THE SURFICIAL GEOLOGY
AND
HYDROGEOLOGY
OF
LONDONDERRY, VERMONT

By

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SURFICIAL GEOLOGY AND HYDROGEOLOGY OF LONDONDERRY, VT

DRAFT REPORT

Location and Geologic Setting

The Town of Londonderry is situated in the northwest corner of Windham County within the Green Mountain physiographic province of Vermont. Much of the Town is at elevations between approximately 1000ft and 1500ft. A waning Wisconsinan ice sheet withdrew from the base of Glebe Mountain in the southeast corner of the town. The existing surficial geologic mapping (Stewart and MacClintock 1970) shows ice contact sediment in the valleys throughout the Town. The map units consist of kame terrace and kame moraine sediment and this indicates retreat of an active ice margin from the buttress of Londonderry Mountain. The existing map shows that till predominates in the uplands and that only the narrow valleys contain sorted overburden materials that might serve as aquifers.

The West River flows generally southward through the Town. Tributary valleys are oriented along southeast and southwest trends, perhaps related to structural controls in the bedrock. Winhall River and Flood Brook are the primary tributary valleys in the Town.

Surficial Geology of Londonderry

The Surficial Geologic Map of Londonderry shows the distribution of the morphostratigraphic units of surficial materials identified during mapping of the town. A brief description of these morphostratigraphic units is supplied in the map key and is reproduced below.

KEY TO MAP UNITS

HOLOCENE

Hf Fill; variable materials used as artificial fill along rail beds, road beds, embankments and low lying areas. Only the larger areas of fill are shown.

Hpm Peat & Muck; organic sediment with inorganic silt and clay in wetlands and swamps; low lying flat lands prone to flooding; unsuitable for development.

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 shallow aquifer if sufficiently thick. Water table typically very close to the ground surface.

Hft Fluvial Terrace; old flood plains; fine sand, silt and gravel generally less than 5 meters thick overlying other material; flat to gently sloping lands; variable permeability but 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; perc rates may be locally variable and wet areas are not uncommon; banks above streams may be prone to failure; fair aquifer; moderate sand and gravel resource potential.

QUATERNARY

Qow Outwash; glacial meltwater deposits of gravel and sand typically greater than 5 meters thick; gently sloping to flat lands; intermediate to high permeability; high gravel-sand resource potential; possible shallow aquifer if there is sufficient saturated thickness.

Qk Kame, undifferentiated; glacial deposits from streams, slumps and deposition by ice; stratified and unstratified sand, gravel and boulders with variable silt; rolling, hilly lands; intermediate to high permeability; high gravel-sand resource potential; possible shallow aquifer if there is sufficient saturated thickness.

Qgm Ground Moraine; ice contact sediment flow, meltwater 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 protrude; low to high permeability; limited local slope stability problems; gently rolling hills and elongate smoothed hills are possible; shallow aquifer possible if there is sufficient permeability and sufficient saturated thickness.

Qt Till; ice derived deposits of hardpan silt, boulders, gravel and sand which are unsorted and unstratified and deposited beneath the glacier; 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; low permeability; wet at shallow depth in soils on thick till due to inability of water to penetrate the unweathered till; unstable slopes may result in excavations.

Qtt Till, thin; 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 or ledge frequent; surface boulders or erratics are common; moderate to steep mountain slopes and summit areas; low permeability in isolated thicker areas but higher permeability occurs due to weathering and soil formation in most of the thin till areas; steep slopes are unstable and slides are common.

PRECAMBRIAN

r Rock outcrop; includes areas of predominantly outcrop with patches of till or slump or slide debris or colluvium; outcrop areas serve to recharge bedrock aquifer with groundwater; poor sites for septic systems; slopes are generally stable except very steep slopes where rock slides and rock falls may occur. The Londonderry bedrock is not known to produce many high yield wells and this is likely due to the density and connections between fractures in the rock.

A surficial geologist maps by identifying those surficial materials that have the same or similar sediment types, for example, sand versus gravel versus silt-clay versus hardpan till. In addition, the processes responsible for the deposition of these different sediment types often results in an identifiable landform associated with the deposit. For example, a river terrace deposited by a river as an old flood plain has typical sediment

(Hft). Deposits from melting glaciers and the meltwater that flows away from their margins also produces an identifiable suite of landforms with associated sediment type (Qow). These are the morphostratigraphic units of the surficial or glacial geologist or geomorphologist.

> Morphostratigraphic unit (Glossary of Geology, 1997): "…..The term is used in stratigraphic classification of surficial deposits such as glacial moraines, alluvial fans, beach ridges and other such deposits where landforms serve to give identity to a body of clastic sediments."

Glacial History of Londonderry

Models of regional stagnation versus active ice retreat have previously been applied to the deglaciation of the Green Mountains. Yet, discussions of the style of ice retreat have been based upon mapping primarily using 1:62,500 scale topographic maps. The field investigations that went into these maps focused on the then more heavily developed and heavily populated areas of the State outside of the Green Mountains. Since the 1970's, the growth in the ski industry has fostered a parallel growth in second or vacation homes in the tightly confined areas at the base of the ski resort mountains.

The detailed surficial geologic mapping provides insights as to the nature and style of ice retreat from this southern portion of the Green Mountains. Currently, there is no real model for the deglaciation of the southern Green Mountains and the real picture is likely some combination of regional stagnation as determined for the Woodstock area (De Simone 2006) and a retreat of active ice as determined from extensive studies of the Vermont Valley to the west and south of Londonderry (De Simone 2005b, 2005a, 2004, 2001). These latter areas are along the boundary of the Green Mountains and little of this work reached into the uplands of the Green Mountains. Thus, we have very little detailed knowledge of ice retreat from the upland portions of the Green Mountains in southern Vermont.

There is a strong southeasterly structural grain to the topography. Numerous brooks such as Mill, Cook, Flood, Utley and portions of the West River flow southeast in relatively narrow valleys. Similarly, several small and unnamed brooks flow southeasterly toward the base of Glebe Mountain and join the brook that drains Lowell Lake in the northeast corner of the town. This Lowell Lake brook flows southwest and joins the West River.

The mapping indicates that some combination of thinning and stagnation of ice in these narrow valleys coupled with limited active margin retreat prevailed through the town as revealed by areas of kame topography and minor, thin outwash. The hummocky kame topography is only subtly developed and is best seen in the area where Flood Brook joins West River. Here, the sand and gravel deposited by meltwater is sufficiently extensive to have allowed past mining activity. Another area of good kame topography is north of Londonderry village along West River where several gravel and sand mining operations exist or were previously open, especially extending north of the town.

Elsewhere, in the narrow valleys, there is only a hint of hummocky kame topography and the sediment in the valleys is a mix of sand, silt and boulders more typical of ground moraine, the sediment characteristic of stagnant ice. Here, the amount of meltwater deposition is less than in kame areas but there is likely some sorted fluvial sediment along with sandy ablation till and some sediment flow/slump deposits.

Thus, the narrow valleys in town are generally mapped as having either some hummocky kame topography and/or less hummocky ground moraine topography. Still other valley areas are mapped as thick till and well logs along with topographic considerations enabled this thick till designation. Some well logs report a considerable thickness of mixed sand, silt, boulders and clay, sometimes with noted gravel lenses at depth within the sediment. Overall, this drillers' description is most consistent with a typical "Green Mountain till", a till derived from erosionally resistant rocks that generally have a coarse grained texture. These rocks abrade into more sand sized particles beneath a glacier than silt sized particles. The end result is till with a sandy and silty matrix in contrast to the silt matrix till found in major valleys such as the Connecticut and Hudson-Champlain.

The predominant southeastward trending upland ridges between the narrow valleys of Londonderry are mantled with thin till and rock outcrops are quite frequent. The till has been observed to be somewhat sandy in places and silty in other areas and small depressions are typically wetlands. The thin till has weathered to a yellowish brown to locally orange brown color.

The Deglacial History map shows a 3-phase history in the deglaciation of the town. The delineation of these phases is a representation to explain the surficial deposits throughout the town. The overall lack of extensive ice contact sand and gravel except in the northern portion of town is an indication that the ice sheet melted back very rapidly and the entire town was deglaciated likely within a span of no more than 2 decades. This is based upon rates of ice retreat quantified in both the Connecticut and Hudson-Champlain lowlands. Both of these major lowlands had significant lakes fronting the retreating ice margin and this can cause the ice to calve and retreat very rapidly. However, in the mountains, the ice was thinner and may have retreated at a similarly or even greater rate than in the lowlands.

The first ice retreat position reflects the initial thinning of the ice sheet to expose the Glebe Mountain ridge. With ice still in the North Windham valley to the east, meltwater from the ice front west of the Glebe Mountain ridge contributed to the ice contact sediment seen in the North Windham area.

Rapid ice thinning with some marginal retreat places an ice front across the lower flank of Glebe Mountain. Outwash sediment seen along the West River down valley from this ice position was deposited. This outwash contains very large cobbles and boulders and numerous large boulders that likely were derived from debris on the nearby glacier. This outwash is graded to a base level much higher than the present West River base level. This suggests some farther down valley dam of sediment or the ice of the Connecticut lobe or the level of Glacial Lake Hitchcock maintained a higher base level.

