WAITE HEINDEL
Environmental Management

July 5, 2022

To: Manchester Board of Water Commissioners
Manchester, Vermont

Re: Evaluation of Source Protection Area Delineation, Manchester Wells #1, #2
WSID #5022

As authorized by the Town of Manchester on March 25, 2022, this letter / report provides my evaluation of the Source Protection Area [SPA] for the two drilled gravel wells that serve as sources of water for the Public Community Water System in Manchester, Vermont, WSID #5022; particularly, whether any changes in the delineation of the SPA are appropriate since the 1980s.

Table of Contents:

A. Summary of Findings and Recommendations: The current SPA appears to be slightly undersized in comparison to the estimated average annual recharge volume, so I am suggesting a revision to the SPA to achieve a somewhat larger size. A 2006 study by DeSimone and Becker for the Vermont Geological Survey and Town of Manchester evaluated water level measurements in the town production and monitoring wells, in two new wells drilled specifically for the study, and on the adjacent Batten Kill. The authors concluded that there is no indication that the town wells could draw from the portion of the gravel aquifer that is west of the Batten Kill, and also could not likely draw from the Batten Kill itself. Also, groundwater flow paths near the two town wells that were measured in the 2006 study indicate that there is no hydrogeologic reason to delineate the northwest corner of the current SPA all the way north to Boorn Brook near its confluence with the Batten Kill.

Based on the above information, and on mapping of the eastern edge of the high-permeability gravel aquifer from which the two town wells draw their water, and on topographic contours from a USGS base map, I suggest a modified delineation of the Source Protection Area that is somewhat larger in the higher elevations to the east -- to provide a larger total area in order to exceed the permitted annual withdrawal from the two town wells, but narrower in its western section near the wells – to be in accordance with the findings of the 2006 study of water levels. A majority of the proposed expansion to Zone 3 is in the National Forest.

B. Documents Reviewed:

- 1984 – 1986: Several documents from Vermont Dept. of Health and Dufresne-Henry regarding site and source approvals for Well #1, and the proposed "Aquifer Protection Area" delineation;
- *Batten Kill Well Aquifer Protection Area Inventory;* Dufresne-Henry; May 1987;
- *Pumping Test Evaluation; 1988 Pumping Test on Well #2;* Jeff Hoffer, dated 2/14/1994. This report is Appendix A of next document by Hoffer [Sept. 1994];
- *Wellhead Protection Area Delineation; Well #1 and Well #2, Manchester, VT*; Jeff Hoffer, Sept. 1994;
- *Letter, Tim Raymond [VTDEC Water Supply Div.] to Manchester Town Manager re: Wells #1 and #2;* 1/13/1995;
- *Letter, Hoffer to Dufresne-Henry re: Wellhead Protection Area Delineation;* 7/24/1995;
- *Report on Batten Kill Wells 1 and 2;* including proposed revised wellhead protection area for Wells 1 and 2; Dufresne-Henry, Aug. 1995;
- *Source Approval, Gravel Well #2, Manchester Public Community Water System, WSID #5022;* 12/08/1995;
- *Surficial Geology and Hydrogeology of Manchester, Vermont;* David DeSimone; Vermont Geological Survey Open File Report VG-4-1; dated 2004;
- *Draft Final Report on Static Water Level Measurements in the Manchester Town Well Aquifer;* David DeSimone & Laurence Becker, VT Geological Survey; dated 4/14/2006;
- *Permit to Operate; Public Community Water System, Manchester Town, WSID #5022*; VTDEC Drinking Water Program; dated 5/23/2013;
- *Source Protection Plan Update, Manchester; WSID #5022*; Dufresne Group; dated 1/21/2019;
- *Sanitary Survey Letter; Manchester PCWS, WSID #5022;* Matthew Hunt [VTDEC Drinking Water Program], dated 2/03/2022.
- *Map of Source Protection Area, Manchester PCWS, Wells #1 and #2, WSID #5022;* downloaded from Vermont Natural Resources Atlas on 3/21/2022.

C. <u>Permitted Well Yields; Basis of Source Protection Area Delineations</u>: The approved well yields that were used as the basis of the historical delineations of the Source Protection Area [originally called "Aquifer Protection Areas", then "Wellhead Protection Areas"] are described below. The sources for this information are:

- For Well #1: VT Dept. of Health approval letter dated 1/13/1986;
- For Well #2 [and confirming for Well #1]: Letter from Tim Raymond, VTDEC Drinking Water Program dated 1/13/1995, at p. 7, Item #8.

- <u>Well #1</u>: Approved for **<u>800 gpm</u>** [gallons per minute] over 24-hour pumping period;
  - Average Day Demand [ADD]: **<u>1,152,000 gpd</u>** [gallons per day] [basis: 800 gpm x 1,440 mins/24-hr day = 1,152,000 gpd].
  - This approved rate is not necessarily the maximum yield of Well #1. The 1/13/1986 approval letter for this well indicates that this approved yield is based on the maximum pumping rate of the pump test that was conducted by Scott Assocs. on this well, as reported

in their report titled *Report Relative to the Hydraulic Investigation of a 24-inch Gravel-packed Well, Manchester,* VT dated July 1985. [I was not able to locate or review a copy of this report].

- Well #2: Approved for **468 gpm** over 12-hour pumping period [referred to in the Water Supply Rule as "Maximum Day Demand"];
  - ADD: **337,000 gpd** [basis: 468 gpm x 720 mins/12-hr day = 337,000 gpd].
  - This approval rate is lower than the proposed long-term safe yield for Well #2 of 1,080 gpm [777,600 gpd] that was proposed by Hoffer in his 2/14/1994 report. Hoffer arrived at his proposed yield for Well #2 by evaluating data from the 1988 pump test on Well #2 by R.E. Chapman. VTDEC apparently disagreed with Hoffer's calculations, and approved Well #2 for 468 gpm over a 12-hour period [or 337,000 gpd], per an approval letter dated 8/8/1994, as stated in Tim Raymond's letter dated 1/13/1995. I was not able to locate or review the original VTDEC 8/8/1994 approval letter.

- Total Approved Yield, Manchester Wells #1 and #2: **1,489,000 gpd, Average Day Demand.** *[Note: It is confusing to express the approved combination of the two well yields in gallons per minute [Max Day Demand], so I do not include that number in Total Approved Yield, because the two Manchester wells are approved for "water days" of different duration: Well #1 is approved for 800 gpm over a full 24-hour period, while Well #2 is approved for 468 gpm, but over a 12-hour period].*
    - For use in later calculations, this combined daily approved yield is equivalent to approx. 200,000 cu.ft/day [1,489,000 gpd x 0.13368 cu.ft./gal = 199,050 cu.ft./day].

D. History of Source Protection Area Delineations, from 1980s and 1990s: Manchester's consultants in the 1980s, Dufresne-Henry, Inc.; and Jeff Hoffer [Hoffer & Assocs.] went back and forth on several proposed delineations of the boundaries for the SPA for Well #1, and then adding the adjacent Well #2. The term in the 1980s for SPA was "Aquifer Protection Area", which then was modified in the 1990s to "Wellhead Protection Area"; each with somewhat different definitions.

- **1986:** The initial approved boundary of the Aquifer Protection Area [1986] for Well #1 was based somewhat on cultural features [East Manchester Rd. to the north; west edge of the airport runway, to the east; Airport Rd. to the south] – and, hydrologically, the Batten Kill to the west.
- **1994:** Eight years later, at the time when Well #2 was installed and pump-tested, the Water Supply Rule required the delineation of four zones for what was then called a "Wellhead Protection Area" [WHPA]. In the Sept. 1994 report, Hoffer proposed the following boundaries for those four areas, as shown on a map in the attachment, and which I describe as follows:
  - Zone 1: "200-foot radius around each well, which must be controlled by the water system".
  - Zone 2: "the area from where there will be probable impacts from potential sources of contamination …" [underline added by me, for emphasis]. Hoffer's proposed Zone 2 was developed by using several calculation methods from the EPA and VTDEC Water Supply Division. His conceptual model from applying these methods results in a Zone 2 that is bounded on the north by Boorn Brook which he inferred to be a hydrologic barrier, on the east by hydrogeologic modeling which was approximately at the western edge of the airport

runway; to the south by about 600 feet from the mid-point of both wells as suggested by groundwater flow models; and on the west by the Batten Kill, which due to the lack of detailed information on contributions from that river he proposed assuming it to be a hydrologic barrier.

  - Zone 3: "the remaining recharge area or area of contribution to the well not delineated in Zone 2, and where there may be possible impacts from potential sources of contamination" [underline added by me, for emphasis]. Hoffer's proposed Zone 2 extends eastward to the "eastern extent of the unconsolidated aquifer" – which happens to fall approximately at Rte. 7; and it extends 1000 feet south from Well #2 along the Batten Kill, and then upgradient to the east, perpendicular to "inferred groundwater contours".
  - Two-Year Time-of-Travel Zone: Using a hydrogeologic model from the EPA, Hoffer proposed the two-year time-of-travel zone to be an elliptical shape extending about 2,000 feet upgradient to the northeast from the two wells.
- **1995:**
  - In January 1995, the VTDEC Drinking Water Program requested that the western boundary of the WHPA be extended to 200 feet west of the Batten Kill because monitor well OW-B, located on the west side of the Batten Kill, responded slightly to the May 1987 pump test on Well #1, and that there may be some component of recharge to the town wells from the Batten Kill itself. They also requested that the eastern boundary of the WHPA be extended southeast to the top of the topographic divide, so that it "includes groundwater recharge from the till and adjacent underlying bedrock in the Green Mountains".
  - In July and August 1995, Hoffer and Dufresne-Henry suggested that there is not enough hydrologic data to support extending the WHPA to the west side of the Batten Kill, but agreed with VTDEC's explanation of this boundary based on "a regulatory approach". He also suggested that the VTDEC's proposed extension of the southern boundary was not appropriate because it followed an intermittent stream valley up the mountain, and he proposed a smaller extension to the south, following a topographic ridge or shoulder up the mountain.
  - These revised WHPA boundaries were accepted, per the "Source Approval – Gravel Well #2" letter from VTDEC dated 12/08/1995.
- **2022:** The current SPA map on the VT ANR Natural Resources Atlas shows these 1995-approved three zone boundaries [but not the 2-year time-of-travel zone, which is typically not shown on the Atlas]. Refer to the current map on page 1 of the Appendix.

My evaluation of these boundaries is contained in Sections E, F and G of this report, below.

E. Annual Recharge Volume, Compared to Permitted Withdrawal Rates: An important component of determining the appropriate boundaries and size of an SPA is an estimate of the annual recharge of water to the three Zones, compared to the annual volume of water that is permitted for withdrawal from the approved sources.

1. Annual Recharge Estimate, 1995 Hoffer evaluation: Hoffer estimated the recharge to the aquifer that supplies the two Manchester wells at 2.0 ft/year. This is 61% of the total average annual precipitation in the area [see next bullet], which is a reasonable estimate for an SPA that spans an area of high recharge potential [the highly permeable surficial deposits from the

wells eastward to approximately Rte. 7] to areas of moderate recharge potential [areas with shallow-to-bedrock conditions veneered with thin till], and areas of low recharge potential [areas with thick low-permeability till; the latter two categories being found in the higher elevations east of Rte. 7].

2. Annual Precipitation: The average total annual precipitation in the Manchester area is approximately 3.3 ft/year [39.8 in./year]. This is based on 24 years of data from the National Weather Service station at Morse State Airport in Bennington, VT, the nearest long-term NWS station with a long period of record at a comparable elevation as the Manchester SPA. Variations in the annual totals range from 0.7 ft. higher [47.5 inches in 2008] to 0.9 feet lower [29.0 inches in 2015]. See the summary table of precipitation records in the Appendix, p. 5.
3. Predicted Average Annual Recharge Volume of Water in Current SPA: 456 mil.gals/year. See calculations in Appendix. This predicted average annual recharge volume is based on the area of the current SPA, which is about 700 acres [1.1 sq.mi.].
4. Permitted Annual Withdrawal Rate from two Manchester wells: 543 mil.gals/year. This is based on the approved ADD of 1,488,960 gpd, times 365 days/yr.

Potential under-sizing of current SPA: Based on the above annual estimates, the current SPA might not have enough recharge to meet the permitted demand on the two Manchester wells, in an average precipitation year by about 16%. This suggests that the current delineation of the SPA is too small an area.

F. New Information since 1995 SPA Approval: A detailed study of water levels in wells at and near the two Manchester wells was conducted in 2005 and 2006 by David DeSimone and Larry Becker for the Vermont Geological Survey, funded by a grant obtained by Town of Manchester. The study culminated in their report titled *Draft Final Report on Static Level Measurements in the Manchester Town Well Aquifer* dated 4/14/2006 [attached].

This study provides important information regarding the size and configuration of the cone of depression around Well #1 under pumping conditions ["capture zone"], including an evaluation of whether the Manchester wells draw from the aquifer on the west [opposite] side of the Batten Kill, and also from the Batten Kill itself. To conduct this study, two new monitoring wells were installed on the west side of the Batten Kill, about 25 feet from the river. One well was 55 feet deep, completed in the same coarse deposits that the town wells are installed in just across the river; and the second well was a bedrock well 260 feet deep. In addition, a staff gauge was installed in the Batten Kill on the Union Street bridge abutment about 350 feet upstream of the town wells, to reads water levels in the river. Finally, water levels were also measured in eight of the monitoring wells that had been installed in the vicinity of the two final production wells of the town's system. Water levels and staff-gauge readings were taken periodically from July 2005 to March 2006. The data were then interpreted by the authors.

The authors make several important conclusions that have a direct impact on adjusting the delineated boundaries of the SPA for the Manchester wells:

1. The bedrock aquifer beneath the unconfined gravel aquifer in which the two town wells are completed discharges water upward into the gravel aquifer. The amount of this upward recharge cannot be quantified with the available data. This observation of the direct connection from the bedrock aquifer into the base of the gravel aquifer is supported by the lack of low-permeability materials at the base of the gravel aquifer that has been reported in earlier studies.

2. A small cone of depression in the water table develops around a town well under pumping conditions, in a pattern that is predictable and consistent with hydrogeologic principles. When the pump is turned off, the cone of depression recovers within a few hours to the pre-pumping condition, indicating that the withdrawal rate from the gravel aquifer is not depleting it.

Refer to the "Water Table Map" on page 6 of the Appendix. This map is taken from the report [Fig. 1], and reflects the largest and deepest cone of depression that was measured in this 2005-2006 study. I have annotated it in red, to show the area to the northwest of Well #1 where groundwater does not flow into the capture zone of Well #1, but rather continues to flow westward into the Batten Kill. I use this observation to suggest that the northwest portion of the current SPA can be reduced in size, and the boundary of Zone 2 can be moved closer to the well.

3. The shape of the cone of depression is not symmetrical around the pumping well. It reaches only about 70 feet westward from the well – not all the way to the Batten Kill, which is about 200 feet west of the town wells. The cone of depression reaches about 120 to 150 feet north and south from the well. The portion of the gravel aquifer that is to the east-northeast of the town wells is directly upgradient of the wells, so groundwater in that upgradient direction flows to the wells in both pumping and non-pumping conditions.

4. There is no hydraulic connection with the water table west of the Batten Kill. That is, groundwater beneath the land west of the Batten Kill is not drawn in to the town wells.

5. The water table is fairly shallow beneath the ground surface in the vicinity of the town wells, averaging about 3.5 feet below ground surface. At wetter times of the year, it is as shallow as 2.9 feet below ground surface.

6. No indications were seen in the staff gauge in the Batten Kill to suggest that the river responds demonstrably to the pumping cycles in the town wells. At most times of the year, the Batten Kill is a "gaining" stream, indicating that groundwater from the surficial aquifer discharges into the river, rather than the river discharging into the aquifer. The authors suggest that more data are needed to determine if these hydrologic conditions are maintained in extremely dry weather.

