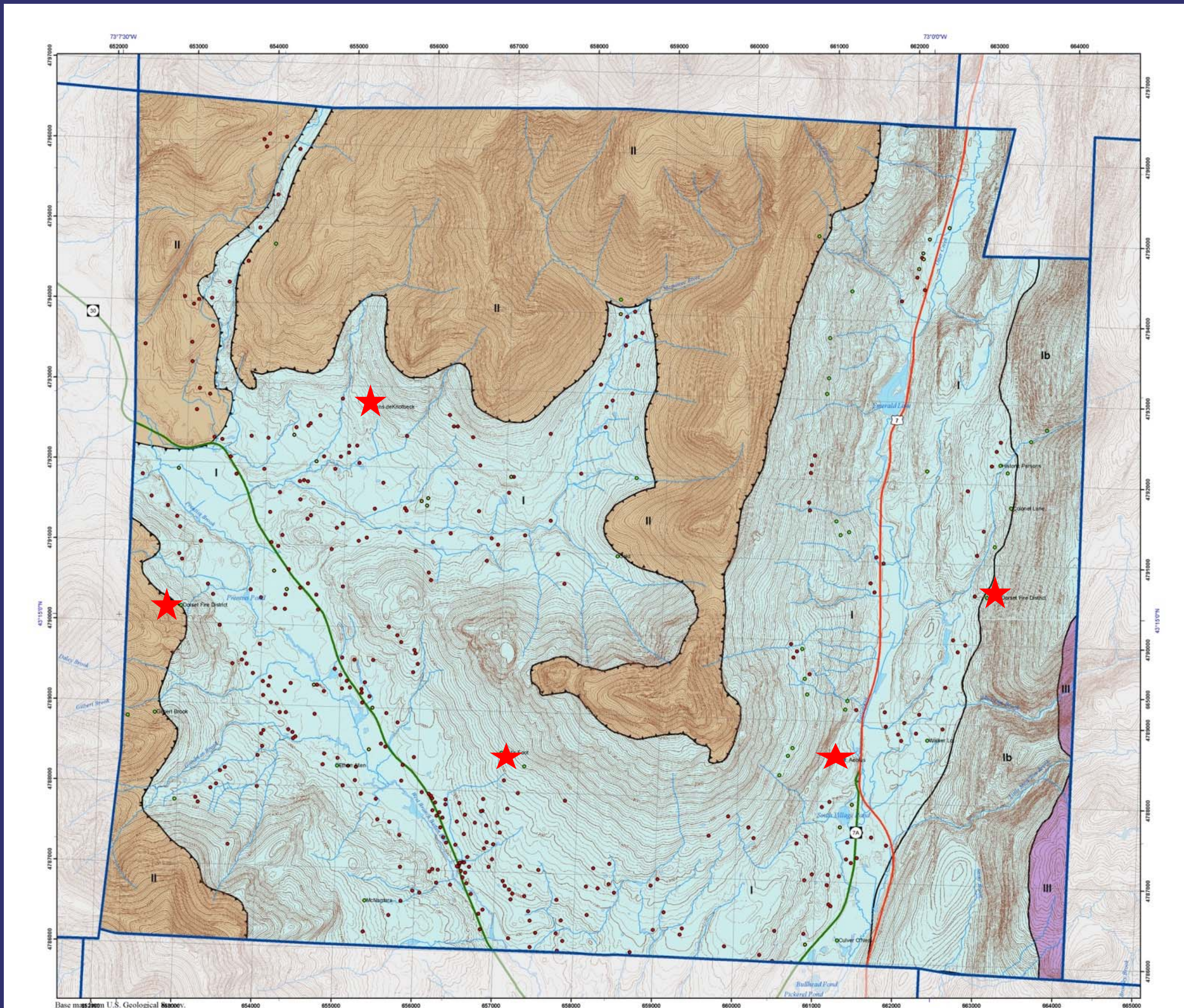
Depth to Bedrock, DeSimone & Gale, 2009

Reported static water levels and Inferred Flow Lines

The groundwater flow lines reveal generalized, inferred directions of recharge from higher regions to regions of discharge in lower portions of an aquifer.