The thinning of the ice sheet in position 2 also resulted in the exposure of numerous southeast trending ridges and this thinning process isolated ice in the narrow southeast trending valleys. Meltwater is depicted as flowing beneath the narrow ice tongues in these minor valleys. At this time, subglacial deposits seen preserved in the Flood Brook and West River valleys extending from South Londonderry and up these valleys was deposited.

Continued very rapid ice thinning and retreat of the ice front melted the ice sheet to position 3. Here, small valley ice tongues are depicted in Flood Brook, Utley Brook and the adjacent portion of the West River valleys. The more extensive ice contact sediment seen north of Londonderry, particularly along the West River valley, accumulated in close proximity to the thinning and retreating glacier margin. Down these and the other minor tributary valleys, residual blocks of decaying ice, separated from the remainder of the ice sheet, have been stranded and melt away. The small esker segment in the lower portion of Flood Brook valley accumulated in a tunnel beneath the melting Flood Brook ice.

Depth to Bedrock

The depth to bedrock or thicknesses of overburden encountered by well drillers is a valuable source of information. These data enable us to recognize where the overburden is thickest in town. In addition, the driller's log or description of this overburden can be interpreted to determine the deglacial history of the town. This overburden can be relatively impermeable hardpan or relatively permeable sand-gravel material or some interlayered sequence of these differing sediment types. Thus, the location of the thickest overburden and the assessment of the relative permeability of this overburden helps us assess the location and potential for overburden aquifers as discussed in that section of this report below.

The Depth to Bedrock map depicts the thickness of overburden using a 30ft contour interval. Areas of bedrock outcrop and located private wells are also shown on the map. The areas of closed contours on the map represent discrete accumulations of thicker overburden, in most places <90ft thick. In the northwest corner of town, overburden thickness is >150ft; in the North Windham region, the overburden is >270ft thick. Unfortunately, most drillers' logs report primarily hardpan, a material inferred to be till, as the predominant sediment.

It is possible that the distribution of thicker overburden through town is an artifact of wells being clustered where the villages and developments are located. This may not actually reflect the true distribution of overburden >20ft thick. Thus, thicker overburden may be present throughout the valley portions of town. However, only additional drilling over time will answer this question.

Aquifer Resources – Hydrogeologic Units

<u>Overburden</u>: 8 gravel wells were able to be accurately located in the Londonderry well data set. These gravel wells reveal an interesting overburden stratigraphy. Some well logs indicate considerable sand, gravel and boulders while others indicate gravel units within or at the bottom of a hardpan or hardpan and boulders unit. Collectively, these well logs appear to reveal a thick but locally permeable till that is the producing unit rather than a thick and extensive well sorted gravel and sand deposited from meltwater streams. As such, the overburden aquifers are likely to be highly localized and not reliably traceable for any lateral distance. However, when encountered, producing gravel and sand aquifers in town have an average yield of 33 GPM (gallons per minute) with a yield range of 4-50 GPM. 6 wells or 75% have reported yield >= 20GPM. -The average overburden well depth is only 112ft with a depth range of 52-210ft.

The hummocky kame and ground moraine terrain does not appear to be a strong source of groundwater for the town. This, however, may be partly due to not having many occasions where drillers stopped drilling at shallow depth. Thus, it may be useful to investigate the hummocky terrain areas and determine if there is a sufficient saturated thickness to produce water at a shallow depth. In general, the town's overburden is not a good source of groundwater and there is little subsurface data to indicate areas of high potential for any overburden aquifer due to the presence of so much hardpan reported in well logs.

It may be warranted to advise well drillers to consider overburden as a water source, especially in those areas discussed on the recharge potential map. While the proven location of high yielding overburden is confined to those locations where there already are producing wells, it may be valuable to consider that sites near to these producing wells may encounter a similarly saturated and permeable overburden either at a relatively shallow depth or beneath an undeterminable thickness of hardpan. Gravel wells should not be dismissed as impossible in the town.

Bedrock: The bedrock aquifer produces highly variable well yields over very short distances. Groundwater flow in the crystalline bedrock of Vermont is mainly along planar features such as fractures, cleavage, faults, and bedding. These planar features may be interconnected and groundwater flow within this system is complex. Well Yield (GPM) is generally estimated in the field with a bucket and timer. The time period is usually short and measurements are not meant to be precise. Depth and yield vary due to many factors, including non-geologic factors. For example, a homeowner may drill until they obtain a desired yield. The factors are not indicative of capacity. Moore et. al., 2002*, published "Factors Related to Well Yield in the Fractured-Bedrock Aquifer of the New Hampshire" in which they discussed a number of factors correlated positively or negatively to well yield. Among these factors are year drilled, median household income, drilling method, up gradient drainage area, thickness of overburden, depth drilled, proximity to streams/water bodies, type of bedrock, steepness of slope, elevation, fractures, and geologic structures. A statewide compilation of well data from 92,316 wells in Vermont is posted at the Vermont Geological Survey web site at http://www.anr.state.vt.us/dec/geo/gwaterSTATEinx.htm

A total of 470 located bedrock wells are shown on the Hydrogeologic Units map. Most well logs in town report either thin or thick hardpan and subsequently penetrate hundreds of feet of rock. 56 wells or 9% report a well yield of 1 GPM or less, with 91% reporting a yield greater than 1 GPM. 111 or 24% of rock wells report yields >= 20GPM. Overburden thickness for these 111 wells ranges from 0-183' and 53 (48%) of these wells have reported overburden of >= 20'. We have an incomplete picture of the capability of the rock to yield water. We can conclude the rock is a generally poor public water supply source with some notable exceptions.

The majority of the bedrock wells are in the Mount Holly complex of pre-Cambrian metamorphic rocks of varying lithologies, predominantly gneiss, but with minor quartzite, amphibolite and schist. These are the blue colored areas of the map. The Mount Holly Complex must be viewed as only a fair rock aquifer highly dependent upon the degree of fractures and the interconnectedness of these fractures. A handful of wells are in the Cavendish, Hoosac or Pinney Hollow formations, also metamorphic lithologies but predominantly schist. These are the green colored areas of the map, largely confined to the eastern edge of town. These formations must be considered a fair aquifer highly dependent upon fracture density and the interconnectedness of these fractures.

The 470 bedrock wells have an average yield of 14 GPM and a yield range of 0-305 GPM. The average depth is 271ft with a depth range of 71-653ft. A comparison with the 8 gravel wells reveals that gravel wells are more than twice as productive as bedrock wells while being less than half as deep based upon averages.

The bedrock well data set reveals only a few (13 wells >= 50GPM) very high yield wells and these yields may be only an estimate. Accordingly, a second data set was prepared by discounting the wells with a suspicious high yield. Regardless of the statistical validity of this process, it nevertheless results in a data set that may be more typical of the average bedrock well yield in town. This data set of 458 rock wells has an average yield of 11 GPM with a yield range of 0-70 GPM, appreciably lower than the average yield and with a smaller yield range than the full rock well data set. The average depth and depth range were not significantly affected by eliminating the 10 highest yielding rock wells from the data set.

Ochre: Only 2 wells were identified as having ochre as the most likely water source in the well. Both wells were 400ft deep and the average yield was 15.5 GPM with a range of 1-30 GPM. Ochre is recognized as a preserved deep weathering profile developed in the bedrock largely during a time of climatic warmth sometime before the Pleistocene Epoch. Repeated Pleistocene glaciations have removed most of this weathering profile but it is sporadically preserved throughout Vermont, New England and New York. It is not possible to predict in any reliable way where ochre might be preserved atop bedrock.

Recharge Potential to Bedrock Aquifer

Recharge potential is ranked from highest, I to lowest, III. Criteria provided enable you to better understand the reasoning behind this evaluation. These criteria combine knowledge of surficial geology, overburden thickness and stratigraphy of the overburden. Recharge potentials are qualitative and no absolute values on rates of recharge through each of the surficial material types can be provided. This is especially true because of the heterogeneous nature of most surficial materials deposited in glacial environments. The Recharge Potential to Bedrock Aquifer map delineates areas of high, moderate and low recharge potential to the bedrock aquifer.

I: HIGH

Thin till areas in mountain regions offer little impedance to downward water infiltration due to the weathered and relatively permeable shallow soils over bedrock. These are the high elevation areas where the thin till veneer and frequent rock outcrops enable some recharge into the underlying fractures and foliation of the rock. Most prominently, these are the summit ridge lines and steep mountain flanks. The ease with which water can infiltrate the soils to the underlying rock in areas of till is dependent upon weathering and thinness of this till veneer. On the high elevation slopes, ridge lines and mountain summits, the till is typically a very thin veneer, typically less than 3 ft. While unweathered till is dense and impermeable, the soils that develop on till veneer allow relatively easy infiltration of water through the thin soil into the rock. Exposed rock has had a long time to weather since the retreat of the glaciers and fractures have opened to allow surface water to infiltrate in the high elevations. This is the reasoning behind the traditional and accepted view of high mountain areas serving as major recharge zones to rock aquifers.