However, I note that even if the river is briefly "losing" [discharging into the base of the gravel aquifer], it does not appear likely that the town wells could draw on that water. The intake screens of the town wells are 70 to 75 feet below the bed of the Batten Kill [far below], and the cone of depression in the surface of the water table due to the town well was shown not to reach even half-way to the river in all dates measured in the 2005-2006 study. So it is very unlikely that the *groundwater flowpaths, even in drought conditions, could induce flow from the river into the town wells.*

Recent Water Quality in Town Wells: Indirect evidence about the viability of the SPA, and about the water quality protection measures that have been in place within the SPA for several decades, can be provided by examining the water quality data from the raw water drawn by the wells. I have briefly looked at the water quality data that is available from the on-line database on the VTDEC Drinking Water Program's website. I see no indications of compromised water quality. PFAS ["per- and polyfluoroalkyl substances"] have been tested for, three times, and found to be not present at detectable levels [April 2016, Oct. 2019, Oct. 2020]. Volatile organic compounds [VOCs, which can indicate industrial or petroleum contamination] were not detected in the most recent analysis [March 2020]. Elevated Nitrate concentrations [an indication of possible contamination by sewage or animal wastes] are not seen [tested annually in March]. Therefore, there is no indication in the water quality data that would suggest the need for a quality-based adjustment to the source protection area delineation.

G. <u>Suggested revision to SPA Delineation and Zones</u>: Following up on my calculation that the current SPA may be somewhat too small, in comparison to the annual recharge volume necessary to provide the permitted yields of the two wells, and following up on the information about the shape and extent of the cone of depression around the wells from the 2006 DeSimone & Becker study, I suggest that the boundaries of the Source Protection Area for the two wells serving the Manchester public community water system [WSID #5022] be modified as explained below, and as shown on the map titled *Suggested Source Protection Area;* WHEM, dated 5/19/2022 on page 2 of the Appendix. For a comparison with the current SPA, see the map on page 3 of the Appendix titled *Suggested Source Protection Area, with Current SPA shown;* WHEM, dated 6/30/2022.

- **<u>Zone 1 for each well</u>:** No change to the 200 ft. radius around each well on the east side of the Batten Kill. The western limit of each Zone 1 would be the eastern edge of the Batten Kill; Zone 1 would not extend into the Batten Kill itself, or to its west.

- **<u>Zone 2</u>** [areas where there will be <u>probable</u> impacts from potential sources of contamination]:
  - North boundary of Zone 2, close to wells: extending eastward to the east-northeast from the radius of the 200-ft. Zone 1 for Well #1, following the boundary of the north edge of the capture zone of Well #1;
  - South boundary of Zone 2, close to wells: extending to the southeast from the radius of the 200-foot Zone 1 for Well #2, then eastward up the inferred groundwater flow fall-line as suggested by ground contours and earlier studies;
  - West boundary of Zone 2: east bank of the Batten Kill;
  - East boundary of Zone 2: eastern edge of the high-permeability gravel aquifer, as mapped by DeSimone in 2004, and as shown on the Surficial Geology Map available through the ANR Natural Resources Atlas [see map titled *Surficial Geology near Manchester Wells;* page 7 in the Appendix]. This proposed eastern boundary of Zone 2 is shown as a darker black line on my suggested SPA map [App., p. 2].

    It is not appropriate or necessary to extend Zone 2 [areas of probable impacts from potential sources of contamination] further to the east, into the area underlain by glacial till because the glacial till provides substantial protection to the underlying bedrock aquifer from contamination at the ground surface due to its low permeability dense nature. Any contamination in the underlying bedrock aquifer in the area east of Zone 2 will be substantially diluted by clean groundwater in both bedrock and gravel aquifers, so this area does not pose a <u>probable</u> impact on water quality for the town wells.

- **<u>Zone 3</u>** [the <u>remaining recharge area</u> or area of contribution to the well not delineated in Zone 2 areas, and where there may be <u>possible</u> impacts from potential sources of contamination]:
  - North boundary, eastern portion of Zone 3: from the northeast edge of the high-permeability gravel aquifer [see map in Attachment], continue eastward perpendicular to ground contours but crossing to the north side of Boorn Brook at a location south of the brook's confluence with Bromley Brook. It is possible that a portion of the Boorn Brook flow may discharge ["lose"] into the eastern edge of the gravel aquifer. But this flowpath

would not reach the town wells from the portion of Boorn Brook that is down-stream of the Bromley Brook confluence, as indicated by the groundwater flow paths on the water table map in the 2006 DeSimone and Becker report. Accordingly, the downstream section of Boorn Brook can be eliminated from the SPA. I propose to include a portion of the upper elevations of Boorn Brook's watershed, by following its northern watershed boundary uphill [crossing ground contours perpendicularly, in the standard method of watershed delineation] to a significant ridgeline above "Prospect Rock" on the USGS base for my suggested SPA map [App., p. 2].

- o South boundary, eastern portion of Zone 3: from the eastern edge of the high-permeability gravel aquifer, continue eastward perpendicular to ground contours, following the ridgeline that denotes the watershed divide between Boorn Brook [to the north] and Lye Brook [to the south]. Follow this watershed divide uphill to the east, to a significant height of land [2900 ft. elev.].
- o East boundary of Zone 3: connect the eastern ends of the two eastern portions of the boundaries described just above, using the standard method of crossing ridgetop contours perpendicularly.

- **Area of Zones 1, 2 and 3; Annual Estimated Recharge:** The combined area of Zones 1, 2 and 3 is about 2.0 square miles [1,250 acres; refer to the same calculations on page 3 in the Appendix], which is more than adequate to meet the permitted annual water demand of the two town wells.

- **Two-Year Time-of-Travel Zone:** The 1995 Hoffer analysis uses a reasonable flow model method to estimate the upgradient extent of the two-year time-of-travel zone to be approximately 2,000 feet. This distance would be measured in the up-gradient direction from the wells [east-northward] as indicated by the groundwater flowpaths shown in the 2006 DeSimone & Becker report. The suggested 2-year T-o-T zone is shown in the red dashed lines on my suggested SPA map. The northern and southern boundaries of this zone are the boundaries of Zone 2, which is conservatively somewhat wider than the predicted north-south extent of the cones of depression around the wells. The western boundary of this zone could conservatively be set at the eastern bank of the Batten Kill, although in actuality the predicted cone of depressions of the two wells only reaches about half-way from the wells to the river.

H. Question about Limitation on Septic Systems in Zone 3: The Town Committee asked the following question: *"Should the Town limit septic systems in Zone 3, via the zoning regs (Aquifer Protection Overlay)? For example, limit septic system numbers or capacities to XX gpd per acre of land."*

My answer: Significant limitations are already in place that apply to any proposed septic systems in Zones 2 and 3 [and they are essentially prohibited in the 200-foot radius Zone 1]. Those current limitations are explained in the Water Supply Rule, App. A, Sect. 3.3.1.1 [p. 22 of App. A], by this sentence: *"On site sewage disposal systems located within the recharge area shall be located a minimum of a two year travel time in saturated materials from proposed source sites."*

I suggest that an applicant proposing a wastewater disposal system in Zones 2 or 3 be required to provide a time-of-travel analysis by a qualified hydrogeologist, AND provide a letter of concurrence from the VTDEC Drinking Water Program. In my judgment, it would not be necessary or fruitful [and potentially it might not be legally defendable] to limit septic system numbers or capacities by some other method.

I would also point out that septic systems are not the only potential sources of aquifer contamination. So the town could consider requiring an analysis of all potential sources of contamination by an applicant who is proposing any type of land use change, such as commercial or industrial activities [even if there is no septic system proposed], followed by a concurrence letter from VTDEC. This PSOC analysis could include review of proposed stormwater infiltration, hazardous materials and waste management, underground storage tanks of virgin or waste products, and so on. Time-of-travel analyses do not generally apply to these types of chemicals, because they can travel for many more than 2 years in an aquifer and still be present at unsafe levels. The 2-year time-of-travel restriction on septic systems is specifically focused on the estimated time for significant die-off of human pathogens in wastewater, and it is a state-wide generic number; it was developed a couple of decades ago based on VTDEC's review of the scientific literature regarding the viability of common viruses in wastewater – so it was a reasonable attempt by the regulators to characterize the die-off time of some of the more common pathogens [for example, viruses that cause gastrointestinal problems, and so on] as they travel in "typical" Vermont soils.

Prepared by:

Craig Heindel, C.P.G.
Senior Hydrogeologist

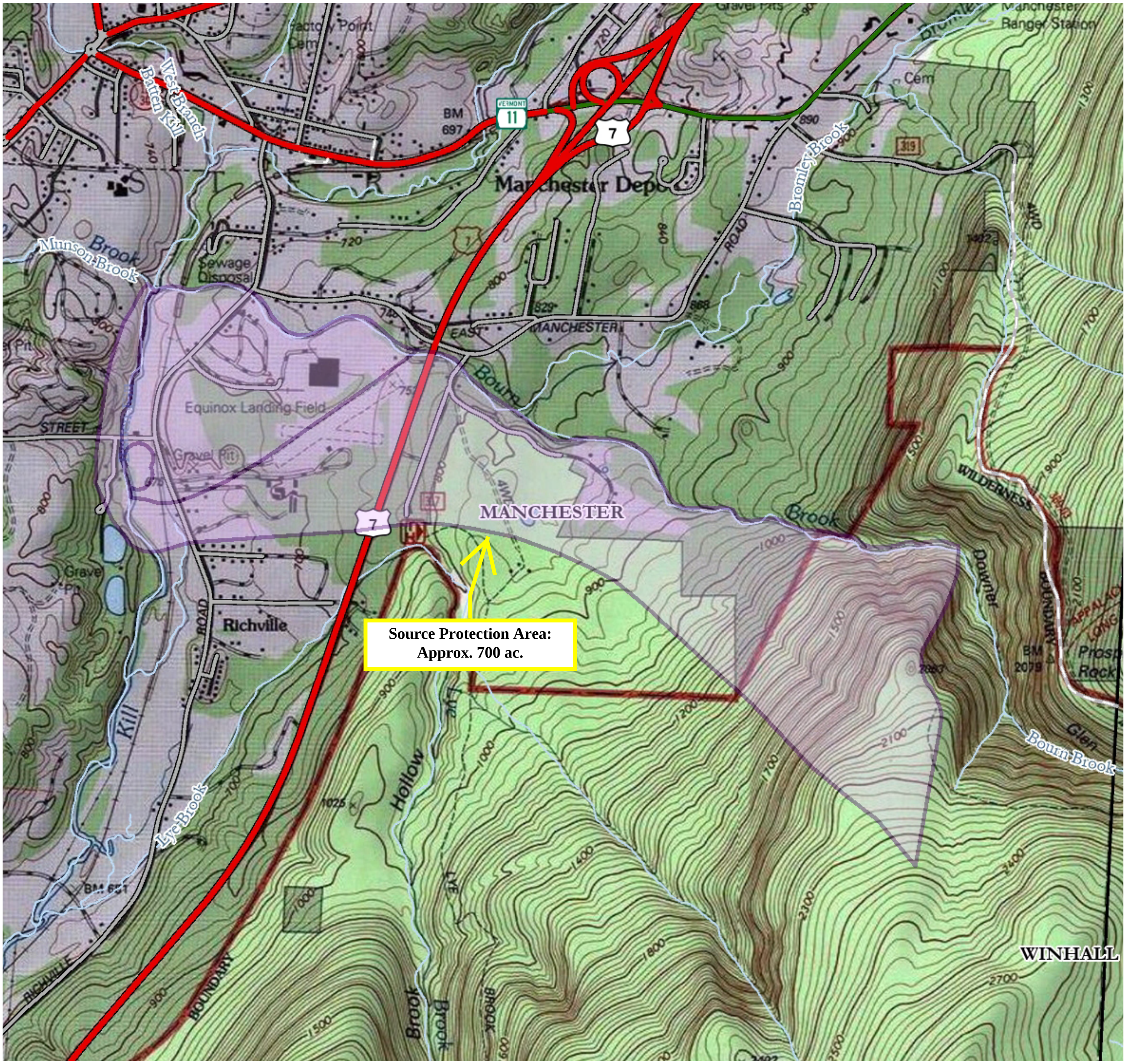
[U:\PROJECTS - WHEM\Manchester SPA\Report\
2022.07.05 - Manchester SPA Evaluation Report TEXT - C.Heindel, WHEM.docx]