Legend

Bedrock Lithology and Well Yield

I & Ib — Champlain Valley Sequence
I - Carbonates (with some quartzites and conglomerates) of the Bascom, Shelburne, Clarendon Springs, Winooski, Dunham, Danby, Monkton, and Dalton Fms.;
Ib - mainly Cheshire quartzite
*290 wells - Mean yield: 21 gpm, Mean depth: 309'
Median yield: 10 gpm, Median depth: 280'

II — Taconic Sequence
Slate, phyllite, and carbonate of the St. Catherine and Brezee Formations.
*24 wells - Mean yield: 10 gpm, Mean depth: 424'
Median yield: 3 gpm, Median depth: 400'

III — Green Mountain Sequence
Gneiss of the My. Holly Fm.
*No wells

- Fault - teeth on upper plate
- Located bedrock wells
- Located gravel wells
- Springs and seeps
- Town Boundary

Major Roads
- Interstate Highway
- US Highway
- Vermont State Highway
- Class 1 Town Highway

Explanation

The map portrays the distribution of major lithologic units in the town. Formation contacts are from Vermont Geological Survey Bulletin 30, Vermont Geological Survey Bulletin 18, and USGS digital data of the 1961 Cenntennial Geologic Map of Vermont, scale 1:250,000. Geology has been slightly modified based on field outcrops.

References:

Shumaker, R.C. and Thompson, J.B., Jr., 1967, Bedrock Geology of the Pawlet Quadrangle, Vermont: Vermont Geological Survey Bulletin 30, scale 1:62,500.

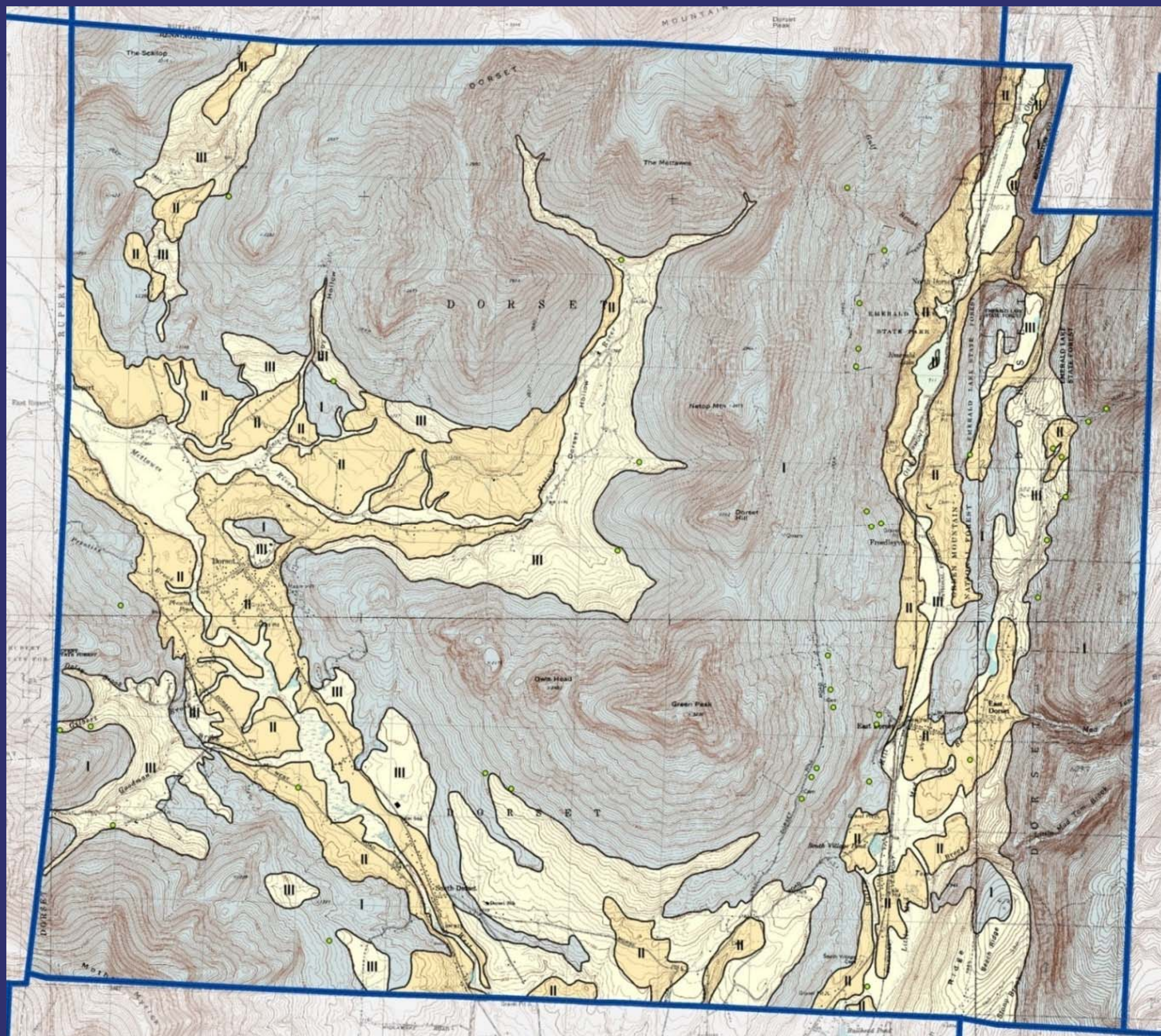
Hewitt, P.C., 1961, The Geology of the Equinox Quadrangle and Vicinity, Vermont: Vermont Geological Survey Bulletin 18, scale 1:62,500.