Typically, the contact between thick till and thin till may be recognizable in the field by the occurrence of seeps or occasional springs and very often a break or flattening of the slope. The groundwater flowing at shallow depth cannot penetrate deeper into thick till and may flow out onto the surface in these contact areas. The lower elevation boundary between thin till and thick till can often be seen as a place of seepage where shallow groundwater and, possibly, deeper groundwater, may emerge again to the surface.

II: MODERATE

Areas of comparatively permeable surface sediment may be partly or wholly in contact with bedrock and this facilitates recharge of the bedrock aquifer. These are the areas of ground moraine (Qgm), undifferentiated ice contact sediment (Qk) and outwash sediment (Qow). All 3 of these surficial mapping units are relatively limited in extent throughout the town. Further, their thickness and the homogeneity of the permeable sediment are unknown.

The ground moraine is the most highly variable sediment in this category. Older surficial maps identify this material as ablation till. However, more recent mappers have determined that a variable portion of this sediment was deposited by meltwater streams and is permeable. This permeable sediment may be mixed, interlayered with or even predominantly a much less permeable silt to sandy silt loam with abundant stones and relatively low permeability. Individual well logs reveal the highly variable nature of ground moraine.

Undifferentiated ice contact sediment is often predominantly sand and gravel deposited by meltwater streams but can be interlayered with material similar to ground moraine. Often, the distinction that can be made during mapping is due to the presence of excavations into the sediment that reveal the extent of the stream deposited sand and gravel.

Outwash sediment is chiefly sand and gravel of moderate to high permeability. However, this sediment unit can be of limited thickness and limited recharge potential to an underlying bedrock aquifer.

III: LOW

Areas of impermeable thick till do not easily allow water to penetrate any deeper than the base of the soil profile. These occur along the lower mountain flanks in areas where there are no permeable surficial deposits and where thick till blankets lower valley ridges.

Where there is thick till mantling the Green Mountains lithologies, there is a comparatively thick and relatively impermeable barrier to the infiltration of groundwater through the till into the underlying bedrock. Till is an impermeable sediment and even though the upper surface of the till has weathered and has a more permeable soil developed upon it, beneath the soil there is dense, impermeable unweathered till. Thus, thick till areas are not places where the underlying rock can be easily recharged.

The areas mapped as Holocene (Hft, Hal) sediment are more recent deposits of silt, sand and gravel of variable permeability and typically very limited thickness. In most cases, it is usually true these sediments overlie an eroded surface developed upon older sediment. It is unknown whether the underlying sediment is permeable or impermeable without site specific studies. However, these sediments lie at low elevations adjacent to modern streams and infiltrating groundwater most probably flows through these sediments and discharges into the nearby streams without contributing recharge to any underlying bedrock aquifer.

Wetlands, typically places of groundwater discharge to the surface, do not serve to recharge the underlying rock aquifer.

Potential Overburden Aquifer and Recharge

The Potential Overburden Aquifer with Direct Recharge map depicts the inferred potential for any overburden aquifers in town. The first area delineated is that consisting of permeable sand and gravel with some till having a sand-gravel matrix as recognized from field mapping and from water well logs. This permeable sediment extends from the surface down to depths generally <60ft. This area is inferred to have very limited potential for development of an overburden aquifer resource. However, there may be potential for individual home supply wells and this possibility should be recognized during drilling in the delineated areas.

A second area of generally thick till containing a variable sand-gravel-boulder component exists at shallow depth or more deeply buried beneath a thick and denser till with a lower permeability. This delineated area also includes areas of shallow permeable terrace sediment. Whether at surface to shallow depth or more deeply buried, this area of permeable sediment is considered too widely scattered and too localized to be of much value as an overburden aquifer. Thus, the potential for development of overburden wells is considered very low but comparable to the other area described above.

The existing gravel and 2 ochre wells in town are shown on this map to highlight their association with these delineated potential overburden aquifer areas. All of the gravel wells lie within these areas. The 2 ochre wells are in close proximity and their logs also reveal they may have an association with the buried permeable till unit in the lee or down ice side of the Glebe Mountain ridge in the North Windham area.

Recharge to any of these isolated, fragmented overburden aquifers is likely by direct infiltration of water through the permeable sand-gravel deposits and through the sandy matrix till areas.

Target areas approximately a half mile in diameter are depicted. These areas have slightly higher probability for encountering permeable overburden than other areas due to their being evidence of permeable sediment in existing well logs and/or there being thicker overburden present based upon the depth to bedrock map. These targets are not meant in any way to indicate recharge zones around any existing overburden well.

Conclusions

1. Both the uplands and valleys of town have an abundance of till, generally impermeable sediment that is not an overburden aquifer.

2. Limited areas of sand-gravel and permeable till sediments exist and offer some potential for overburden aquifer development. However, this overburden aquifer potential is rated as very low. Nevertheless, some additional drilling, especially in target areas, would provide considerable useful data.

3. While there are few existing overburden wells, their high average yield and comparatively shallow depth warrant further study as a possible aquifer resource.

4. The bedrock aquifer in town exists in rock that is generally low in secondary permeability and this low permeability in comparison to overburden aquifers results in wells with considerably greater average depth and less than half the average yield versus overburden wells.

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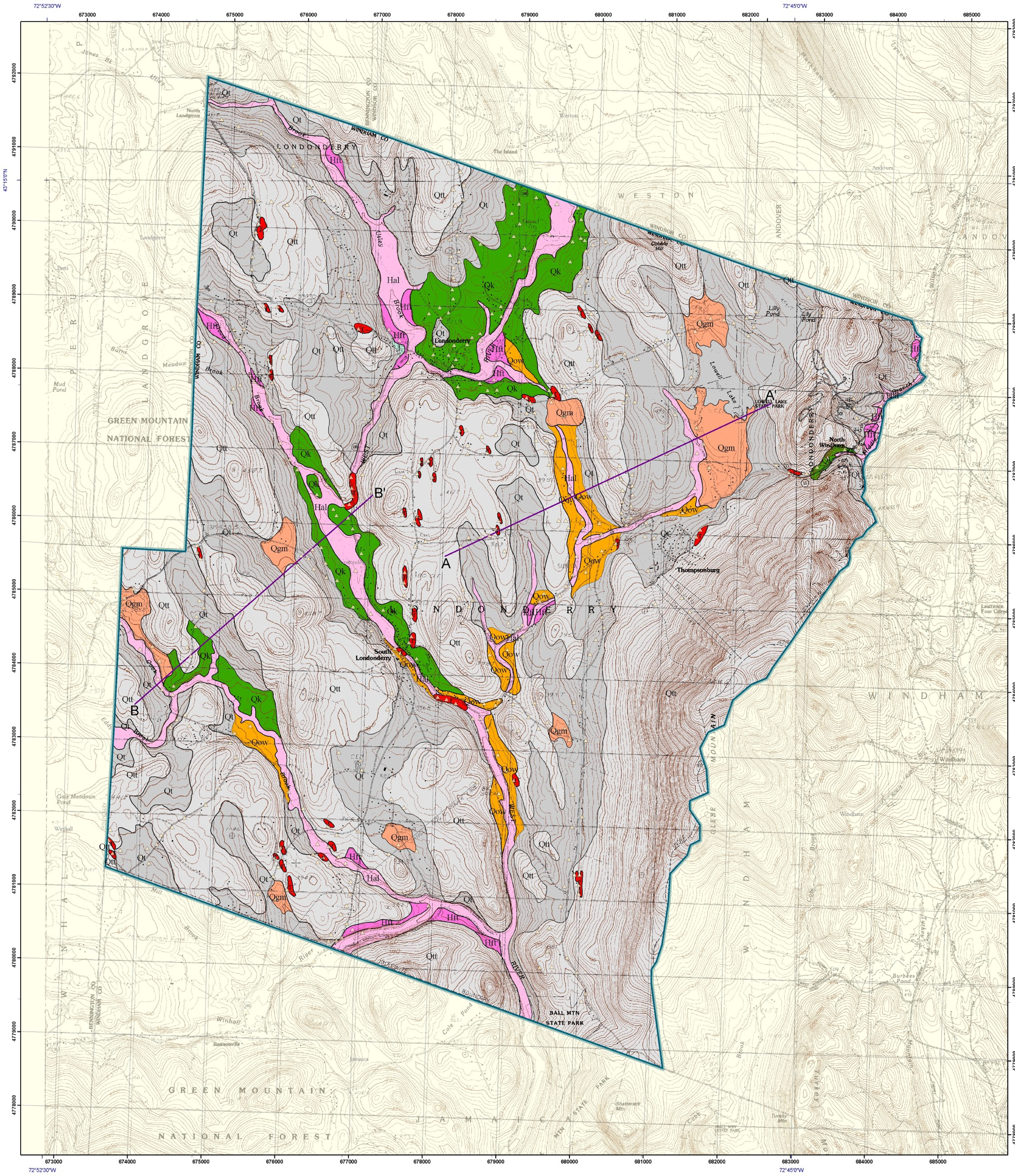