APPENDIX

Source Protection Area, Manchester Wells

Vermont Agency of Natural Resources

vermont.gov



LEGEND

Ground Water SPA

- Active/Shared SPA; SHARED
- Proposed
- Inactive

Roads

- Interstate
- US Highway; 1
- State Highway

NOTES

Map created by C. Heindel in 4/2022 using ANR's Natural Resources Atlas

1: 24,000

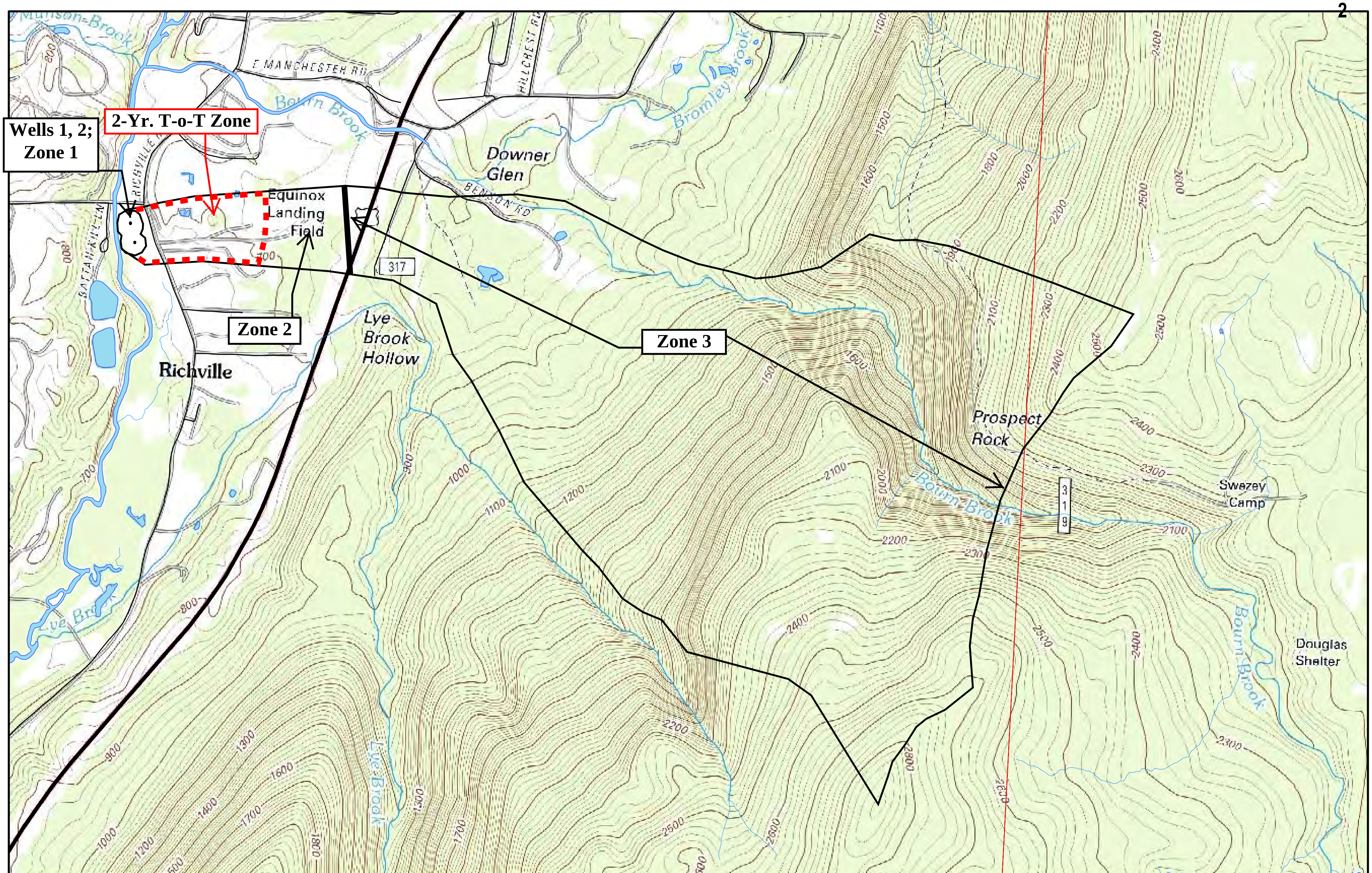
May 20, 2022

4,000.0 0 2,000.00 4,000.0 Feet

WGS_1984_Web_Mercator_Auxiliary_Sphere

1" = 2000 Ft. 1cm = 240 Meters

THIS MAP IS NOT TO BE USED FOR NAVIGATION



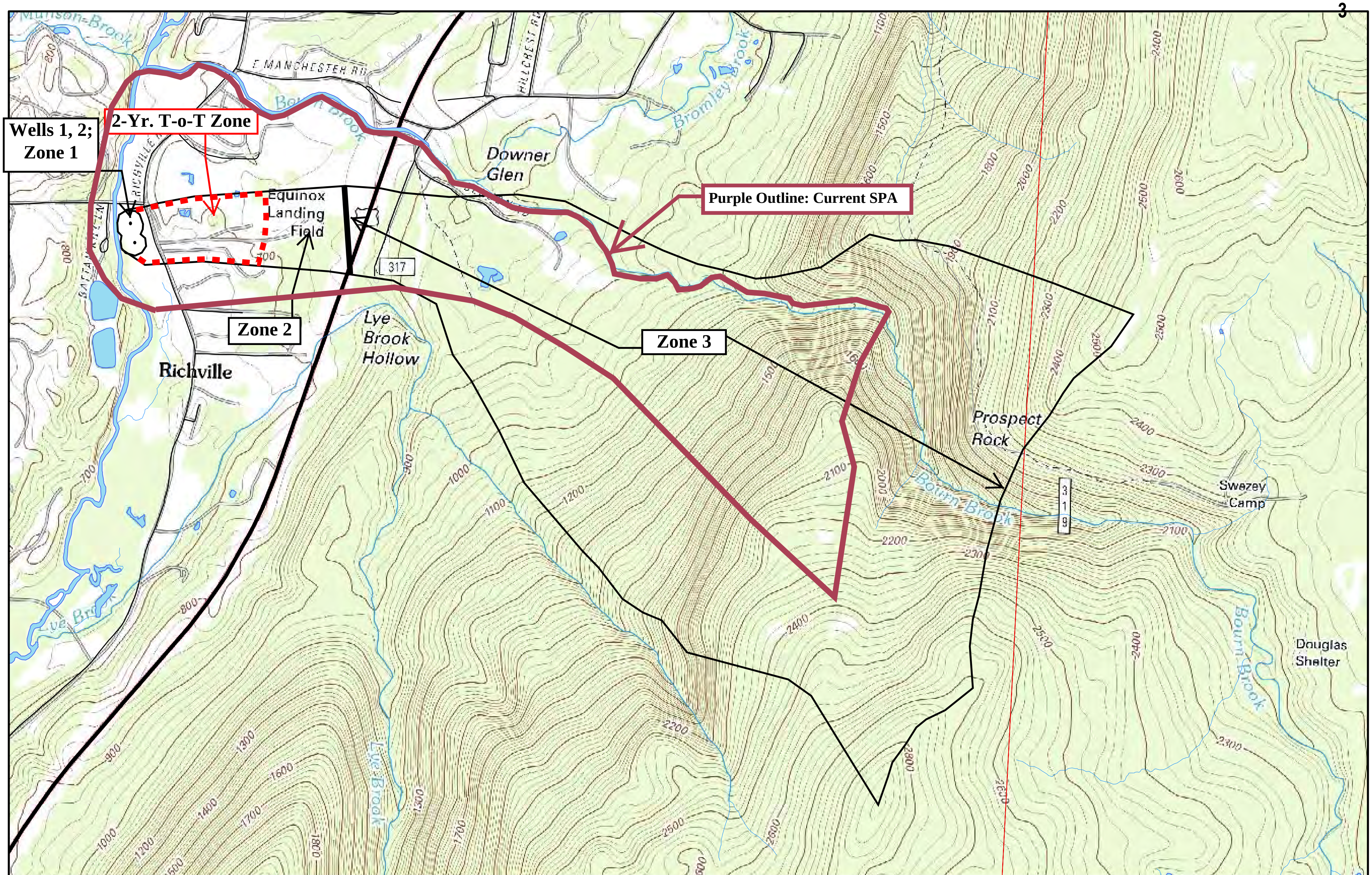
Suggested Source Protection Area
Manchester Wells

Feet
0 1,000 2,000
1 inch = 2,000 feet

N W E S

WAITE HEINDEL
Environmental Management

May 19, 2022
Map produced by: C. Heindel.
U: Manchester SPA.



Suggested Source Protection Area
Manchester Wells

with Current SPA shown

1 inch = 2,000 feet

June 30, 2022

Map produced by: C. Heindel.
U: Manchester SPA.

Calculations: Manchester Source Protection Area Details

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Environmental Management

A. Permitted Well Yields:

Source: Letter Re: *Report on Batten Kill Well #1 and backup well #2;*
T. Raymond, VTDEC Water Supply Div., 1/13/1995 [pages 6 -7, Items 7, 8].
[Note: some more recent VTDEC documents such as Permit to Operate appear to contain conflicting information]

Well #1: 800 gpm over 24-hour period:

	1,152,000	gpd [ADD; Average Day Demand]

Well #2: 468 gpm over 12-hour period:

	336,960	gpd [ADD]
Total:	**1,488,960**	**gpd [ADD]**
conversion:	199,044	cu.ft./day [gpd x 0.13368 cu.ft./gal]
conversion:	**72,651,123**	**cu.ft./yr** [ADD x 365]
conversion:	**543,470,400**	**gal/yr**

B. Recharge Rate for Source Protection Area: 2.0 ft/yr

Source: Estimated by Hoffer in *Wellhead Protection Area Delineation, Well #1 and Well #2, Manchester, VT;* Sept. 1994.

C. Average Annual Recharge Volume to Current SPA:

Area of Current SPA:	700	acres, approx. [measured using Adobe Acrobat Tool]
conversion:	1.1	sq.mi.
conversion:	30,492,000	sq.ft.

Calculate Average Annual Recharge Volume in SPA:

multiply SPA area by avg. annual recharge rate:	**60,984,000**	**cu.ft./year** [sq.ft. of SPA x 2.0 ft/yr recharge rate]
conversion:	**456,193,896**	**gal/year**

Calc. Shortfall in Annual Recharge Volume, in current SPA:

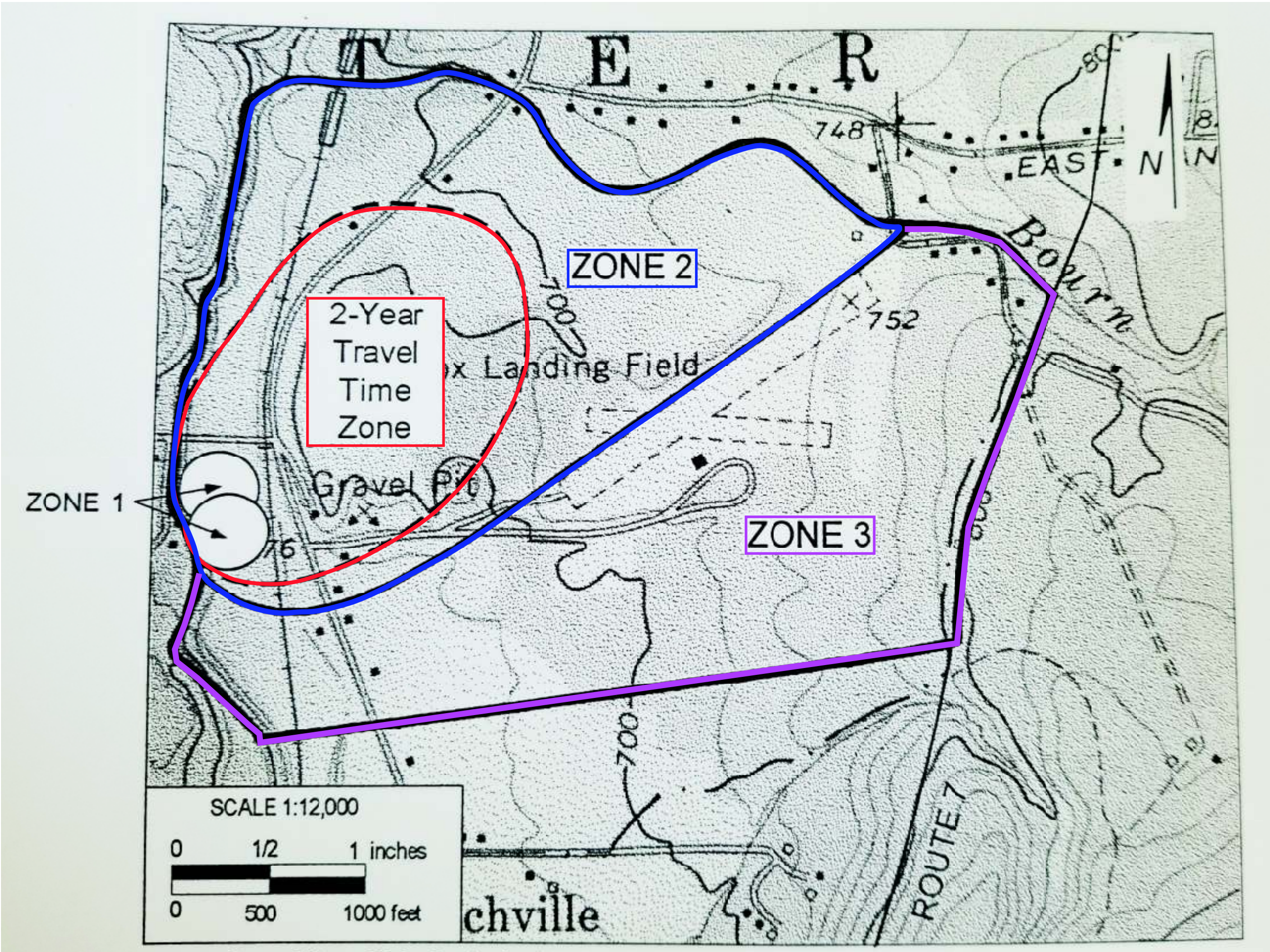
87,276,504	**gals, annual shortfall**
	[based on ESTS. of Avg. annual precip. and recharge]
16%	**Percent, annual shortfall**

D. Area Needed to Provide Permitted Average Day Demand:

	36,325,562	sq.ft. [ADD in cu.ft./yr divided by recharge rate, ft/yr]
conversion:	**834**	acres
conversion:	1.3	sq.mi.

E. Area of Suggested Source Protection Area:
[C. Heindel, WHEM, 5/2022].

1,250	acres [measured using Adobe Acrobat Tool]
2.0	sq.mi.



from Hoffer (1994) *"Wellhead Protection Area Delineation, Well #1 and Well #2, Manchester, Vermont"*

ZONE 1 - This zone consists of a 200 foot radius surrounding a well which must be controlled by the water system.

ZONE 2 - This zone consists of the area from where there will be probable impacts from potential sources of contamination, and is based on the radius established in the VWSR, Chapter 21, 3.3.5.2 (c).

ZONE 3 - This zone consists of the remaining recharge area or area of contribution to the well not delineated as ZONE 2 and where there may be possible impacts from potential sources of contamination.

TWO YEAR TRAVEL TIME ZONE - The two year travel zone is used to identify a protection area to provide adequate protection from pathogenic wastes resulting from on-site sewage disposal

Monthly Total Precipitation for BENNINGTON MORSE STATE AP, VT

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1998	M	M	M	M	M	M	M	M	M	M	M	M	M
1999	4.17	1.69	2.55	0.26	3.08	2.29	4.60	4.62	5.05	1.56	2.24	0.63	32.74
2000	2.43	1.99	1.86	1.57	3.20	3.23	M	5.95	M	1.12	0.68	2.40	M
2001	1.30	2.10	M	0.75	1.26	2.61	2.28	1.92	3.18	1.42	2.17	2.13	M
2002	2.91	2.53	2.99	3.48	4.86	6.29	2.27	4.07	3.72	3.64	4.03	2.93	43.72
2003	1.79	1.23	2.50	2.11	5.35	2.19	3.40	6.29	4.54	5.12	4.73	4.54	43.79
2004	0.63	1.01	2.40	2.66	4.61	2.28	5.99	5.11	4.90	1.16	2.93	2.79	36.47
2005	3.36	1.25	3.05	2.91	1.30	4.65	5.22	2.73	2.08	7.45	4.46	2.14	40.60
2006	3.67	0.91	1.36	2.76	5.36	6.57	6.58	3.57	3.62	4.28	2.74	2.23	43.65
2007	3.06	1.75	3.38	3.64	4.14	3.72	4.38	2.75	3.26	4.64	3.24	3.00	40.96
2008	1.02	4.81	5.12	2.55	1.35	4.18	6.53	4.63	5.67	5.02	1.77	4.87	47.52
2009	1.57	1.09	2.62	1.62	3.76	6.68	6.70	4.64	1.44	4.44	2.03	2.05	38.64
2010	1.93	2.36	2.71	1.66	2.04	5.32	5.86	2.41	2.56	6.72	2.75	2.77	39.09
2011	1.71	2.48	2.66	3.52	4.02	5.14	2.52	9.03	6.64	3.51	1.90	4.37	47.50
2012	1.73	0.77	1.58	2.18	5.76	2.00	2.99	2.95	4.65	4.25	0.79	2.85	32.50
2013	1.45	1.21	1.28	3.37	7.16	7.29	5.60	4.36	4.03	3.54	2.61	2.88	44.78
2014	2.92	2.94	2.15	2.46	2.36	3.33	7.95	1.85	1.02	3.83	2.24	3.91	36.96
2015	2.40	1.01	1.14	2.04	0.97	2.95	2.00	1.73	7.42	2.30	1.26	3.75	28.97
2016	1.11	3.93	2.46	2.63	2.92	1.74	2.39	4.13	3.03	3.57	2.63	2.11	M
2017	1.71	2.11	3.11	2.37	7.13	7.08	6.20	2.83	3.50	2.26	1.45	2.14	41.89
2018	3.05	3.61	1.89	3.17	1.85	3.43	5.27	4.84	4.73	3.72	5.73	3.23	M
2019	1.96	2.07	1.41	3.04	4.03	5.77	3.37	4.28	2.27	5.94	3.03	3.30	40.47
2020	1.34	2.81	2.66	2.93	2.08	2.91	4.58	3.97	3.81	3.75	2.95	3.15	36.94
2021	1.65	1.39	1.54	1.86	3.46	M	9.48	4.24	6.88	6.08	2.69	3.46	M
2022	1.18	3.01	3.46	5.01	M	M	M	M	M	M	M	M	M
Mean	2.09	2.09	2.43	2.52	3.57	4.17	4.83	4.04	4.00	3.88	2.65	2.94	39.84
Max	4.17 1999	4.81 2008	5.12 2008	5.01 2022	7.16 2013	7.29 2013	9.48 2021	9.03 2011	7.42 2015	7.45 2005	5.73 2018	4.87 2008	47.52 2008
Min	0.63 2004	0.77 2012	1.14 2015	0.26 1999	0.97 2015	1.74 2016	2.00 2015	1.73 2015	1.02 2014	1.12 2000	0.68 2000	0.63 1999	28.97 2015