USGS Open-File Report 2006-1272: Preliminary Integrated Geologic Map Databases for the United States: Connecticut, Maine, Massachusetts, New Hampshire, Rhode island and Vermont http://pubs.usgs.gov/of/2006/1272/

Champlain Valley Sequence -
The vast majority of Dorset wells, 290, tap into carbonate and quartzite of the Champlain Valley Sequence. The carbonate units are aerially extensive and cover the majority of the valley bottom and much of the valley slopes in town. Exposures of carbonate bedrock reveal that dissolution has resulted in high secondary porosity and permeability.
Karst terrain is exposed in a few locations and is inferred to be buried beneath the extensive cover of glacial deposits. The eastern margin of town where the flanks of the Green Mountains are underlain by quartzite or interbedded quartzite and conglomerate are sites where there are no well data. However, the quartzite produces relatively good well yields, as shown by work in Wallingford, Manchester and Arlington. In Dorset, the quartzite has springs and seeps issuing from the Green Mountains flanks.

Taconic Sequence -
The Taconic Sequence lithologies can be found in the mountains west of Dorset along the border with New York and in the Dorset Mountains in the central portion of town. The higher Taconic Mountains elevations are underlain by fine grained phyllite or similar rock. Mean well yields are relatively low (10 gpm). However, this rock does contribute recharge through its numerous fractures and foliation to the underlying rock units. The high elevations in these areas are underlain largely by a very thin veneer of till. The summit ridges and steep mountain flanks contain a veneer that may be only a foot or so thick. This thin till has weathered and become relatively permeable over time and the underlying rock readily weathers. The soils on areas of thin till with frequent rock outcrops allows water to infiltrate the shallow soil profile and some of this water can penetrate the weathered fractures and foliation in the phyllite and carbonate rocks found at the high Taconic elevations. Therefore, these areas represent good recharge zones.