Legend

Descriptions of Map Units

Recent

- f — Fill - variable materials used as artificial fill along rail beds, road beds, embankments and low lying areas.
- Hal — Alluvium - stream flood plains; fine sand, silt and gravel of river channel, bar, and bank areas; river bottom lands.
- Hft — Fluvial Terrace - old stream terrace deposits above the flood plain; fine sand, silt and gravel to cobble size; generally less than 5 meters thick overlying other material; flat to gently sloping lands.;

Quaternary

- Qgm — Ground Moraine - 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 protrude.
- Qk — Kame - undifferentiated; glacial deposits from streams, slumps and deposition from ice; stratified and unstratified sand, gravel and boulders with variable silt; rolling, hilly lands to individual hills.
- Qow — Outwash - glacial melt water deposits of well sorted gravel and sand typically greater than 5 meters thick; gently sloping to flat lands.
- Qt — Till - ice derived deposits of hardpan silt, boulders, gravel and sand which are unsorted and unstratified and deposited beneath the glacier; thickness greater than 3 meters (10 feet) 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.
- Qtt — Thin till - 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 (10 feet) with rock outcrops or ledge frequent; surface boulders or erratics are common; moderate to steep mountain slopes and summit areas.

Paleozoic and Proterozoic

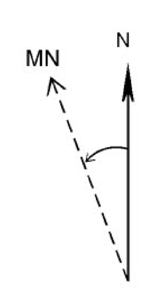
- r — Bedrock outcrop

Explanation of Map Symbols

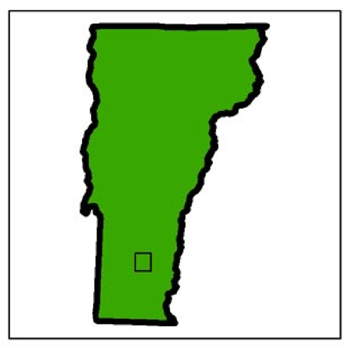
- Field Stations
- Cross section lines
- Town Boundaries

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.
Digital Cartography by Marjorie Gale and Marci Young
Date: September 2008

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



Magnetic declination
15.5 degrees west, 1968



OPEN FILE REPORT - SURFICIAL GEOLOGIC MAP OF THE TOWN OF LONDONDERRY, VERMONT

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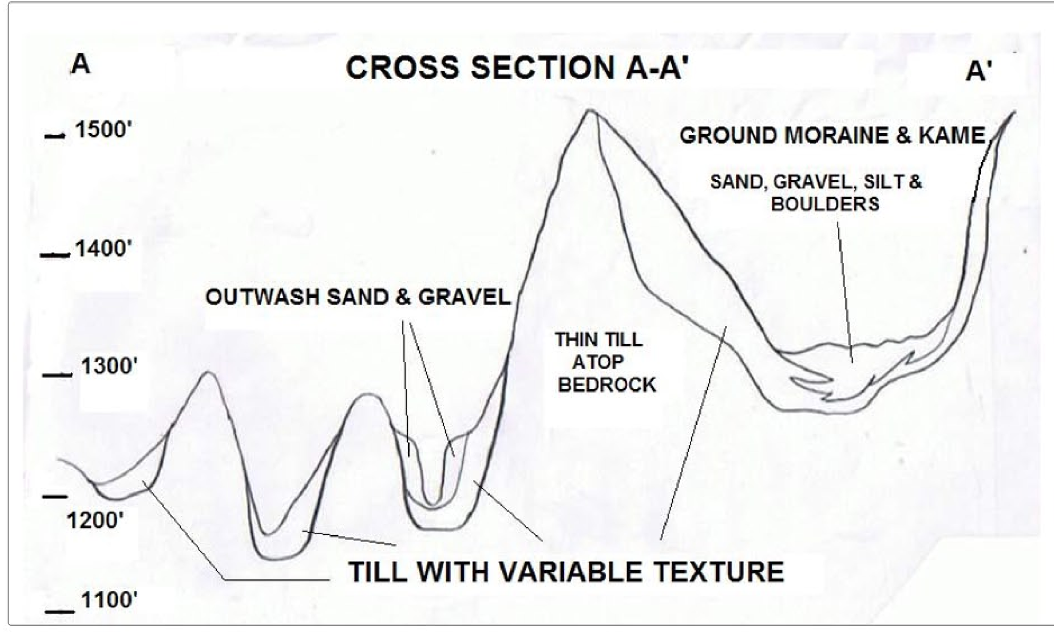
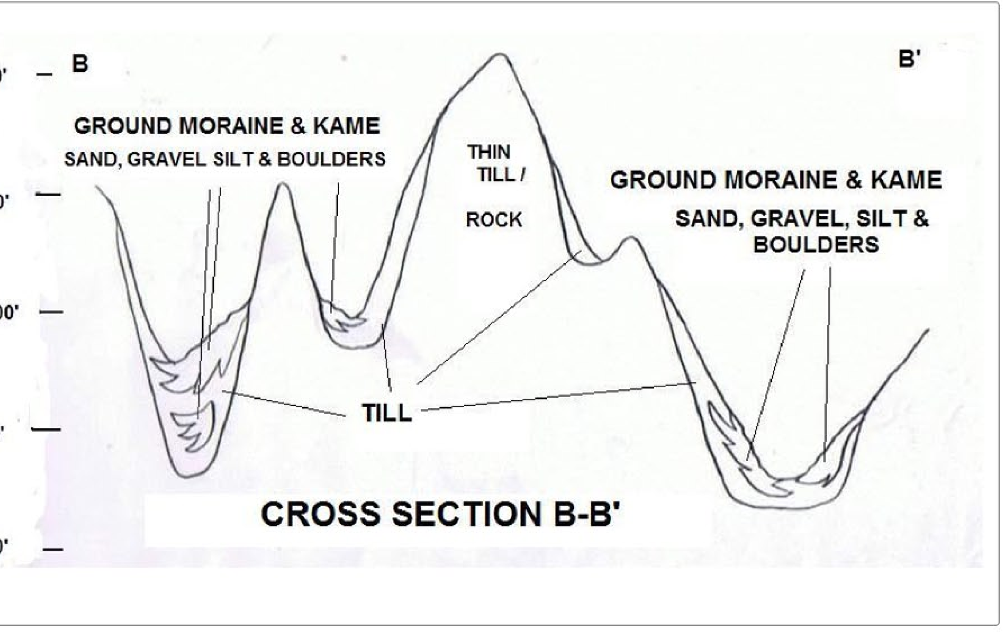
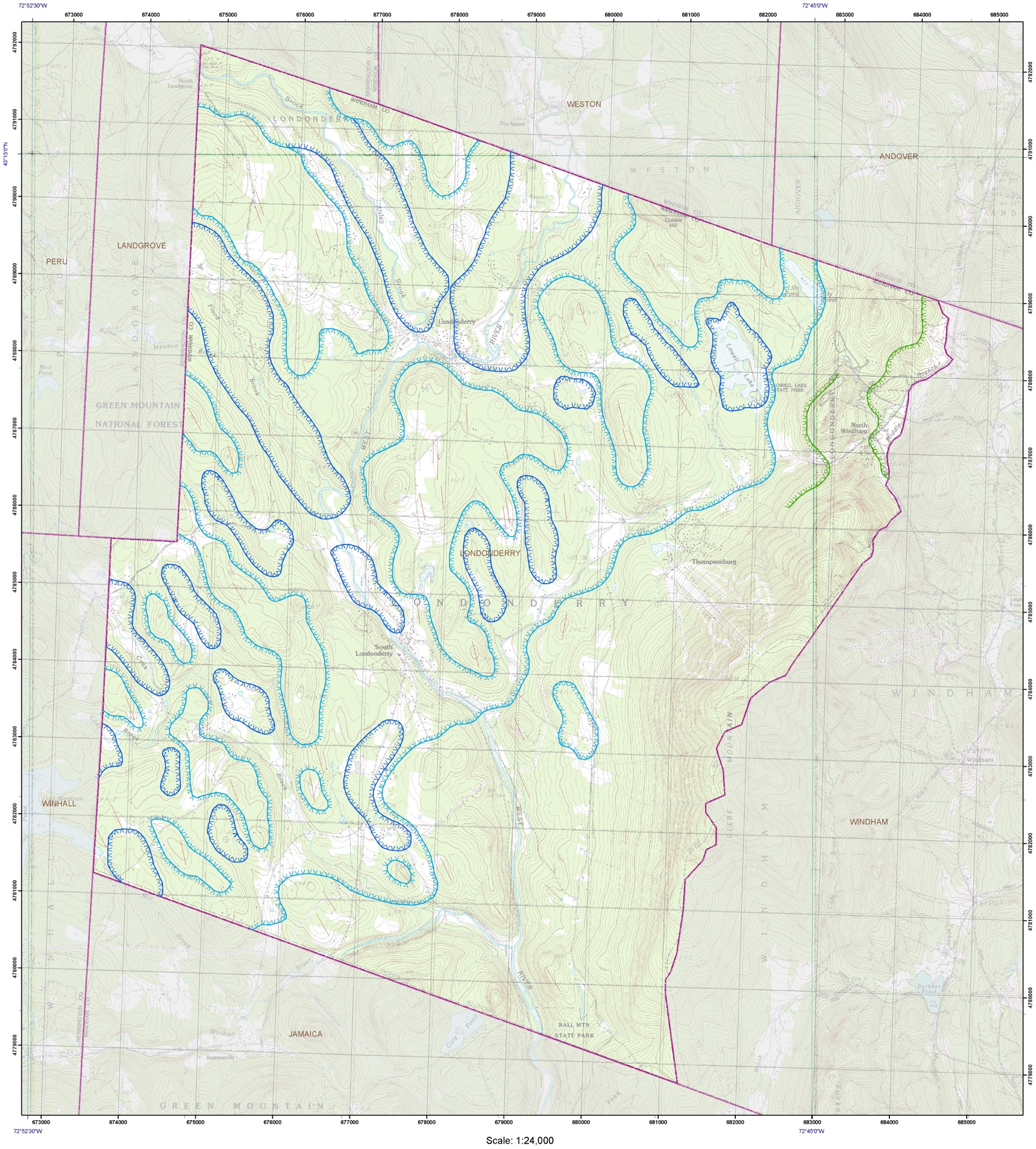