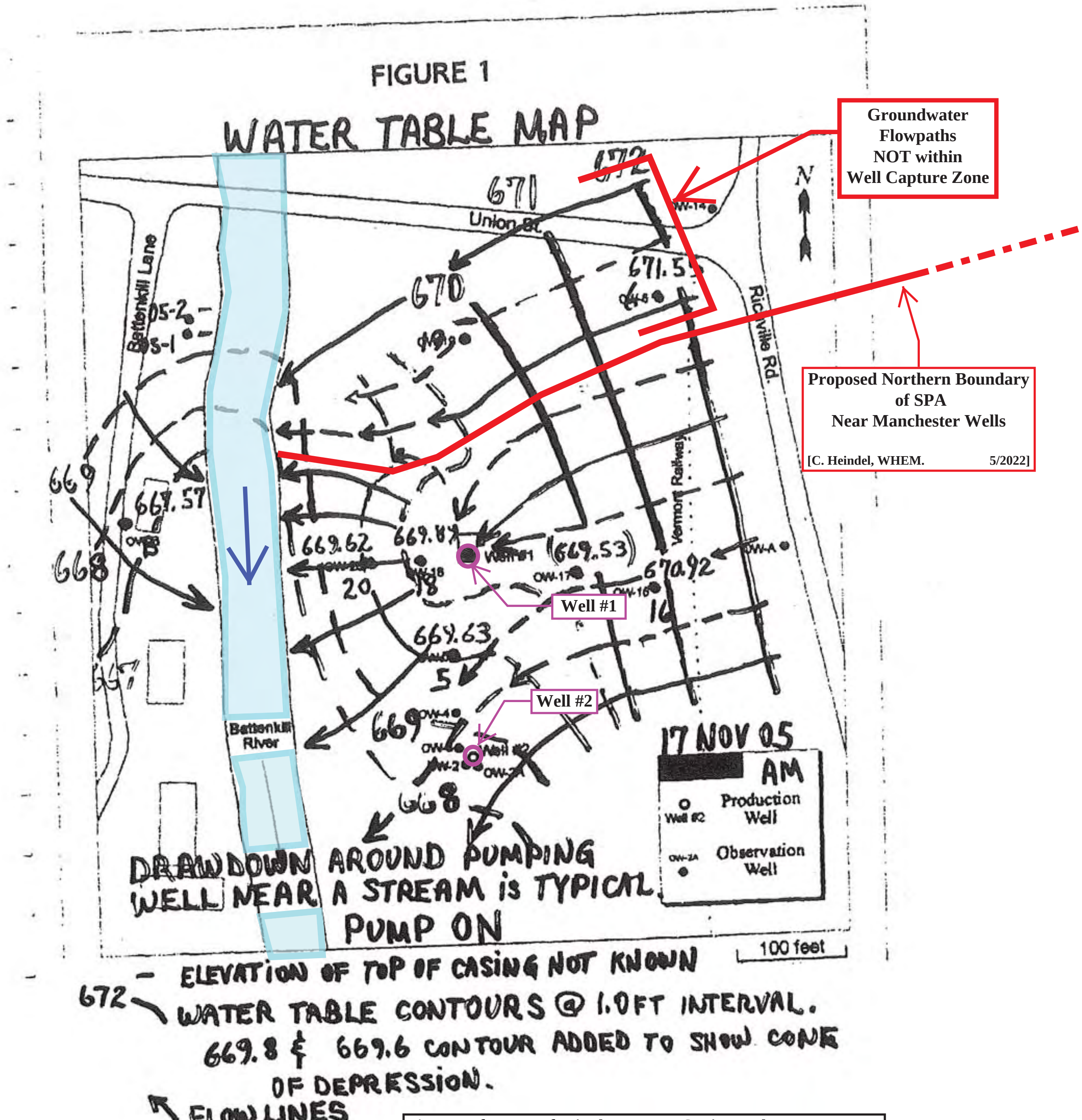
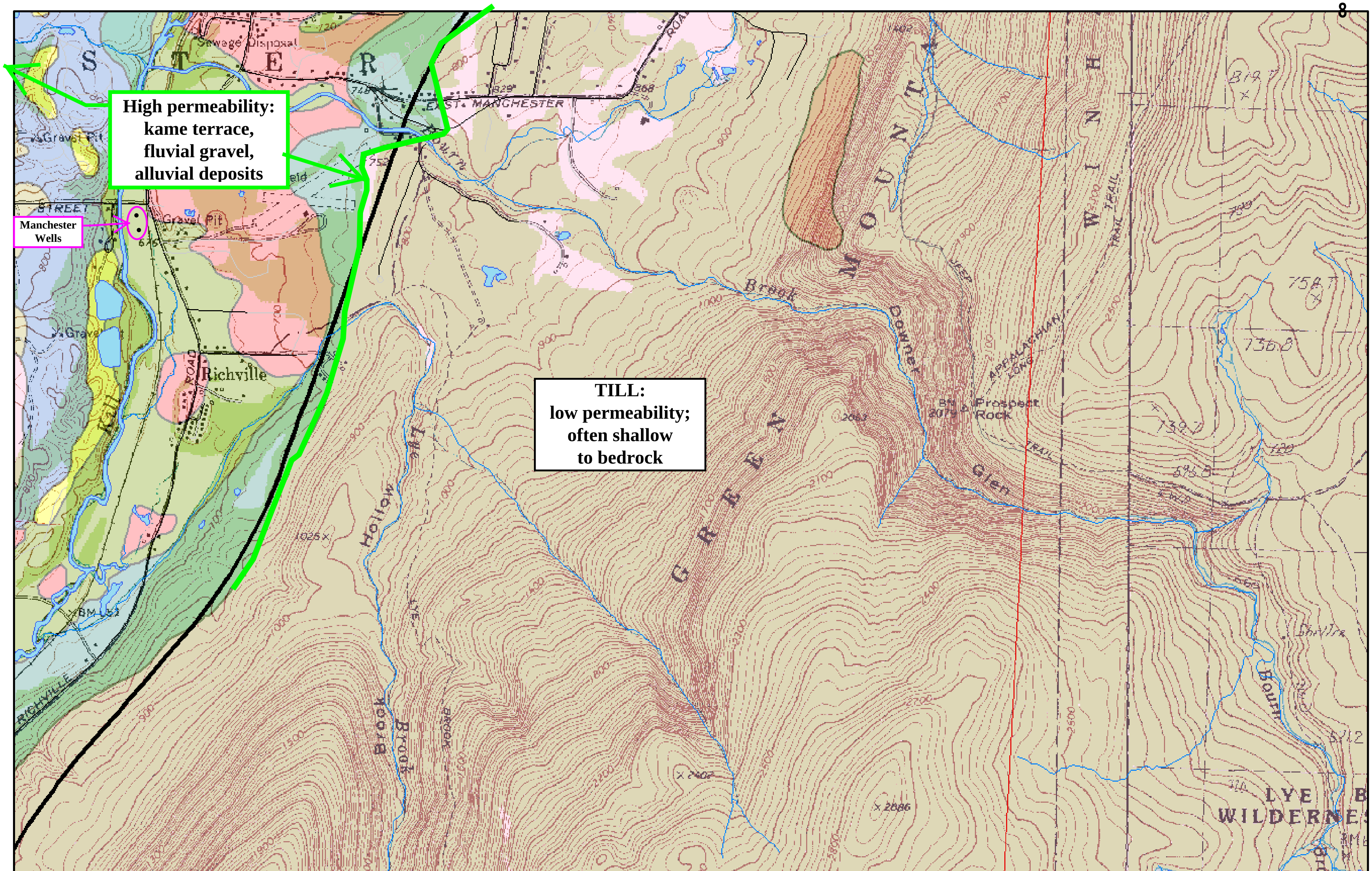


Figure 1: from *Draft Final Report on Static Level Measurements, Town of Manchester Well Aquifer.*
DeSimone, D.; Becker, L. VT Geological Survey.

Annotations in color: by Craig Heindel, C.P.G.
Waite-Heindel Envir. Mgmt. 5/2022.



Surficial Geology near Manchester Wells

0 1,000 2,000 Feet
1 inch = 2,000 feet

WAITE HEINDEL
Environmental Management

May 19, 2022
Map produced by: C. Heindel.
U: Manchester SPA.

DRAFT FINAL REPORT ON STATIC LEVEL MEASUREMENTS IN THE MANCHESTER TOWN WELL AQUIFER

April 14, 2006

By

David J. De Simone

Laurence R. Becker

Vermont Geological Survey
VT Department of Environmental Conservation

EXECUTIVE SUMMARY

* Two distinct but hydraulically connected aquifers exist beneath the Town well region. A deeper bedrock aquifer represents a confined aquifer overall but is not locally confined in the area of the 2 Town wells and 2 wells drilled in 2005. The overlying aquifer is a thick, high yielding unconfined aquifer developed in an interbedded sequence of glaciofluvial gravel and sand overlain by Batten Kill gravel. The thickness of the unconfined aquifer varies due to the sediment thickness variation that is a consequence of infilling a bedrock channel with glacial melt water deposits and their later erosion and terracing by the Batten Kill during post-glacial time.

* The absence of an impermeable confining layer of till or silt-clay demonstrates that there is no hydraulic barrier between the bedrock aquifer and the overlying aquifer. The bedrock aquifer maintains a higher static level than the overburden aquifer under all conditions measured to date. This demonstrates that the direction of water movement between the 2 aquifers is upward from the bedrock aquifer into the overburden aquifer. The amount of this recharge is problematic as too little is known about this hydraulic connection between the bedrock and overburden aquifers.

* The water table surrounding the pumping Town well experiences drawdown during pumping and the cone of depression appears to stabilize by the end of a period of pumping. Immediately after pumping ends, the cone of depression begins to fill in and the water table is fully restored to non-pumping or pre-pumping conditions within a few hours of pumping cessation. The cone of depression is asymmetrical and typical of those theorized and modeled for a pumping well near a stream. The ground water flowlines oriented toward the well during pumping come primarily from the area east and east-northeast of the Town well.

* There is no drawdown in wells west of the Batten Kill suggesting there is no hydraulic connection across the hydraulic boundary represented by the Batten Kill as originally hypothesized.

* The water table fluctuates with precipitation events and its level mimics the level of the Batten Kill. During dry conditions, the water table is approximately 1.9ft lower than during wet conditions. The wet conditions result in a water table which varies from 2.9-4.2ft below the ground surface in the vicinity of the Town well and averages 3.5ft below the ground surface in this area. These wet conditions exist for moderate to high rain events but only slightly lower water table elevations exist during wet conditions caused by moderate rain events.

* The extent of leakage from the bed of the Batten Kill to the Town well during pumping is unknown. We still need data on the fluctuations of the water table during extremely dry conditions accompanied by pumping to assess whether the Batten Kill transitions from a gaining stream to a losing stream in this reach.

CONTENTS

INTRODUCTION & PURPOSE

The impetus for the VGS proposal to investigate the Town's water supply aquifer came as an outgrowth of an earlier investigation into Manchester's geology conducted by De Simone (2003) as a contractor to the Vermont Geological Survey. De Simone studied the surficial geology and hydrogeology of Manchester, producing a technical report, a non-technical report or users manual, and a set of GIS registered map layers. These maps depict the surficial geology, the bedrock lithology, the depth to bedrock, the overburden thickness, the configuration of the water table, the configuration of the piezometric surface, the recharge potential to the carbonate aquifer, and the recharge potential to the overburden aquifer. Additional maps were generated to show details of the area's glacial geology and glacial geologic history. The water table and piezometric surface maps were strikingly similar and suggested the overburden aquifer and bedrock aquifer were not hydraulically isolated from each other. The water table map also depicted a steep hydraulic gradient on the west side of the Batten Kill west and northwest of the Town's well. This raised the possibility that a strong hydraulic gradient might enable ground water flow beneath the Batten Kill and to the Town's well during pumping. Although this would be an unexpected occurrence, it warranted further research based upon the unknowns in the nature of ground water flow under certain conditions discussed below.

MODFLOW is the most widely used ground water flow model and it continues to undergo changes as investigators learn more about the true nature of ground water flow. Currently, there are uncertainties in our understanding of ground water flow near a stream related to many parameters including the thickness of the unconfined aquifer, anisotropy in the aquifer, permeability of the stream bed, hydraulic head in the aquifer, the presence of a pumping well near the stream, and the nature of hydraulic flow across a boundary as represented by a stream (Butler et al, 2001, Chen and Yin, 1998, Darama, 2005, Kontis et al, 2005, Lange, 1991, Lillys et al, 2005, Matteo and Dragon, 2005, Ndambuki et al, 2000, Nyholm et al, 2002) . The geology of the Manchester Town well aquifer posed uncertainties in the nature of ground water flow under pumping conditions such as the effect of pumping on the nearby Batten Kill, the possibility of flow across the hydraulic boundary represented by the Batten Kill, the role of the steep hydraulic gradient and high hydraulic head west of the Batten Kill, and the role of the anisotropic nature of the aquifer (Todd, 1980, David and De Wiest, 1966). These uncertainties resulted in questions as to whether the high hydraulic head and steep gradient west of the Batten Kill might drive horizontal flow in the anisotropic unconfined aquifer beneath the Batten Kill, across the hydraulic boundary of the Batten Kill, and toward the Town well during pumping.

These questions and uncertainties prompted the VGS proposal to investigate ground water flow on both sides of the Batten Kill during pumping and non-pumping conditions of the Town well. The Town of Manchester secured a grant and agreed with the Vermont Geological Survey to undertake a study of the Town's water supply aquifer.

METHOD

The VGS proposed drilling 2 observation wells on the west side of the Batten Kill in order to monitor static level changes in these wells during pumping and non-pumping conditions of the Town well. The existing observation well network on both sides of the Batten Kill would also be monitored in order to maximize data and enable more complete understanding of ground water flow near the Town well and Batten Kill during pumping and non-pumping conditions. Additionally, a staff gauge would be installed on the Batten Kill at the nearby Union Street Bridge in order to integrate water level measurements with surface water level of the Batten Kill. This would enable understanding of water table changes in the unconfined aquifer as a consequence of precipitation and seasonal variables.

Finally, it was decided that one of the two new wells on the west side of the Batten Kill would be a bedrock well in order to investigate any possible hydraulic connection between the underlying confined bedrock aquifer and the overlying unconfined overburden aquifer. The known nature of the overburden stratigraphy suggested the possibility that the bedrock and overburden aquifers may not be hydraulically isolated. This derived from De Simone's (2003) previous investigation in which the existing water well logs failed to show the presence of a persistent layer of impermeable till atop bedrock in the Batten Kill valley. Also, the stratigraphy of the Town wells #1 and #2 showed no till layer beneath the gravel and sand of the unconfined aquifer.

The procedure would be to drill the 2 new wells, install the Batten Kill staff gauge, and then make static level measurements of these new wells and selected existing observation wells during pumping and non-pumping conditions.

WELL DRILLING & BATTEN KILL GAUGE INSTALLATION

Drilling of two water wells began on Wednesday, 6 July, 2005 and was completed on Friday, 8 July 2005. In addition, a staff gauge was installed on the Batten Kill at the Union Street Bridge during this time.