Hydrogeologic Units, DeSimone & Gale, 2009

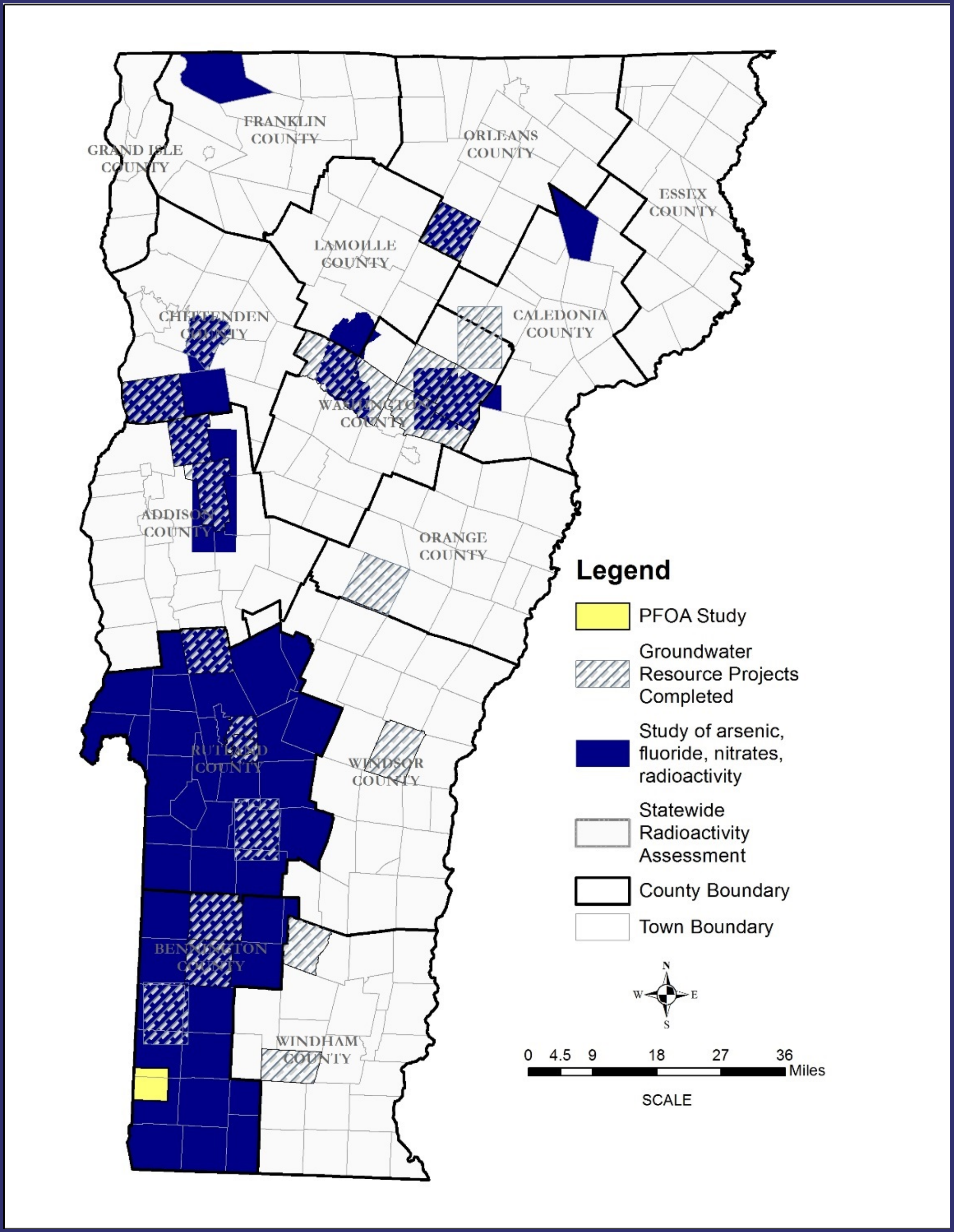


I – Higher: high elevation areas with thin till or exposed bedrock

II – Moderate: permeable sediment in contact with underlying bedrock;

III – Lower: thick impermeable till mainly on lower mountain flanks; impedes infiltratration

Recharge Potential to Bedrock Aquifer



Andover
Bennington
Brandon
Bristol
Cabot
Calais
Charlotte
Craftsbury
Dorset
Dover
East Montpelier
Londonderry
Manchester
Monkton
Randolph
Rutland
Wallingford
Weathersfield
Williston
Woodstock

McNamara Spring, Dorset

Disappearing stream

And remember…surface water and groundwater are part of the same system

THANK YOU