Research supported by the Vermont Geological Survey, Dept. of Environmental Conservation, VT ANR. Research funded in part by the Londonderry Conservation Commission and the Londonderry Planning and Development Commission. This geologic map was funded in part by the USGS National Cooperative Mapping Program. 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.



Vermont Geological Survey Open File Report VG08-2

EXPLANATION

The Deglacial History map shows a 3-phase history in the deglaciation of the town. The delineation of these phases is a representation to explain the surficial deposits throughout the town. The overall lack of extensive ice contact sand and gravel except in the northern portion of town is an indication that the ice sheet melted back very rapidly and the entire town was deglaciated likely within a span of no more than 2 decades. This is based upon rates of ice retreat quantified in both the Connecticut and Hudson-Champlain lowlands. Both of these major lowlands had significant lakes fronting the retreating ice margin and this can cause the ice to calve and retreat very rapidly. However, in the mountains, the ice was thinner and may have retreated at a similarly or even greater rate than in the lowlands.

Position of Ice Margin or of Stagnant Ice: Vees open toward the ice, arrows indicate meltwater flow direction

1
1

The first ice retreat position reflects the initial thinning of the ice sheet to expose the Glebe Mountain ridge. With ice still in the North Windham valley to the east, melt water from the ice front west of the Glebe Mountain ridge contributed to the ice contact sediment seen in the North Windham area.
Rapid ice thinning with some marginal retreat places an ice front across the lower flank of Glebe Mountain.

2
2

The thinning of the ice sheet in position 2 also resulted in the exposure of numerous southeast trending ridges and this thinning process isolated ice in the narrow southeast trending valleys. Melt water is depicted as flowing beneath the narrow ice tongues in these minor valleys. At this time, subglacial deposits seen preserved in the flood Brook and West River valleys extending from South Londonderry and up these valleys was deposited.

Outwash sediment seen along the West River down valley from this ice position was deposited. This outwash contains very large cobbles and boulders and numerous large boulders that likely were derived from debris on the nearby glacier. Thus, the position of the ice font is likely very close to the correct one due to the presence of large clasts in the outwash that were not capable of being transported very far from the ice margin. This outwash is graded to a base level much higher than the present West River base level. This suggests some farther down valley dam of sediment or the ice of the Connecticut lobe or the level of Glacial Lake Hitchcock maintained a higher base level.

3
3

Continued very rapid ice thinning and retreat of the ice front melted the ice sheet to position 3. Here, small valley ice tongues are depicted in Flood Brook, Utley Brook and the adjacent portion of the West River valleys. The more extensive ice contact sediment seen north of Londonderry, particularly along the West River valley, accumulated in close proximity to the thinning and retreating glacier margin. Down these and the other minor tributary valleys, residual blocks of decaying ice, separated from the remainder of the ice sheet, have been stranded and melt away. A small unmapped esker segment in the lower portion of Flood Brook valley accumulated in a tunnel beneath the melting Flood Brook ice.

Striation or other ice flow direction indicator

VT Town Boundaries

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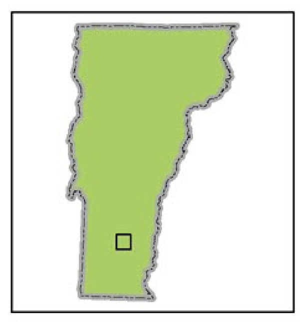

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Department of Environmental Conservation
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Scale: 1:24,000

Base map from U.S. Geological Survey.
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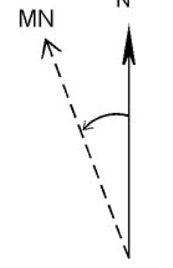
Grid overlay on map is Universal Transverse Mercator, Zone 18N, NAD 27.
Digital Cartography by Marjorie Gale and Marci Young
Date: September 2008

0 625 1,250 2,500 3,750 5,000 Meters

1 centimeter = 0.24 kilometers



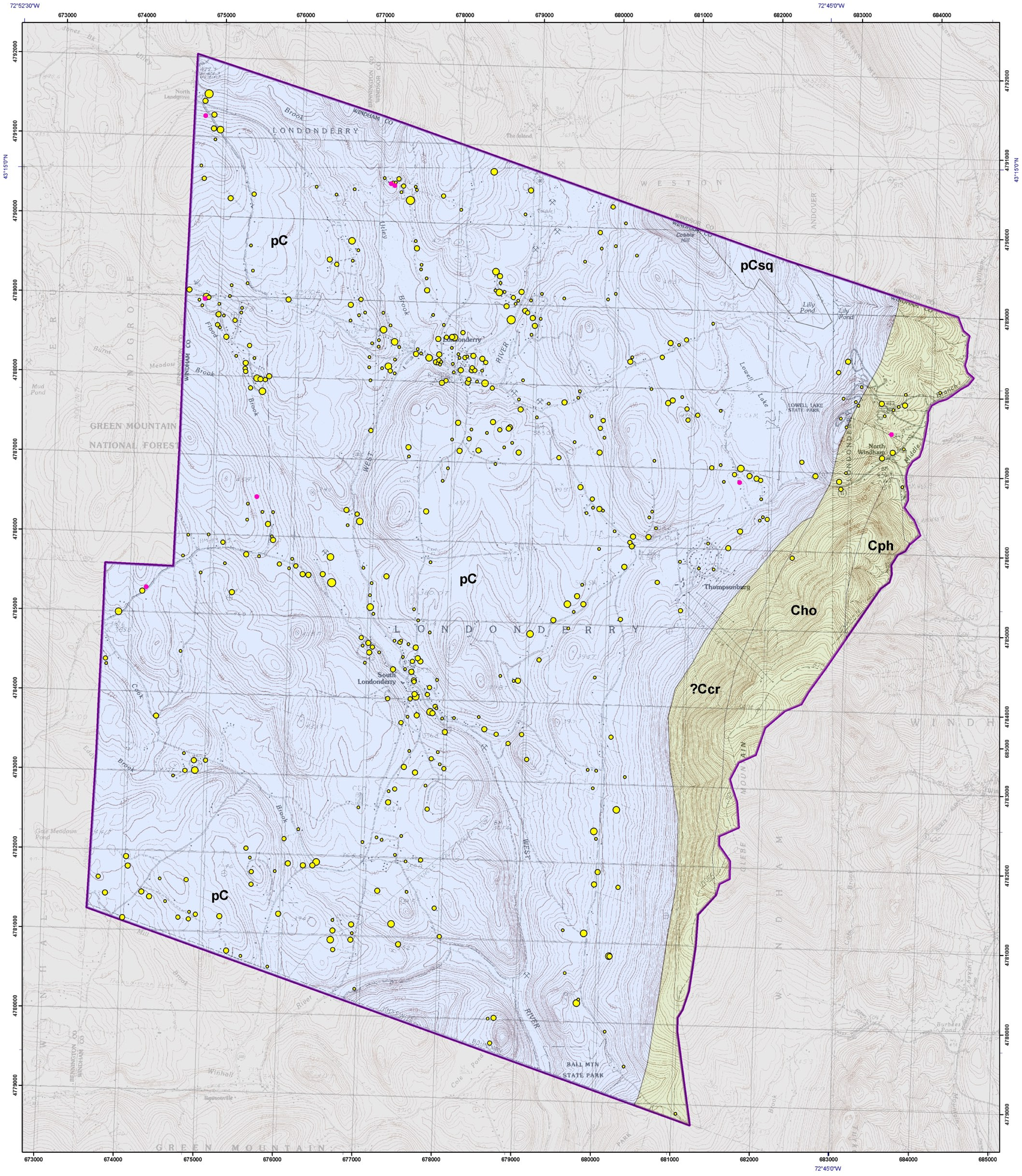
Magnetic declination
15.5 degrees west, 1968

OPEN FILE REPORT - DEGLACIAL HISTORY OF LONDONDERRY, VERMONT

by
David De Simone
2008

VERMONT GEOLOGICAL SURVEY, Division of Geology and Mineral Resources, VT DEC, Waterbury, VT

Vermont Geological Survey Open File Report VG08-2



Legend

Londonderry located bedrock wells, yield in gallons per minute

470 wells
Mean gpm: 14.2 gpm
Mean depth: 271.5'

- 0.0 - 5.0 gpm
- 5.1 - 10.0 gpm
- 10.1 - 40.0 gpm
- 40.1 - 100.0 gpm
- 100.1 - 305.0 gpm

Gravel well
8 wells
Mean gpm: 33 gpm
Mean depth: 111.75'

Hydrogeologic units: bedrock formations from Doll, 1961, Centennial Geologic Map of Vermont

Predominantly schist with minor phyllite and quartzite.
Fair to poor aquifer material dependent upon degree to which water can flow through fractures and along foliation.