<u>Staff gauge installation:</u> A staff gauge composed of two 4-ft sections of pressure treated 1" x 4" board was installed using construction adhesive on the eastern abutment of the Union Street crossing of the Batten Kill on 6 July 2005. The gauge was set using a "0" elevation to be the bottom of the concrete abutment at the contact with the stream bottom. A drawback of this placement is that the water level may frequently be lower than the bottom of the gauge and require estimates of the Batten Kill level. However, the opposite abutment of the Union Street Bridge does not afford easy access to read the level on a gauge and installation on this opposite abutment would have been difficult. The gauge is divided into 0.1" increments along its length of 8ft. Increments were routed into the gauge lumber and highlighted with a waterproof marker. Gauge measurements are

currently being made whenever observation water well levels are measured, approximately once weekly or as precipitation and season dictate.
Water well drilling and completion: Mr. David Girard of 73 Battenkill Lane gave VGS permission to drill 2 new water wells on his lands near the Batten Kill on the west side of the stream along Battenkill Lane. Dave Girard also allowed VGS continued and routine access to his lands to observe the level of water in the 2 new wells and in the old observation well located off the corner of his barn.

The drilling method used a concentric rotary technique which advanced casing into the well bore as drilling continued. The casing was advanced into bedrock 25ft in an attempt to ensure a proper seal between the tightly fitting casing and the bedrock.

Frost Well Drilling of Dorset, VT, began drilling the first of 2 wells on 6 July, 2005. Both wells were drilled along Battenkill Lane near the Batten Kill and approximately opposite the Town water supply well #1.

Well 2005-1, Tag #30254, was drilled approximately 55 ft into overburden composed of mixed gravel and sand comparable to that described below for the overburden well. An additional 205 ft was drilled into bedrock composed of gray and white carbonate rock. At a depth of 135ft, we encountered a fracture with minor water. At 240-245ft, we encountered iron-stained white marble with fractures yielding approximately 5GPM Drilling to a final depth of 260ft penetrated iron-stained light red marble with a total yield of approximately 7GPM. The driller's log for this well can be found in the Appendix to this report. High hydraulic pressure in the overburden aquifer was encountered with flow rates exceeding 100GPM. Despite our advancing casing 25 feet into bedrock, the overburden aquifer continued to push water around the end of the casing and into the well bore. This well was subsequently isolated from the overburden aquifer by means of a sleeve inserted into the well bore. The sleeve consists of a section of PVC pipe with a lower rubber seal inserted into the well bore. Bentonite seal material was packed into the space between the PVC sleeve and the steel casing. The sleeve was lowered into the well bore until the top could be capped with a rubber seal. The sleeve was then driven to bracket the end of the steel casing. Leakage of water from the overburden aquifer around the end of the steel casing caused the Bentonite seal material to swell and block off further leakage. The Bentonite and rubber end caps on the sleeve have effectively isolated the bedrock well from the overburden aquifer as evidenced by the static level in the bedrock well being consistently above the static level in the adjacent overburden well.

Well 2005-2, Tag#30255, was drilled 55 ft into the same mixed gravel and sand overburden material on Thursday, 7 July. Casing was backed off approximately 1 ft and the yield is greater than 100 GPM. The driller's log for this well can be found in the Appendix to this report. Details of the VGS log are as follows:
*0-22ft, pebble gravel and coarse to very coarse sand with predominantly carbonate clasts; more matrix in the upper 10ft and clasts with little matrix in the lower 12ft; a little water; interpreted to be Batten Kill fluvial deposits.
*22-34ft, medium sand with minor coarse and fine sand and pebble gravel; water at approximately 5GPM; glaciofluvial outwash sediment.

*34-46ft, yellowish red to yellowish brown "heaving" fine to medium sand with abundant water; ice contact glaciofluvial deposits.
*46-50ft, compact pebble gravel with medium to coarse sand; kame moraine diamicton.
*50-55ft, light yellowish brown to yellowish brown very coarse sand with pebble gravel; water pressure at 68PSI and estimated flow at >100GPM; basal ice contact deposits.
*55ft, refusal; limestone bedrock.

The site was cleaned up on Friday, 8 July 2005. The drill cuttings were spread evenly, brush was cleared away from the landowner's lawn, the area was raked smooth, and hay was spread to facilitate recovery of disturbed lawn grass and regrowth of vegetation in the brushy area adjacent to the Batten Kill. Hay bales were used during drilling to minimize influx of drill cuttings into the Batten Kill. No sediment was observed to enter the Batten Kill during drilling operations or after drilling was completed.

WELL MEASUREMENTS

Ten wells were selected and levels are currently being measured along with the level of the Batten Kill:

OW-B	OW-19	OW-5	OW-6
2005-1	OW-18	OW-17	
2005-2	OW-20	OW-16	

All of the observation wells surround Town Well #1 on the east side of the Batten Kill except for wells OW-B, 2005-1 and 2005-2 which are on the west side of the Batten Kill.

Well levels are being measured approximately once weekly or to take advantage of precipitation events and seasonal changes. Wells are usually measured twice over a span of approximately 1-3 hours. Wells have been measured at times of maximum pumping and at times when pumping has ceased, thus allowing measurement of recovery of the water table after a period of pumping. All of the well measurement data are provided in the Appendix of this report. To date, the 10 selected wells were each measured 28 times.

Well measurements have occurred during normal summer weather conditions with typically dry weather as evidenced by the low level of the Batten Kill. A major and lengthy period of rainfall occurred prior to the 17 November measurements and significantly raised the Batten Kill and the water table. So, there are some data related to wet conditions occurring after foliage is gone from the trees. The winter season was an especially mild one and the Batten Kill did not freeze over at any time. There were no major snow storms and no persistent snow cover during the season. Rather, there were numerous rain events similar to the one which preceded the 17 November measurements. Consequently, there was no spring snowpack melting event accompanied by a spring rain event to bring the Batten Kill up to an anticipated spring high water or flood condition. Therefore, there are no data on how high the water table may rise as a result of a major rain event which would cause the Batten Kill to rise toward or above bank full conditions.

Range of error of measurements: The water level meter represents the largest source of error in these data. The tape on the water level meter had only markings every 1.0ft. Markers at 0.1ft were placed at intervals along the tape. Familiarization with this 0.1ft increment enabled measurements within +/-0.05ft. Later measurements were made using temperature and traditional plunking due to failure of the conductivity sensor. The range of error for this substitute method was assigned to be +/- 0.1ft, double the +/- 0.05ft range of error for measurements made using the conductivity sensor. Measurements were repeated in the field to arrive at the value recorded in the data table in the Appendix. Precision and accuracy would improve by using another water level meter with finer marking increments. Nevertheless, the value of these data are in their comparisons rather than in the absolute value of each measurement. Since all measurements were made using the same device, there is internal consistency in the dataset.

DATA ANALYSIS

The full dataset in the Appendix has been analyzed and it was determined this report would focus on those data which provided the most insight to answer the objectives of this study as posed in the Introduction.

Drawdown during pumping: The data reveal drawdown produces a cone of depression around the pumping well and indicates rapid recovery of this drawdown within a few hours of cessation of pumping. Drawdown was evident on 27 July, 10 August and 17 November. No drawdown was observed in wells on the west side of the Batten Kill on these days. Pump on & off times are shown in the Appendix. The 17 November 2005 morning measurement data show the most drawdown and serve as the basis for Figure 1.

Figure 1 shows the contour of the water table at 11:00AM on 17 November 2005 with the pump on for approximately 2 hours. The static levels measured at each of the wells were subtracted from the elevation of the top of casing for each well. Elevations for the top of casing for OW-19, 2005-1 and 2005-2 are not known at this time and are excluded from the figure. The water table configuration is shown on Figure 1 using a 1.0ft contour interval with additional contours at 669.8ft and 669.6ft shown to illustrate the shape of the cone of depression around the pumping well. The contours are labeled with elevations in feet above mean sea level. Wells are represented by dots and the corresponding well number is printed adjacent to the well. Flowlines with arrows were added and cross the water table contours at right angles. These flowlines depict the path of ground water movement in the vicinity of the pumping well. This cone of depression around a pumping well near a stream is consistent with theoretical models of similar situations modeled by the EPA (1987) and mathematically derived many decades earlier (Davis & De Wiest, 1966). Flow paths to the pumping well come primarily from the east through east-northeast sector surrounding the well. Flowlines from OW-14, OW-6 and OW-19 north of the pumping well are not turned to the well. Similarly, flowlines from OW-A, OW-16 and OW-5 are oriented away from the pumping well. Flowlines oriented to the pumping well come from the area between OW-6 and OW-16. Flowlines west of the pumping well are oriented west toward the Batten Kill. However, the slope of the water table west of the Town well is very nearly flat and the ground water divide indicated at the approximate location of OB-18 is shallow. The range of error of our measurements indicates this is a tentative conclusion as a change of +/- 0.05ft in elevation of the water table at either OB-18 or OB-20 to the west would flatten or possibly reverse the slope of the water table west of the Town well. A flattened water table between the Town well and the Batten Kill would still necessitate a ground water divide as there are no data to suggest the slope of the water table reverses and the Batten Kill becomes a losing stream during pumping of the Town well. Additional measurements may contribute to a better understanding of the water table profile during pumping conditions and at times of extremely low water table elevation.

Recovery of the water table after pumping subsides: Measurements reported in Table I reveal significant recovery in the wells east of the Batten Kill but show no consistent water level change in wells west of the Batten Kill.

Table I: Recovery Data for Paired Measurements Made With Pump Off Reveal No Recovery in Wells 2005-1 and 2005-2 Compared To Average Recovery in All Wells on East Side of Batten Kill

Date	Ave Recovery	Well 2005-1 Recovery	Well 2005-2 Recovery
18 August	0.15ft	0.00ft	0.00ft
7 September	0.10	0.10	0.05
20 September	0.06	0.05	0.05
28 September	0.04	0.20	0.10
11 October	0.06	0.00	0.00
16 February	0.10*	0.00*	0.30*

**Measurements made with non-working conductivity sensor have larger +/-0.1ft error.*

These data reveal that recovery over the span of time measured is small but consistent even though the amount of average recovery is not significant in wells east of the Batten Kill. Bedrock well 2005-1 does not show any consistent trend toward recovery along with the observed wells east of the Batten Kill. These and additional measurements of 2005-1 indicate that drawdown does not occur with this well. Similarly, overburden well 2005-2 does not show a consistent trend toward recovery. These and additional measurements of 2005-2 indicate that drawdown does not occur with this well.

Recovery on these and other dates appears to be rapid. On days when the pump turned off prior to measurement, a small amount of recovery was measured within 1 hour of pump cessation. On 17 November 2005, the maximum amount of recovery was observed and the equipotentials and flowlines for these data reveal a water table which has completely recovered as shown in Figure 2.

Figure 2 depicts the recovered configuration of the water table at the time of the second set of measurements made on 17 November 2005 with the pump off approximately 2.5 hours. The contour of the water table is smoother and lacks the cone of depression seen in Figure 1. The non-pumping condition is typical of a simple water table beneath nearly flat terrain and adjacent to a stream. Flowlines on Figure 2 are straight, sub-parallel to the Batten Kill, and curve only as they merge with the Batten Kill. There is no deflection of ground water flow toward a pumping well once the pump is off and recovery is complete.

Figure 3 depicts the total water level change observed between the 2 measurements made on 17 November 2005. Contours are at +0.5ft of water level change. The pattern of Figure 3 is consistent with classical recovery around a well located near a stream (Davis & De Wiest, 1966, Todd, 1980). Remember, however, that the total amount of recovery and shape of the contours of this figure will vary as a function of the range of error of our measurements.

DISCUSSION

The pattern of recovery around the Town well: Table II depicts the data for day of maximum recovery recorded on 17 November 2005.

Table II: Recovery Values and Average Recovery of All Wells Surrounding the Town Well On 17 November

Well #	OW-19	OW-18	OW-20	OW-5	OW-17	OW-16	OW-6	Ave
Recovery (ft)	0.7	1.0	1.3	1.0	1.5	0.1	0.5	0.9

All wells on the east side of the Batten Kill experienced recovery as recorded in the second set of measurements. All 3 wells on the west side of the Batten Kill essentially showed no change in static level on this day. The observation wells surrounding the Town well showed highly varying amounts of recovery between the measurements as shown on Table II.

The 2 wells which are both easternmost and farthest from the pumping well, OW-16 and OW-6, recovered the least amounts. The amounts of recovery are greater than for any other set of measurements but also the pattern of recovery is illuminating. OW-18 is closest to the pumping well but did not recover as much as OW-20 and OW-17 which are equidistant to the west and east, respectively, of the pumping well.

This pattern of recovery is consistent with the location of the pumping well near a stream. All wells on the east side of the Batten Kill experienced drawdown but the cone of depression is not symmetric due to the setting near a stream. Shallow ground water flow is maintained away from the pumping well between the pumping well and the stream except for the area very close on the west of the pumping well. Assuming this is true even after considering the range of error of measurements, then, it would be valid to state that pumping establishes a cone of depression around the pumping well as shown in Figure 1. This cone of depression establishes a temporary ground water divide west of the pumping well approximately at the location of OB-18. This ground water divide is established because *both* the pumping Town well and the Batten Kill are sites of ground water discharge. The cone of depression about the Town well is exactly as predicted by theory using an image well placed an equal distance from the Batten Kill and on the opposite side of the stream as the Town well (Davis & De Wiest, 1966).

The interaction of the pumping well, the Batten Kill, and the area west of the Batten Kill: **Figure 4** depicts the same data from 17 November 2005 shown in Figures 1 and 2 as cross sections. The upper cross section on Figure 4 depicts the simple configuration of the water table and flowlines when the pump has been turned off and recovery is complete.

The drawdown and cone of depression data are shown in the lower cross section with schematic ground water flowlines drawn in to highlight the directions of ground water flow. Note the asymmetry in the cone of depression with a very steep western slope and much broader and gentler eastern slope. Flow to the well comes primarily from the east. Shallow contribution to the pumping well from the west is minimal. As stated in the analysis above, this conclusion infers the range of error of measurements would not result in a flattened or reversed slope of the water table in the area between the Town well and the Batten Kill. Deeper ground water flow coming from leakage through the bed of the Batten Kill is shown and thought to exist but there are no data to support this conclusion.

Flowlines shown on Figure 4 are necessarily schematic. In the upper cross section, these flowlines are probably a fairly true representation of ground water flow during non-pumping conditions. Ground water follows flow paths that discharge the ground water into the Batten Kill, a typical gaining stream in this reach whose base flow is recharged by ground water from an unconfined overburden aquifer. The slope of the water table toward the Batten Kill demonstrates the Batten Kill is a gaining stream here.

Flowlines in the lower cross section of Figure 4 are highly schematic and meant to show that shallow ground water flows both toward the Batten Kill and the pumping well from the temporary divide area between those 2 discharge sites. The Town well is screened only for the bottom 20ft, a condition represented on Figure 4. Deeper ground water flow possibly comes to the well from the area beneath the Batten Kill. We show dashed flow paths to illustrate the possible leakage of water from the bed of the Batten Kill during pumping. Further measurements when the water table is low because of dry conditions and pumping occurs might show a flattening of the water table or even a reversal of the water table from the Batten Kill towards the pumping well. If this reversal occurs, it would indicate that this reach of the Batten Kill can be either a gaining stream or a losing stream depending upon a combination of both seasonal and pumping conditions.

The depth to bedrock to bedrock shown on the lower cross section depicts the slope of the buried pre-glacial Batten Kill channel. There is no attempt to display the overburden stratigraphy. However, it is known that the overburden is composed of an anisotropic interlayered sequence of gravel and sand with well sorted sands at approximately 34-55ft bearing the highest yield of ground water. In our original hypothesis, during pumping, ground water *might* have followed a path beneath the Batten Kill *if* the steep hydraulic gradient and higher head west of the Batten Kill combined with possible heightened horizontal flow along the high ground water flow layers in the overburden (34-55ft in well 2005-1) drove water across the hydraulic boundary represented by the Batten Kill

and enabled recharge to the pumping well from *west* of the Batten Kill. The data collected indicate this is *not* the condition at the Town well during pumping.
The Batten Kill *is* an effective divide and sink for discharge of ground water flowing toward the stream from both sides. Thus, there is no hydraulic connection between the portion of the gravel aquifer west of the Batten Kill and its larger portion east of the Batten Kill. Pumping only affects the water table east of the Batten Kill resulting in a cone of depression like the one shown on Figure 1 and in cross section on Figure 4.

Meteorological impacts on the water table: Comparison of the static levels on 18 August and 17 November also demonstrates the variability of the water table as a function of wet or dry conditions, including significant precipitation events. The second set of measurements of 18 August can be compared to the second set of measurements of 17 November. Both readings were made several hours after pumping stopped but at very different levels of the Batten Kill. The 18 August readings were made at the Batten Kill's lowest level of -1.5ft while the 17 November readings were made at the Batten Kill's highest level of +1.2-1.3ft. The 18 August level of the Batten Kill has an assigned range of error of 0.2ft due to the water being away from and below the bottom of the staff gauge. There had been an extended dry period prior to the 18 August readings while there was a substantial precipitation event prior to the 17 November readings. In addition, the 17 November rainfall came at a time when there were no leaves and vegetative growth was at a minimum. Table III shows the static levels and their differences on 18 August and 17 November.

Table III: Static Levels of 18 August And 17 November Show a Wide Range And Reflect Dry versus Wet Conditions

Well #	OW-B	2005-1	2005-2	OW-19	OW-18	OW-20	OW-5	OW-17	OW-16	OW-6
18 August	10.1	9.35	12.7	8.6	6.9	7.9	7.6	7.2	6.45	9.55
17 November	8.2	2.05	10.85	6.7	5.05	6.1	5.7	5.3	4.4	7.5
Difference	1.9	7.2	1.85	1.9	1.85	1.8	1.9	1.9	2.05	2.05

The water table in the overburden aquifer during moderately wet conditions is approximately 1.9ft higher than during the dry summer conditions The Batten Kill level difference on these dates was 2.7ft as measured on the staff gauge. The level of the Batten Kill fluctuates more than the water table because the Batten Kill receives runoff during wet conditions and its level rises more than the water table during and after precipitation events.

One consequence of the higher water table during wet conditions is that the water table is considerably closer to the ground surface during wet times than previous data revealed. The data for the second set of measurements on 17 November can be used to quantify the high water table and its nearness to the ground surface beneath the terrace where the observation wells and the Town well are located. Table IV shows these data.

Table IV: The High Water Table of 17 November Brings the Top of the Zone of Saturation Close to the Ground Surface.

Well #	OW-19	OW-18	OW-20	OW-5	OW-17	OW-16	OW-6
Static Level	6.7	5.1	6.1	5.7	5.3	4.4	7.5
Casing Height (approx.)	2.5	2.0	2.0	2.5	2.0	1.5	3.5
Depth to Water Table	4.2	3.1	4.1	3.2	3.3	2.9	4.0

The depth to the water table from the ground surface in the above 7 wells is 3.5ft with a range from 2.9 – 4.2ft. This represents a precipitation driven high water table. However, values were nearly as high on 11 October, 6 February and 16 February and this suggests that more moderate runoff from medium precipitation events which occur at least during the fall and winter seasons can produce a high water table within 4ft of the ground surface. So, the occurrence of a high water table is not limited to infrequent moderately large to large precipitation events. It remains to be seen whether other occurrences of a high water table will happen with spring rain events.

Trends in static level in the bedrock aquifer: The piezometric surface is a surface of zero pressure or hydraulic head and represents the static level that water will rise to in a well tapping a confined aquifer. Bedrock well 2005-1 was successfully isolated from the unconfined or overburden aquifer by sealing methods described earlier. This is demonstrated by the persistently different static levels in the adjacent wells 2005-1 and 2005-2, the latter tapping the unconfined gravel and sand overburden aquifer. In ALL measurements to date, the static level in the bedrock well was above the static level in the gravel and sand well. Furthermore, the static levels in these 2 wells do not follow the same trends. The gravel and sand well, 2005-2, follows a trend similar to the other observation wells which tap the unconfined aquifer. Its level fluctuates with precipitation events but does not fluctuate with pumping of the Town well on the other side of the Batten Kill.

In contrast, the static level in bedrock well 2005-1 appears to show a long term trend toward a higher level in the 2005 fall and 2006 winter seasons. Through the winter season, the static level in the bedrock aquifer fluctuated slightly but maintained a high level. In fact, for most of the fall and winter measurements, the bedrock well static level was near or above the ground surface. The surface of the water was iced over during the colder periods of the winter. The bedrock well static level ranged from 1.6 – 3.8ft below the top of casing during the wet fall and winter season from October through March.

During the dry summer season, the bedrock well static level was lower and fluctuated more than the overlying overburden aquifer static level. Static level in the bedrock well during the dry season from July through September ranged from 6.8 – 11.3ft below the top of casing. . The piezometric surface in the bedrock aquifer is 7.2ft higher during wet conditions than during dry conditions as shown in Table III above.

Ground water movement between the bedrock and overburden aquifers: The persistently higher static level of the bedrock aquifer versus the overburden aquifer indicates the direction of water movement is FROM the bedrock aquifer TO the overburden aquifer. Thus, if there is water movement from one aquifer to the other it is UPWARD and the BEDROCK AQUIFER RECHARGES THE OVERBURDEN AQUIFER.

This assumes a hydraulic connection exists between the 2 aquifers. The stratigraphy of the overburden answers this question. In the logs of the Town wells and the 2 new wells drilled in 2005, there was no thick impermeable confining layer of till or lacustrine silt-clay encountered during drilling. Both Town wells penetrated nearly 100ft of interbedded glaciofluvial gravel and sand and reached bedrock without encountering any till or silt-clay layers. Wells 2005-1 and 2005-2 penetrated approximately 55ft of interbedded glaciofluvial gravel and sand without encountering till or silt-clay. Depth to bedrock was less than across the stream where the Town wells were drilled because of the slope of a buried bedrock channel of the Batten Kill. Consequently, these 4 wells indicate that there is no impermeable layer separating the bedrock aquifer from the immediately adjacent and overlying overburden aquifer in the vicinity of the Town wells.

CONCLUSIONS

* Two distinct but hydraulically connected aquifers exist beneath the Town well region. A deeper bedrock aquifer represents a confined aquifer overall but is not locally confined in the area of the 2 Town wells and 2 wells drilled in 2005. The overlying aquifer is a thick, high yielding unconfined aquifer developed in an interbedded sequence of glaciofluvial gravel and sand overlain by Batten Kill gravel. The thickness of the unconfined aquifer varies due to the sediment thickness variation that is a consequence of infilling a bedrock channel with glacial melt water deposits and their later erosion and terracing by the Batten Kill during post-glacial time.

* The absence of an impermeable confining layer of till or silt-clay demonstrates that there is no hydraulic barrier between the bedrock aquifer and the overlying aquifer. The bedrock aquifer maintains a higher static level than the overburden aquifer under all conditions measured to date. This demonstrates that the direction of water movement between the 2 aquifers is upward from the bedrock aquifer into the overburden aquifer. The amount of this recharge is problematic as too little is known about this hydraulic connection between the bedrock and overburden aquifers.

* The water table surrounding the pumping Town well experiences drawdown during pumping and the cone of depression appears to stabilize by the end of a period of pumping. Immediately after pumping ends, the cone of depression begins to fill in and the water table is fully restored to non-pumping or pre-pumping conditions within a few hours of pumping cessation. The cone of depression is asymmetrical and typical of those theorized and modeled for a pumping well near a stream. The ground water flowlines

oriented toward the well during pumping come primarily from the area east and east-northeast of the Town well.

* There is no drawdown in wells west of the Batten Kill suggesting there is no hydraulic connection across the hydraulic boundary represented by the Batten Kill as originally hypothesized.

* The water table fluctuates with precipitation events and its level mimics the level of the Batten Kill. During dry conditions, the water table is approximately 1.9ft lower than during wet conditions. The wet conditions result in a water table which varies from 2.9-4.2ft below the ground surface in the vicinity of the Town well and averages 3.5ft below the ground surface in this area. These wet conditions exist for moderate to high rain events but only slightly lower water table elevations exist during wet conditions caused by moderate rain events.

* The extent of leakage from the bed of the Batten Kill to the Town well during pumping is unknown. We still need data on the fluctuations of the water table during extremely dry conditions accompanied by pumping to assess whether the Batten Kill transitions from a gaining stream to a losing stream in this reach.

RECOMMENDATIONS

The nature and extent of the hydraulic connection between the bedrock and overburden aquifers might be studied by dye or tracer testing. Installation of a stream gauging station along the Batten Kill, perhaps at the Union Street Bridge, would add data on Batten Kill flow and enable quantification of ground water contribution to Batten Kill flow during low flow conditions. Continuous monitoring of water table fluctuations with pumping and with precipitation events might be accomplished by installation of transducers in several of the observation wells. A survey to determine the elevation of the top of casing for wells 2005-1 and 2005-2 would enable determination of water table elevation at these wells. Installation of a weather monitoring station, perhaps on the grounds of the Town well near the pump house, would enable collection of precipitation, temperature, barometric pressure, wind speed and direction, and possibly solar data. These data would prove useful in long term monitoring of the link between meteorological events and ground water conditions. Long term monitoring of hydrological and meteorological conditions at the site of the Town of Manchester public water supply well would provide valuable data on the inter-relationships impacting this high yield glacial aquifer.

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APPENDIX

WELL #	OW-B	2005-1	2005-2	OW-19	OW-18	OW-20	OW-5	OW-17	OW-16	OW-6	GAUGE
DATE	15-Jul	15-Jul	15-Jul	15-Jul	15-Jul	15-Jul	15-Jul	15-Jul	15-Jul	15-Jul	
TIME	PM 3:15										
STATIC LEVEL	9.25	7	11.85	8	6.35			6.4			
CONDUCTIVITY	0.48	0.248	0.42	0.225	0.28			0.248			
COMMENTS											0.5
DATE	20-Jul-05										
TIME	2:15 PM	2:25 PM	2:25 PM	2:35 PM	2:40 PM	2:42 PM		2:46 PM	2:50 PM	2:55 PM	
STATIC LEVEL	9.4	8.1	12	9	7.7	9		8.5	6	9.75	
CONDUCTIVITY	0.44	0.242	0.405	0.225	0.3	0.156		0.253	0.119	0.405	
COMMENTS											0.25
DATE	27-Jul										
TIME	2:00 PM	2:25 PM	2:25 PM	2:35 PM	2:39 PM	2:43 PM		2:46 PM	2:49 PM	2:54 PM	
STATIC LEVEL	9.75	10.2	12.2	9.25	7.85	9.2		8.7	6.3	9.9	
CONDUCTIVITY	0.5	0.246	0.389	0.227	0.298	0.152		0.245	0.115	0.41	
COMMENTS	< T-Storm	> T-Storm									0.2
DATE	27-Jul										
TIME	3:27 PM	3:29 PM	3:32 PM	3:35 PM	3:39 PM	3:42 PM		3:44 PM	3:47 PM	3:49 PM	
STATIC LEVEL	9.9	10.2	12.2	9.25	7.9	9.2		8.7	6.2	9.95	
CONDUCTIVITY	0.551	0.249	0.389	0.228	0.309	0.155		0.246	0.118	0.421	
COMMENTS											0.2
WELL #	OW-B	2005-1	2005-2	OW-19	OW-18	OW-20	OW-5	OW-17	OW-16	OW-6	GAUGE
DATE	3-Aug										
TIME	1:58 PM	2:05 PM	2:07 PM	2:17 PM	2:20 PM	2:22 PM	2:26 PM	2:29 PM	2:31 PM	2:36 PM	
STATIC LEVEL	9.85	10.9	12.3	9.4	8	9.3	8.6	8.7	6.4	9.9	
CONDUCTIVITY	0.531	0.248	0.382	0.227	0.308	0.15	0.108	0.244	0.115	0.415	
COMMENTS											-0.25
DATE	3-Aug										
TIME	3:44 PM	3:48 PM	3:50 PM	3:55 PM	3:55 PM	3:58 PM	4:02 PM	4:05 PM	4:08 PM	4:11 PM	
STATIC LEVEL	9.9	10.8	12.3	9.3	8.05	9.3	8.4	8.75	6.3	10	
CONDUCTIVITY	0.572	0.246	0.384	0.227	0.316	0.155	0.109	0.244	0.118	0.42	
COMMENTS											-0.25
DATE	10-Aug										
TIME	3:33 PM	3:38 PM	3:41 PM	3:47 PM	3:51 PM	3:53 PM	3:56 PM	3:59 PM	4:01 PM	4:06 PM	
STATIC LEVEL	10.1	11.3	12.7	9.6	8.2	9.6	8.7	8.9	6.7	10.2	
CONDUCTIVITY	0.525	0.253	0.38	0.225	0.31	0.151	0.109	0.243	0.114	0.402	
COMMENTS	pump on										-0.25

DATE	10-Aug										
TIME	4:33 PM	4:37 PM	4:38 PM	4:43 PM	4:46 PM	4:48 PM	4:51 PM	4:53 PM	4:55 PM	4:59 PM	
STATIC LEVEL	10.1	11.25	12.75	9.65	8.25	9.5	8.7	8.95	6.7	10.2	
CONDUCTIVITY	0.572	0.296	0.382	0.227	0.32	0.153	0.11	0.245	0.115	0.418	
COMMENTS	pump on										-0.25
WELL #	**OW-B**	**2005-1**	**2005-2**	**OW-19**	**OW-18**	**OW-20**	**OW-5**	**OW-17**	**OW-16**	**OW-6**	**GAUGE**
DATE	18-Aug										
TIME	3:57 PM	4:02 PM	4:05 PM	4:12 PM	4:14 PM	4:17 PM	4:20 PM	4:22 PM	4:25 PM	4:29 PM	
STATIC LEVEL	10.1	9.35	12.7	8.75	7.15	8.1	7.7	7.4	6.45	9.7	
CONDUCTIVITY	0.531	0.248	0.381	0.227	0.315	0.161	0.112	0.246	0.116	0.417	
COMMENTS	pump on										-1.5
DATE	18-Aug										
TIME	5:41 PM	5:45 PM	5:47 PM	5:55 PM	5:56 PM	5:58 PM	6:00 PM	6:02 PM	6:05 PM	6:07 PM	
STATIC LEVEL	10.1	9.35	12.7	8.6	6.9	7.9	7.6	7.2	6.45	9.55	
CONDUCTIVITY	0.558	0.247	0.383	0.229	0.317	0.164	0.113	0.246	0.117	0.422	
COMMENTS	pump off										-1.5
DATE	23-Aug										
TIME	2:40 PM	2:46 PM	2:48 PM	2:54 PM	2:57 PM	3:00 PM	3:02 PM	3:05 PM	3:08 PM	3:12 PM	
STATIC LEVEL	10.05	6.8	12.8	8.9	7.4	8.2	7.8	7.55	6.5	9.8	
CONDUCTIVITY	0.521	0.247	0.384	0.228	0.314	0.156	0.112	0.242	0.117	0.421	
COMMENTS	pump off										-0.2
DATE	7-Sep										
TIME	4:30 PM	4:35 PM	4:37 PM	4:43 PM	4:46 PM	4:48 PM	4:50 PM	4:52 PM	4:54 PM	4:58 PM	
STATIC LEVEL	10.05	10	12.55	8.7	6.9	7.9	7.55	7.2	6.4	9.45	
CONDUCTIVITY	0.255	0.246	0.376	0.226	0.306	0.163	0.113	0.24	0.119	.190*	
COMMENTS											-0.1
DATE	7-Sep										
TIME	5:47 PM	5:50 PM	5:52 PM	5:57 PM	6:00 PM	6:02 PM	6:05 PM	6:07 PM	6:09 PM	6:12 PM	
STATIC LEVEL	9.95	9.9	12.5	8.5	6.8	7.8	7.45	7.1	6.3	9.35	
CONDUCTIVITY	0.27	0.25	0.377	0.228	0.306	0.163	0.112	0.24	0.119	0.192	
COMMENTS											-0.1
WELL #	**OW-B**	**2005-1**	**2005-2**	**OW-19**	**OW-18**	**OW-20**	**OW-5**	**OW-17**	**OW-16**	**OW-6**	**GAUGE**
DATE	20-Sep										
TIME	4:45 PM	4:50 PM	4:53 PM	4:58 PM	5:02 PM	5:04 PM	5:06 PM	5:09 PM	5:11 PM	5:15 PM	
STATIC LEVEL	10.1	6.85	12.85	8.7	6.95	7.95	7.6	7.25	6.45	9.55	
CONDUCTIVITY	0.255	0.251	0.356	0.223	0.299	0.162	0.112	0.235	0.116	0.193	
COMMENTS	pump off										-0.1