?Ccr - Readsboro Member of the Cavendish Formation: quartz-muscovite schist containing biotite or chlorite and characterized by conspicuous porphyroblasts of plagioclase.
Wells in ?Ccr - 1 well
Yield: 5 gpm
Depth: 240'

Cph - Pinney Hollow Formation: pale green quartz-sericite-chlorite phyllite and schist with abundant magnetite, chloritoid phyllite and schist, quartz-sericite-chlorite schist, and rare beds of carbonaceous and schistose quartzite.
No wells in Cph

Cho - Hoosac Formation: quartz-sericite-albite-chlorite schist characterized by albite porphyroblasts – biotite and garnet porphyroblasts common southward; locally graphitic.
Wells in Cho - 16 wells
Average yield: 10
Median yield: 4 gpm
Average depth: 331'
Median depth: 378'
# of wells with yield > 1 gpm: 14 or 87.5%

Predominantly gneiss with minor quartzite, amphibolite and schist.
Fair aquifer material dependent upon degree to which water can flow through fractures and along foliation.

pC - Mt. Holly Complex: mainly fine to medium grained biotite gneiss, locally muscovitic; massive in some localities, fine grained and schistose in others; also abundant amphibolite and hornblende gneiss, and minor beds of mica schist, quartzite and calc-silicate granulite; includes numerous small bodies of pegmatite.
Wells in pC – 453 wells
Average yield: 14.4 gpm
Median yield: 6 gpm
Average depth: 269'
Median depth: 243'
# of wells with yield > 1 gpm: 397 or 88%

pCsq - Mt. Holly Complex: quartzite, micaceous quartzite and quartz-mica schist; minor amphibolite, hornblende gneiss, biotite gneiss and pegmatite.
No wells in pCsq

Town Boundary

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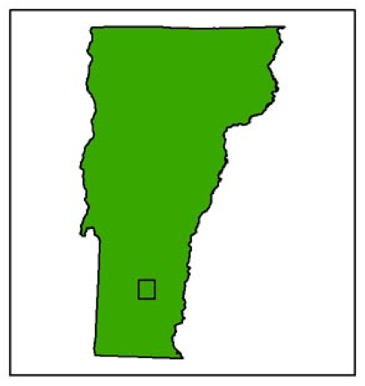

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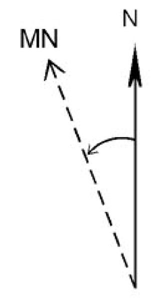
Digital Cartography by Marjorie Gale and Marci Young
Date: March 2009

Scale: 1:24,000

0 600 1,200 2,400 3,600 4,800 Meters

1 centimeter = 0.24 kilometers



Magnetic declination
15.5 degrees west, 1968

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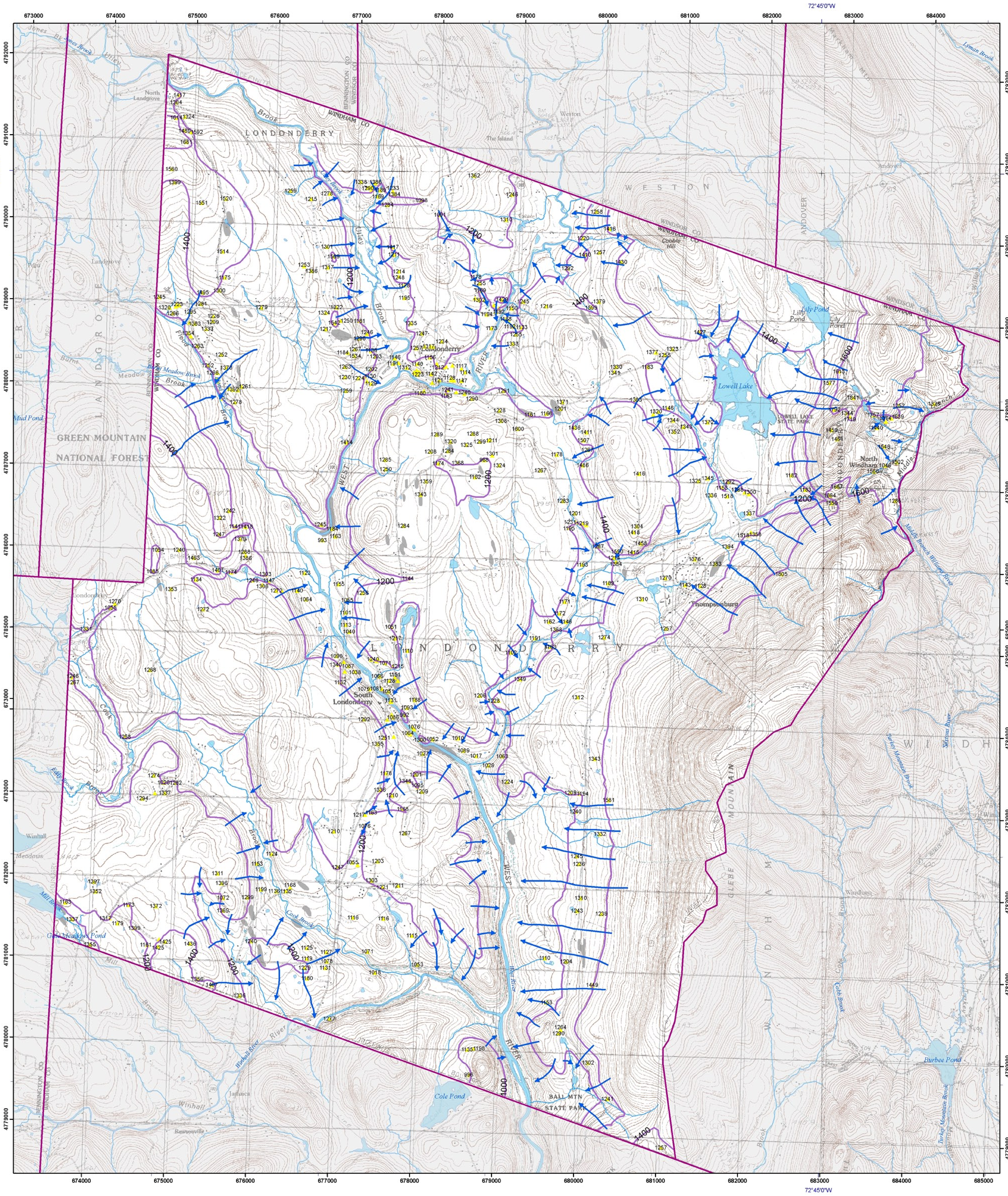
OPEN FILE REPORT - HYDROGEOLOGIC UNITS, LONDONDERRY, VERMONT

by
David De Simone and Marjorie Gale
2008

Vermont Geological Survey Open File Report VG08-2



Legend

Water well, labelled by elevation of static water level

Potentiometric surface contours; contour interval: 200 feet.

Generalized groundwater flow lines

Bedrock outcrop

Town Boundary

Explanation

The static level of water in a well is a useful parameter as it is a factor in determining the amount of water that is stored in the well bore, and thus, available to be pumped into a house or other structure using the water. The elevation of the static water level in bedrock wells reported in the well log data was determined. These data were contoured using a 200ft contour interval only in the portions of the town where there were a sufficient number of wells. The contoured map shows the typical pattern of static levels that mimic the underlying topography. The reported static level for a well may be unreliable if the measurement was made before a well had completely recovered from pumping; such isolated low values of static level were discounted in the construction of the map. In general, static water levels also exhibit seasonal fluctuations and this affects the potentionmetric surface interpretation.

Groundwater flows down the hydraulic gradient from a high potentiometric level to a low potentiometric level. Flow lines are drawn at right angles to the potentiometric contours. The groundwater flow lines reveal the inferred directions or pathways of recharge from higher regions in an aquifer to regions of discharge in lower portions of an aquifer.

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MN N

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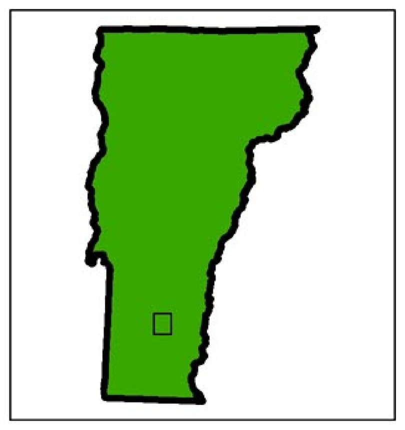

OPEN FILE REPORT - POTENTIOMETRIC SURFACE AND FLOW LINES, LONDONDERRY, VERMONT

by
David De Simone and Marjorie Gale
2009

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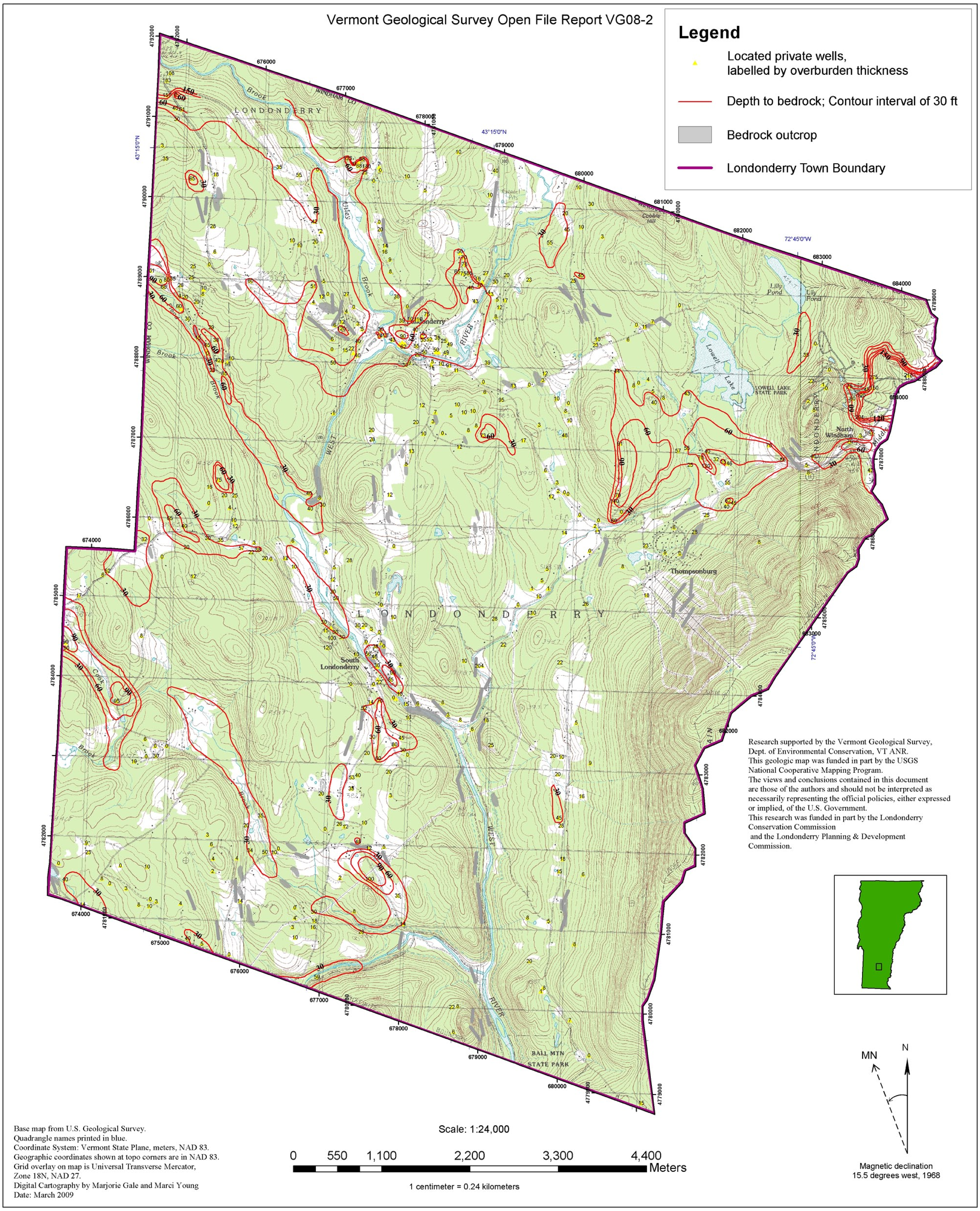

OPEN FILE REPORT - DEPTH TO BEDROCK, TOWN OF LONDONDERRY, VERMONT

by

David De Simone and Marjorie Gale

2008

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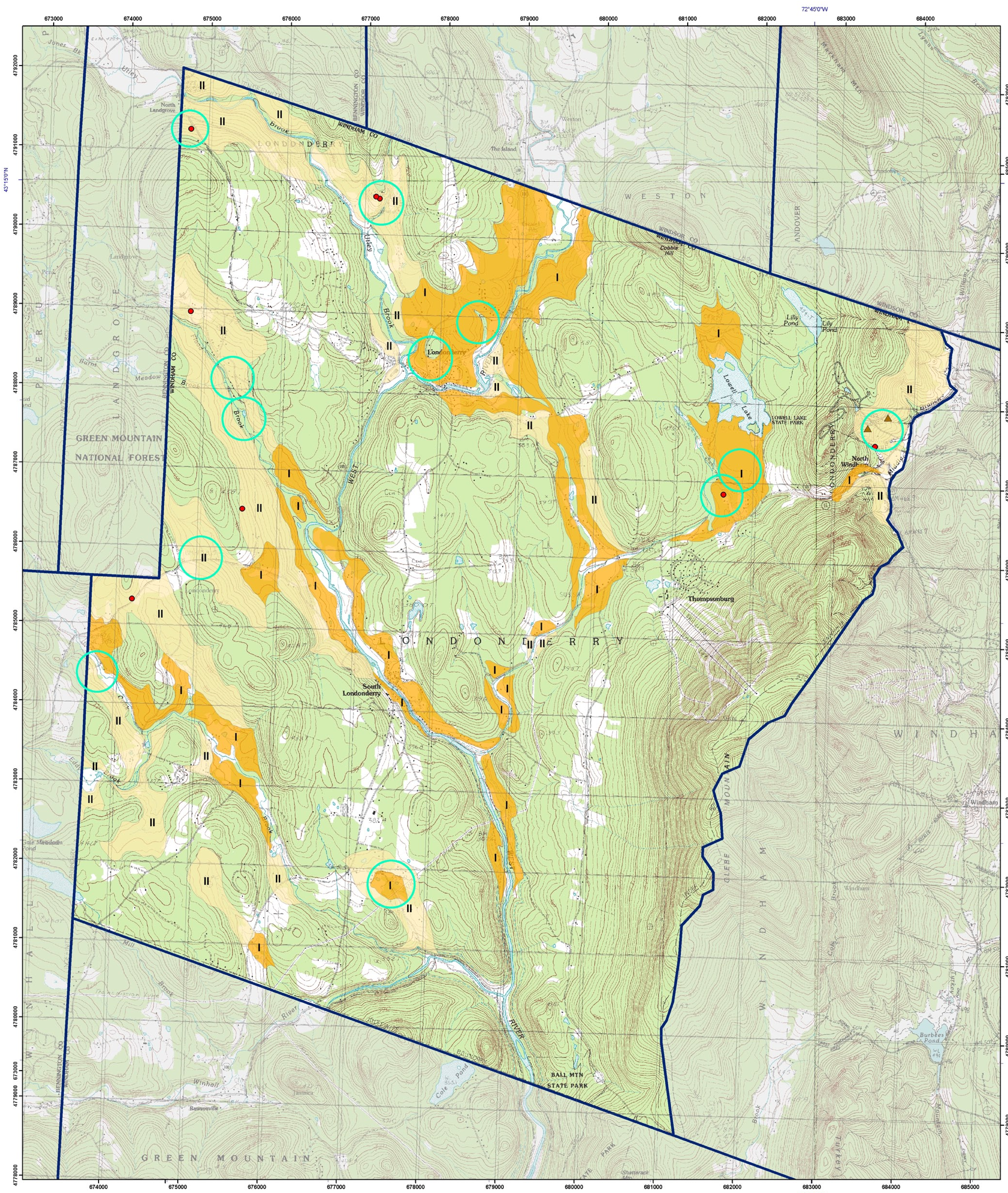

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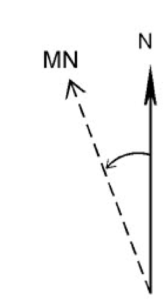
SCALE: 1:24,000

0 0.5 1 2 Miles

0 0.5 1 2 Kilometers

Contour Interval 20 Feet



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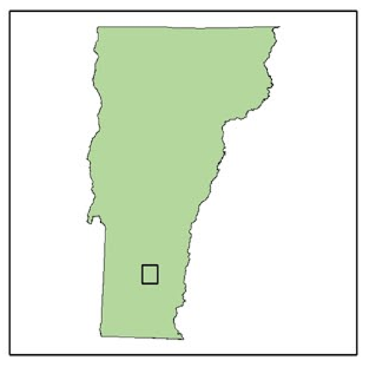

Legend

- I — Areas of permeable sand and gravel; some till containing a sandy matrix component. Permeable sediment extends from surface to depths generally less than 60 feet. Limited aquifer potential based upon existing well data.
- II — Areas of thick till containing a variably sandy to gravelly to bouldery component either at shallow depth or buried beneath lower permeability and denser till; also areas of terrace sediment. Permeable sediment may exist at surface to shallow depths. Permeable sediment may be buried. Limited aquifer potential based upon existing well data.
- Existing gravel well
- Existing ochre wells - two ochre wells may share same aquifer as nearby gravel well.
- Generalized areas where slightly greater potential for overburden aquifer may exist based upon analysis of all well data. Aquifer potential is limited.