DATE	20-Sep										
TIME	5:37 PM	5:42 PM	5:44 PM	5:51 PM	5:54 PM	5:56 PM	5:58 PM	6:00 PM	6:02 PM	6:06 PM	
STATIC LEVEL	10.05	6.8	12.8	8.6	6.85	7.9	7.5	7.2	6.45	9.5	
CONDUCTIVITY	0.269	0.248	0.369	0.22	0.296	0.16	0.112	0.23	0.116	0.197	
COMMENTS	pump off										-0.1
DATE	28-Sep										
TIME	3:05 PM	3:11 PM	3:24 PM	3:33 PM	3:36 PM	3:39 PM	3:42 PM	3:45 PM	3:48 PM	3:52 PM	
STATIC LEVEL	9.7	6.95	12.4	8.35	6.65	7.65	7.35	6.9	6.15	9.3	
CONDUCTIVITY	0.252	0.248	0.175	0.106	0.142	0.071	0.053	0.11	0.11	0.19	
COMMENTS	pump off										0.2
DATE	28-Sep										
TIME	4:05 PM	4:10 PM	4:14 PM	4:21 PM	4:25 PM	4:28 PM	4:33 PM	4:39 PM	4:44 PM	4:47 PM	
STATIC LEVEL	9.7	6.75	12.5	8.35	6.6	7.6	7.25	6.9	6.1	9.25	
CONDUCTIVITY	0.261	0.12	0.177	0.106	0.144	0.073	0.056	0.115	0.057	0.196	
COMMENTS	pump off										0.2
WELL #	OW-B	2005-1	2005-2	OW-19	OW-18	OW-20	OW-5	OW-17	OW-16	OW-6	GAUGE
DATE	11-Oct										3.3 prior
TIME	3:13 PM	3:18 PM	PM 3:21	3:25 PM	3:27 PM	3:29 PM	3:33 PM	3:35 PM	3:37 PM	3:40 PM	
STATIC LEVEL	8.4	3.8	9.8	6.8	5.25	6.35	5.9	5.5	4.4	7.55	
CONDUCTIVITY	0.173	0.119	0.165	0.104	0.138	0.064	0.05	0.106	0.053	0.181	
COMMENTS	pump off										0.8
DATE	11-Oct										
TIME	4:21 PM	4:25 PM	4:28 PM	4:31 PM	4:33 PM	4:34 PM	4:36 PM	4:38 PM	4:40 PM	4:42 PM	
STATIC LEVEL	8.4	3.8	9.8	6.7	5.2	6.3	5.85	5.4	4.35	7.55	
CONDUCTIVITY	0.176	0.118	0.163	0.104	0.138	0.064	0.049	0.106	0.053	0.181	
COMMENTS	pump off										0.8
DATE	17-Nov										1.5 prior
TIME	11:04 AM	11:08 AM	11:11 AM	11:18 AM	11:21 AM	11:23 AM	11:25 AM	11:28 AM	11:31 AM	11:34 AM	
STATIC LEVEL	8.1	2.1*	10.9	7.4	6.1	7.4	6.7	6.8	4.5	7.95	
CONDUCTIVITY	0.219	0.091	0.134	0.088	0.171	0.061	0.048	0.092	0.047	0.225	
COMMENTS	pump on	* ground									1.3
DATE	17-Nov										
TIME	4:03 PM	4:07 PM	4:09 PM	3:42 PM	3:45 PM	3:47 PM	3:49 PM	3:51 PM	3:53 PM	3:57 PM	
STATIC LEVEL	8.2	2.05*	10.85	6.7	5.05	6.1	5.7	5.3	4.4	7.5	
CONDUCTIVITY	0.23	0.098	0.14	0.091	0.174	0.062	0.05	0.093	0.049	0.22	
COMMENTS		*ground									1.2
WELL #	OW-B	2005-1	2005-2	OW-19	OW-18	OW-20	OW-5	OW-17	OW-16	OW-6	GAUGE

DATE	23-Dec										1.2 ice
TIME	1:27 PM	1:35 PM	1:38 PM	1:49 PM	1:53 PM	1:56 PM	1:59 PM	2:02 PM	2:05 PM	2:09 PM	
STATIC LEVEL	9.3	2.7	11.8	8.65	7.4	8.7	7.8	7.95	5.6	9.1	
CONDUCTIVITY	0.211	0.085	0.126	0.088	0.178	0.061	0.05	0.09	0.046	0.218	
COMMENTS	pump on										0.6
DATE	4-Jan										0.7 prior
TIME	1:47 PM	1:57 PM	1:59 PM	2:11 PM	2:15 PM	2:18 PM	2:22 PM	2:26 PM	2:30 PM	2:34 PM	
STATIC LEVEL	9.1	2.5	11.6	7.6	6	7.1	6.5	6.2	5.2	8.4	
CONDUCTIVITY	0.213	0.078	0.127	0.086	0.175	0.06	0.049	0.088	0.046	0.223	
COMMENTS	pump off										0.5
DATE	6-Feb										1.3 prior
TIME	2:40 PM	2:48 PM	2:50 PM	2:57 PM	3:00 PM	3:02 PM	3:05 PM	3:08 PM	3:14 PM	3:18 PM	
STATIC LEVEL	8.3	1.8*	10.8	6.9	5.3	6.4	6	5.6	4.6	7.7	
CONDUCTIVITY	0.177	0.07	0.105	0.157	0.142	0.11	0.086	0.161		0.197	
COMMENTS	pump off	* >ground									1.1
DATE	14-Feb										
TIME	2:55 PM	3:01 PM	3:04 PM	3:30 PM	3:36 PM	3:39 PM	3:41 PM	3:43 PM	3:46 PM	3:49 PM	
STATIC LEVEL	9	1.6*	11.4	7.4	6	7	6.7	6.1	5.1	8.6	
CONDUCTIVITY	0.201	#	0.124	0.187	#	#	#	0.112	#	#	
COMMENTS		* >ground	#plunked								0.5
WELL #	**OW-B**	**2005-1**	**2005-2**	**OW-19**	**OW-18**	**OW-20**	**OW-5**	**OW-17**	**OW-16**	**OW-6**	**GAUGE**
DATE	16-Feb										
TIME		1:55 PM	2:00 PM	2:08 PM	2:10 PM	2:13 PM	2:14 PM	2:16 PM	2:18 PM	2:22 PM	
STATIC LEVEL	>11!	2*	11.9	7.7	6.1	7.1	6.7	6.5	5.3	8.7	
CONDUCTIVITY	! dry?	@	@	@	@	@	@	@	@	@	
COMMENTS	pump off	* ground	Temp @								0.5
DATE	16-Feb										
TIME	2:34 PM	2:38 PM	2:40 PM	2:47 PM	2:50 PM	2:51 PM	2:53 PM	2:56 PM	2:57 PM	3:00 PM	
STATIC LEVEL	9	2*	11.6	7.7	6.1	7	6.5	6.2	5.3	8.6	
CONDUCTIVITY	0.211	@	@	@	@	@	@	@	@	@	
COMMENTS	pump off	* ground	Temp @								0.5
DATE	6-Mar										ice
TIME	3:59 PM	4:04 PM	4:08 PM	4:14 PM	4:17 PM	4:20 PM	4:23 PM	4:26 PM	4:29 PM	4:33 PM	
STATIC LEVEL	9.7	2*	12.4	8.2	6.6	7.5	7.2	6.7	5.9	9.1	
CONDUCTIVITY	@	@	@	@	@	@	@	@	@	@	
COMMENTS	pump off	* ground	Temp @								0.4

PUMP ON & OFF TIMES

Water Pumping Records for the Following Dates; Town of Manchester Water Department

PUMPING RATE=________________ PER MIN.

DATE	Pump on	Pump off	Pump on	Pump off	Pump on	Pump off	Total Hrs. Pumped		TOTAL Gal/Day
July 20,05	7:00am	3:30pm	7:45pm	12:00am			12.75	X rate	
July 27,05	12:00am	12:15am	6:45am	4:00pm	8:15pm	12:00am	13.25	X rate	
August 3,05	12:00am	12:30am	7:00am	3:45pm	7:45pm	12:00am	13.5	X rate	
August 10,05	12:00am	12:30am	7:00am	5:15pm	8:30pm	12:00am	14.25	X rate	
August 18,05	6:45am	3:00pm	7:00pm	11:45pm			12.5	X rate	
August 23,05	6:15am	2:00pm	6:15pm	11:15pm			12.75	X rate	
September 7,05	6:15am	2:00pm	6:15pm	11:30pm			13	X rate	
September 20,05	6:30am	2:00pm	6:15pm	11:00pm			11.25	X rate	
September 28,05	12:00am	1:00am	6:45am	1:45pm	6:30pm	10:45pm	11.25	X rate	
October 11,05	7:15am	1:30pm	6:30pm	11:00pm			10.75	X rate	
November 17,05	7:30am	8:15am	8:45am	1:30pm	7:15pm	11:30pm	9.75	X rate	
December 23,05	2:00am	5:30am	8:15am	2:45pm	8:30pm	12:00am	13.5	X rate	
January 4,06	7:45am	12:45pm	5:00pm	10:15pm			10.25	X rate	
Febuary 6,06	12:00am	1:15am	8:15am	1:45pm	7:30pm	11:30pm	10.75	X rate	

DRILLER LOG FOR BEDROCK WELL 2005-1

STATE OF VERMONT - DEPT. OF ENVIRONMENTAL CONSERVATION
Water Supply Division, 103 So. Main St., Waterbury, VT 05671-0403 Tel. (802) 241-3400
WELL COMPLETION REPORT

WELL TAG No. 30254
(Fill In Number from Tag)

WELL LOCATION
Well Owner or Purchaser: Vermont Geological Survey
E-911 Address: 73 Battenkill Lane
Town: Manchester
Subdivision Name:
Lot Number:

GEOGRAPHIC LOCATION (Complete A OR B, not both)
Date Well Drilled: 7-7-05

A. GPS Location: 43°09'42.0"N (Latitude Rdg.) 073°03'22.0"W (Longitude Rdg) Garmin 12 (GPS Make/Model) 4 (# of Satellites Used (Min. 3))
(OR)
B. Attach a Town Map showing location of well marked with a clear dot.

WELL TYPE (Check One)
- [x] Bedrock
- [ ] Gravel
- [ ] Monitoring
- [ ] Other:

WELL USE (Check one)
- [ ] Domestic
- [ ] Public
- [ ] Agricultural
- [ ] Industrial
- [x] Other: Monitoring

REASON FOR WELL (Check one)
- [ ] New Supply
- [ ] Replace Existing Supply
- [ ] Deepen Existing Supply
- [ ] Additional Supply
- [ ] Test/Exploration
- [x] Other: Monitoring

WELL CONSTRUCTION INFORMATION

DEPTHS
To Bedrock 55 ft
Total: 260 ft.

CASING
Total Length: 80 ft
Casing Exposed: 24 in.
Diameter: 7 in.
Material: Steel
Weight: 17 lb/ft

SEALING METHOD
- [x] Drive Shoe
- [ ] Grouted
Grout Type:

LINER OR INNER CASING
Total Length: 26 ft.
Depth to Liner Top: 65 ft.
Diameter: 4 in.
Material: PVC
Weight: Sch 40 lb/ft
Seal Type: Jazzwell X 3 + Bentonite

SCREEN DETAILS
Make/Type:
Material:
Diameter: in.
Depth to Screen Top: ft.
Slot Size
Gravel Pack (Type & Size):

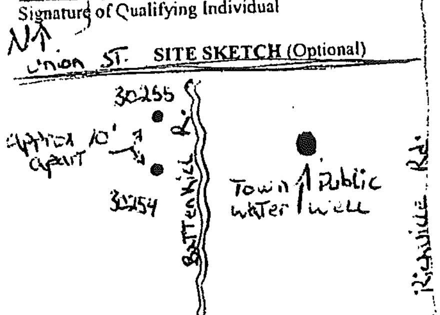
YIELD TEST
Tested for 1 hr. @ 7 GPM
Static Water Level ____ Ft. Below Land Surface
- [ ] (Check Here if Overflowing)
- [ ] Hydrofractured, Resulting flow= ____ GPM

WELL LOG

From	To	Formation Information and Water Bearing Fractures
0	20	Rocks Gravel
20	34	Sand & Gravel
34	53	Sand & Water
53	55	R-Broken-up Limestone
55	120'	R-Gray Limestone
120	245	R-white Limestone / fracture 245
245	260	R-white / Brown Limestone

WELL DRILLER INFORMATION
Drilled By: Mark Onorato
Company: Frost Well & Pump Lic#: 23
Jack Frost
Signature of Qualifying Individual

SITE SKETCH (Optional)



COMMENTS

White Copy - WSD Yellow Copy - Owner Pink Copy - Driller 09/01/99

DRILLER LOG FOR OVERBURDEN WELL 2005-2

STATE OF VERMONT - DEPT. OF ENVIRONMENTAL CONSERVATION
Water Supply Division, 103 So. Main St., Waterbury, VT 05671-0403 Tel. (802) 241-3400
WELL COMPLETION REPORT

WELL TAG No. 30255
(Fill In Number from Tag)

WELL LOCATION
Well Owner or Purchaser: Vermont Geological Survey
E-911 Address: 73 Battenkill Lane
Town: Manchester
Subdivision Name:
Lot Number:

GEOGRAPHIC LOCATION (Complete A OR B, not both)
Date Well Drilled: 7-7-05

A. GPS Location: 43°09'42.7"N (Latitude Rdg.) 073°03'21.4"W (Longitude Rdg) Garmin 12 (GPS Make/Model) 5 (# of Satellites Used (Min. 3))

(OR)

B. Attach a Town Map showing location of well marked with a clear dot.

WELL TYPE (Check One)
- ☐ Bedrock
- ☒ Gravel
- ☐ Monitoring
- ☐ Other:

WELL USE (Check one)
- ☐ Domestic
- ☐ Public
- ☐ Agricultural
- ☐ Industrial
- ☒ Other: Monitoring

REASON FOR WELL (Check one)
- ☐ New Supply
- ☐ Replace Existing Supply
- ☐ Deepen Existing Supply
- ☐ Additional Supply
- ☐ Test/Exploration
- ☒ Other: Monitoring

WELL CONSTRUCTION INFORMATION

DEPTHS
To Bedrock: 55 ft
Total: 55 ft.

CASING
Total Length: 54 ft
Casing Exposed: 24 in.
Diameter: 7 in.
Material: Steel
Weight: 17 lb/ft

LINER OR INNER CASING
Total Length: ft.
Depth to Liner Top: ft.
Diameter: in.
Material:
Weight: lb/ft
Seal Type:

SCREEN DETAILS
Make/Type:
Material:
Diameter: in.
Depth to Screen Top: ft.
Slot Size
Gravel Pack (Type & Size):

SEALING METHOD
- ☒ Drive Shoe
- ☐ Grouted

Grout Type:

YIELD TEST
Tested for 1 hr. @ 100+ GPM
Static Water Level ____ Ft. Below Land Surface
- ☐ (Check Here if Overflowing)
- ☐ Hydrofractured. Resulting flow= ____ GPM

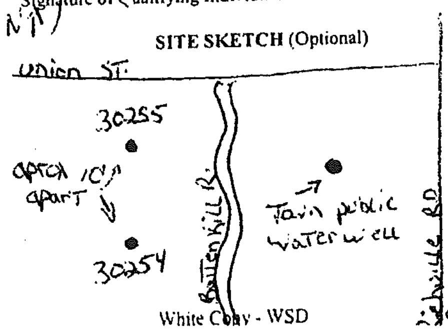
WELL LOG

From	To	Formation Information and Water Bearing Fractures
0	19	Rocks, Gravel
19	32	Sand, Gravel
32	45	Sand, water
45	50	Gravel, Clay
50	55	Gravel, Broken-up Limestone
55	55	R-Gray Limestone

WELL DRILLER INFORMATION
Drilled By: Mark Onorato
Company: Frost Well & Pump Lic#: 23
Jack Frost
Signature of Qualifying Individual

COMMENTS

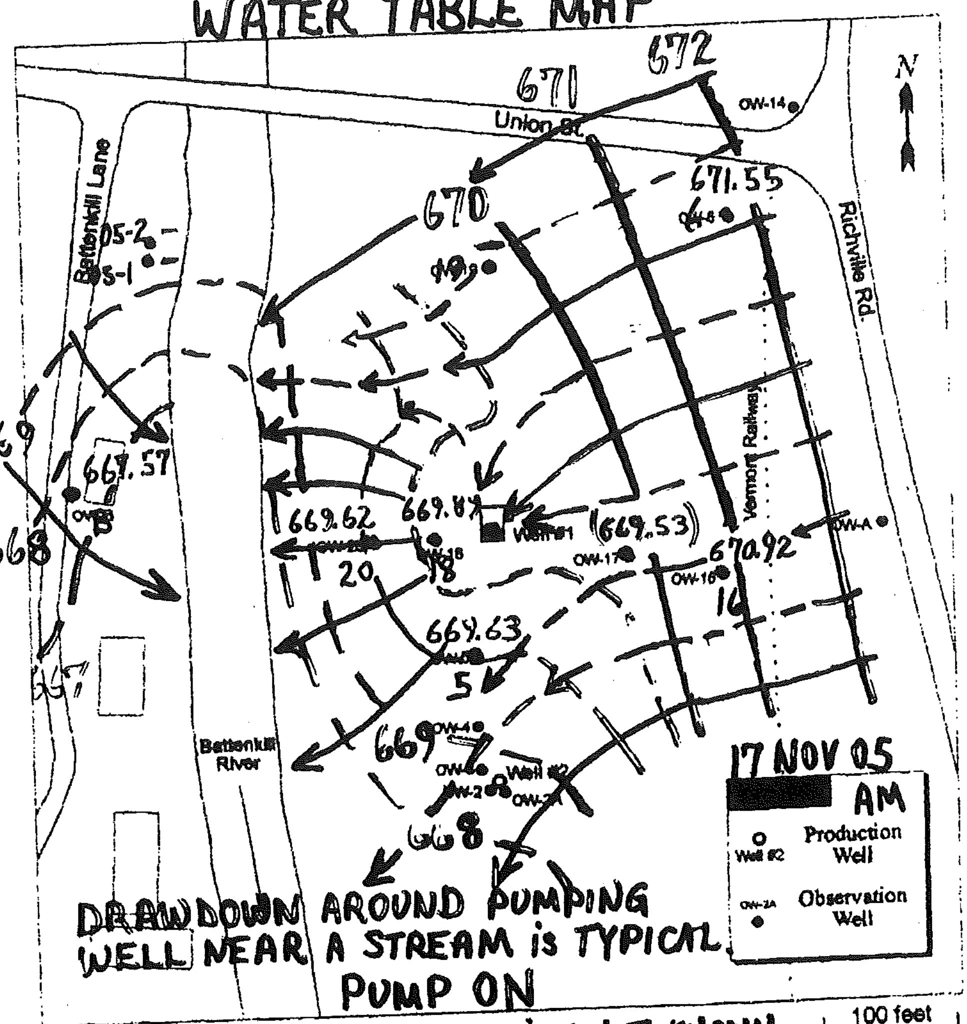
SITE SKETCH (Optional)



White Copy - WSD Yellow Copy - Owner Pink Copy - Driller 09/01/99

FIGURE 1

WATER TABLE MAP



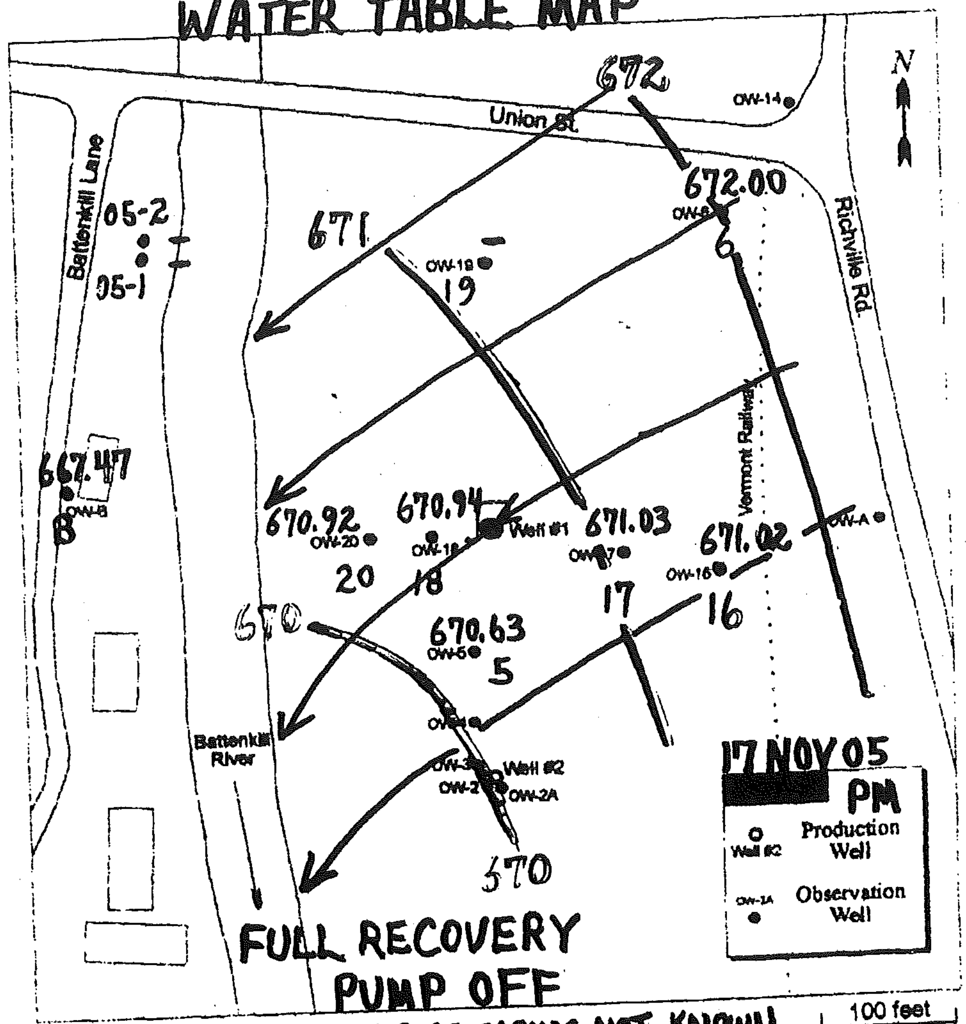
– ELEVATION OF TOP OF CASING NOT KNOWN

672 ⌒ WATER TABLE CONTOURS @ 1.0 FT INTERVAL. 669.8 & 669.6 CONTOUR ADDED TO SHOW CONE OF DEPRESSION.

↖ FLOW LINES

FIGURE 2

WATER TABLE MAP



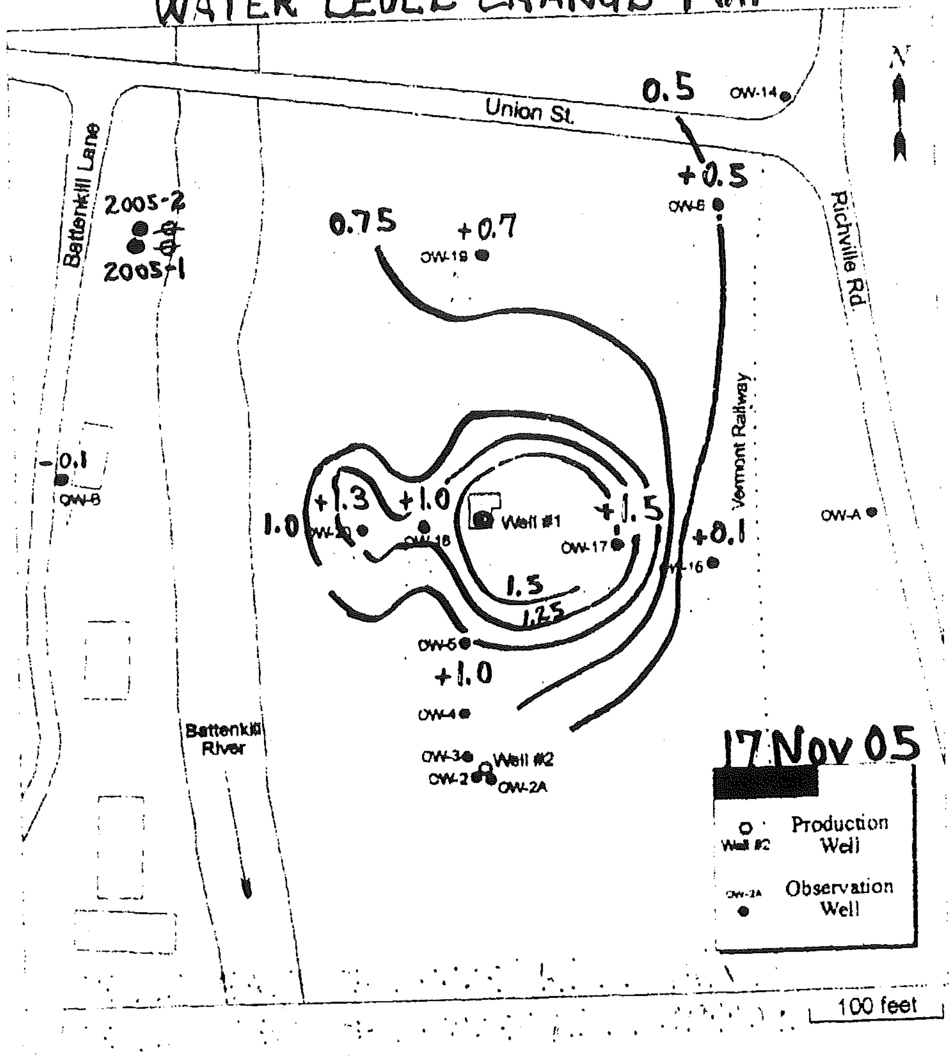
– ELEVATION OF TOP OF CASING NOT KNOWN

672 ↘ WATER TABLE CONTOURS @ 1.0 FT INTERVAL

↙ FLOW LINES

FIGURE 3

WATER LEVEL CHANGE MAP



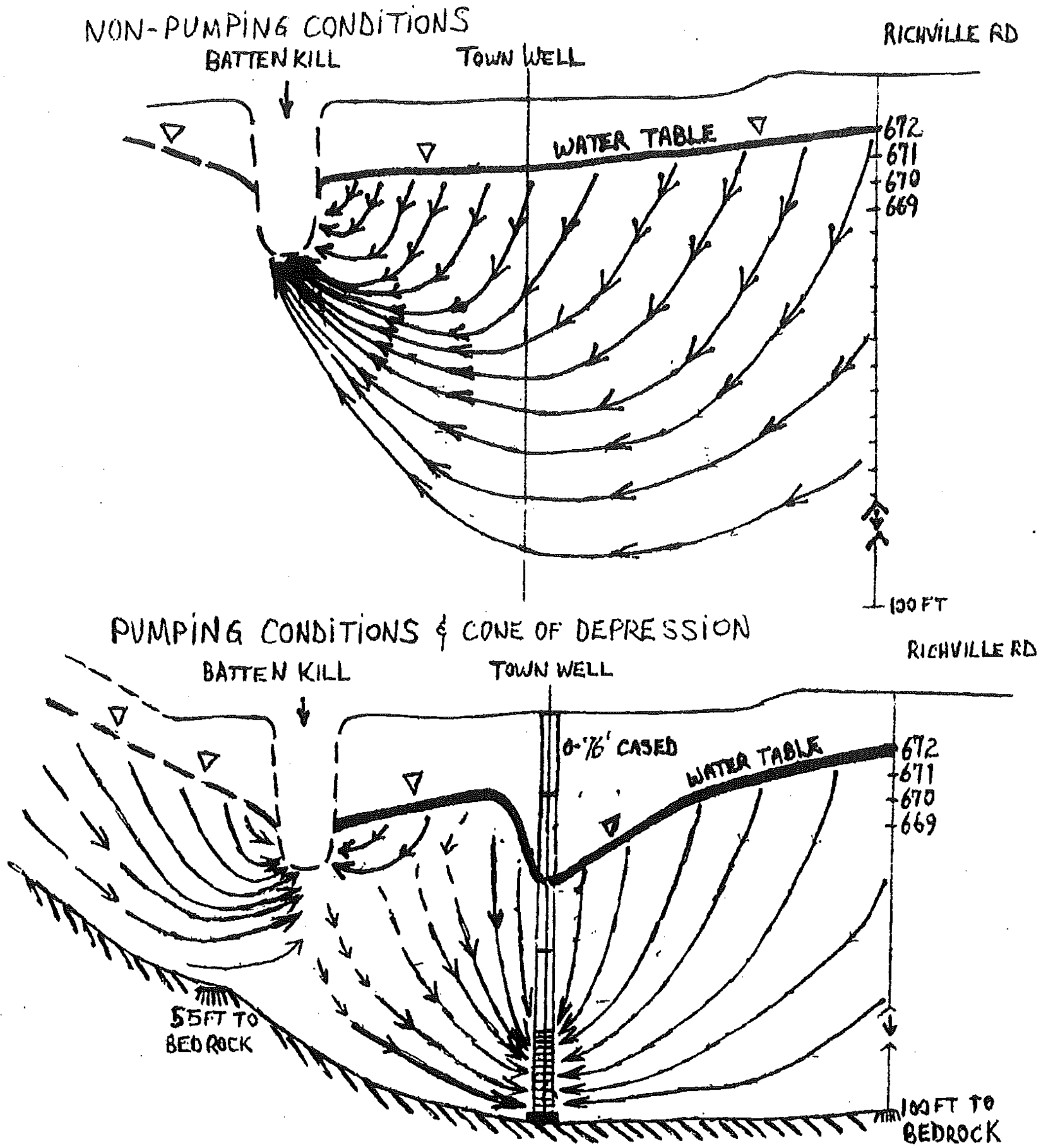

NON-PUMPING CONDITIONS
BATTEN KILL
TOWN WELL
RICHVILLE RD
WATER TABLE
672
671
670
669
100 FT
PUMPING CONDITIONS & CONE OF DEPRESSION
BATTEN KILL
TOWN WELL
RICHVILLE RD
0-76' CASED
WATER TABLE
672
671
670
669
55FT TO BEDROCK
100 FT TO BEDROCK

FIGURE 4