Explanation

The Potential Overburden Aquifer with Direct Recharge map depicts the inferred potential for any overburden aquifers in town. The first area delineated is that consisting of permeable sand and gravel with some till having a sand-gravel matrix as recognized from field mapping and from water well logs. This permeable sediment extends from the surface down to depths generally <60ft. This area is inferred to have very limited potential for development of an overburden aquifer resource. However, there may be potential for individual home supply wells and this possibility should be recognized during drilling in the delineated areas.

A second area of generally thick till containing a variable sand-gravel-boulder component exists at shallow depth or more deeply buried beneath a thick and denser till with a lower permeability. This delineated area also includes areas of shallow permeable terrace sediment. Whether at surface to shallow depth or more deeply buried, this area of permeable sediment is considered too widely scattered and too localized to be of much value as an overburden aquifer. Thus, the potential for development of overburden wells is considered very low but comparable to the other area described above.

The existing gravel and 2 ochre wells in town are shown on this map to highlight their association with these delineated potential overburden aquifer areas. All of the gravel wells lie within these areas. The 2 ochre wells are in close proximity and their logs also reveal they may have an association with the buried permeable till unit in the lee or down ice side of the Glebe Mountain ridge in the North Windham area.

Recharge to any of these isolated, fragmented overburden aquifers is likely by direct infiltration of water through the permeable sand-gravel deposits and through the sandy matrix till areas.

Generalized target areas approximately a half mile in diameter are depicted. These areas may encounter permeable overburden due to there being evidence of permeable sediment in existing well logs and/or there being thicker overburden present based upon the depth to bedrock map. These targets are not meant in any way to indicate recharge zones around any existing overburden well.

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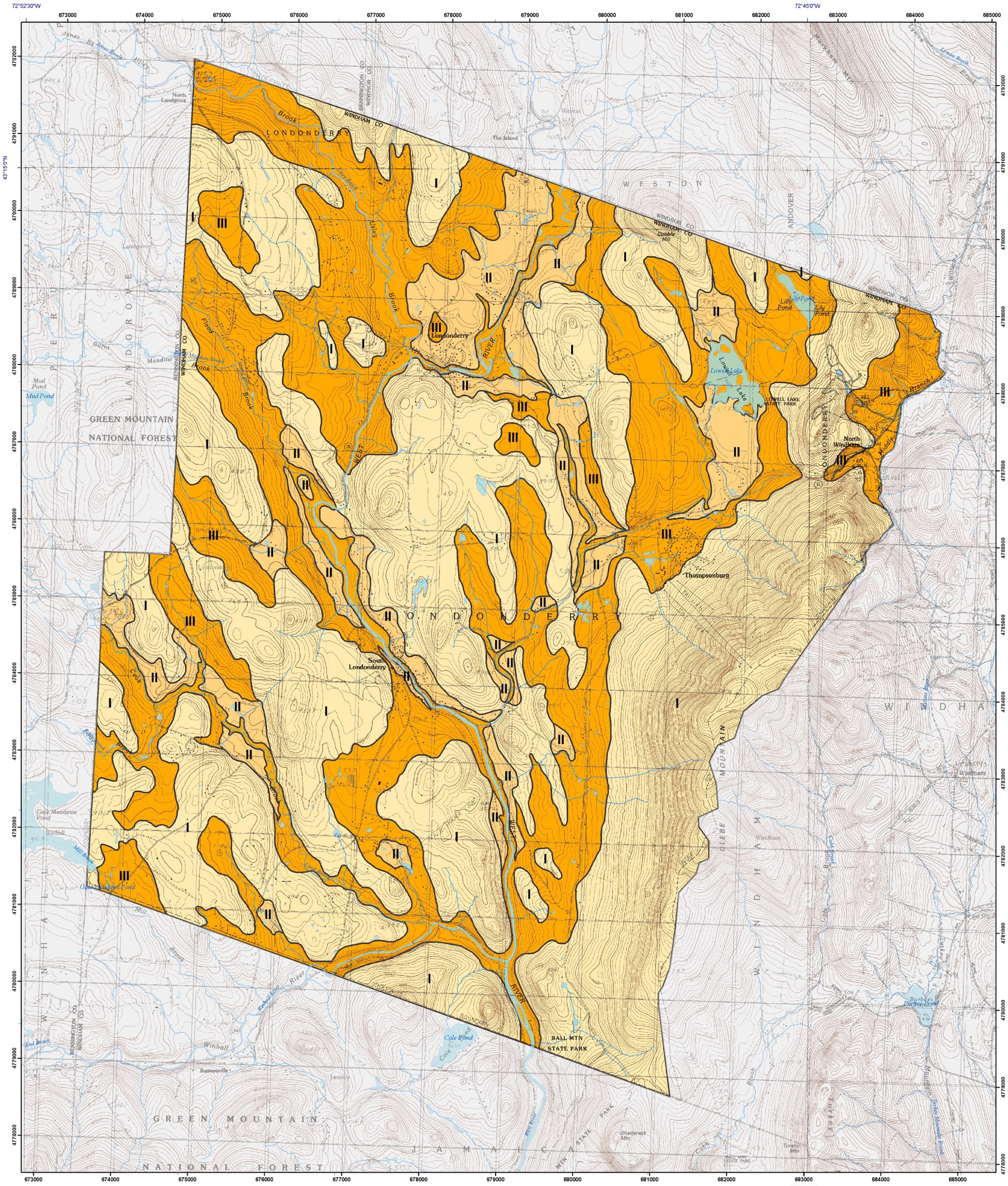

Legend

Recharge Potential to Bedrock Aquifer

I Higher - Thin till areas in mountain regions offer little impedance to downward water infiltration due to the weathered and relatively permeable shallow soils over bedrock. These are the high elevation areas where the thin till veneer and frequent rock outcrops enable some recharge into the underlying fractures and foliation of the rock. Most prominently, these are the summit ridge lines and steep mountain flanks. The ease with which water can infiltrate the soils to the underlying rock in areas of till is dependent upon weathering and thinness of this till veneer. On the high elevation slopes, ridge lines and mountain summits, the till is typically a very thin veneer, typically less than 3 ft. While unweathered till is dense and impermeable, the soils that develop on till veneer allow relatively easy infiltration of water through the thin soil into the rock. Exposed rock has had a long time to weather since the retreat of the glaciers and fractures have opened to allow surface water to infiltrate in the high elevations. This is the reasoning behind the traditional and accepted view of high mountain areas serving as major recharge zones to rock aquifers.

Typically, the contact between thick till and thin till may be recognizable in the field by the occurrence of seeps or occasional springs and very often a break or flattening of the slope. The groundwater flowing at shallow depth cannot penetrate deeper into thick till and may flow out onto the surface in these contact areas. The lower elevation boundary between thin till and thick till can often be seen as a place of seepage where shallow groundwater and, possibly, deeper ground water, may emerge again to the surface.

II Moderate - Areas of comparatively permeable surface sediment may be partly or wholly in contact with bedrock and this facilitates recharge of the bedrock aquifer. These are the areas of ground moraine (Qgm), undifferentiated ice contact sediment (Qk) and outwash sediment (Qow). All 3 of these surficial mapping units are relatively limited in extent throughout the town. Further, their thickness and the homogeneity of the permeable sediment are unknown.

The ground moraine is the most highly variable sediment in this category. Older surficial maps identify this material as ablation till. However, more recent mappers have determined that a variable portion of this sediment was deposited by melt water streams and is permeable. This permeable sediment may be mixed, interlayered with or even predominantly a much less permeable silt to sandy silt loam with abundant stones and relatively low permeability. Individual well logs reveal the highly variable nature of ground moraine.

Undifferentiated ice contact sediment is often predominantly sand and gravel deposited by melt water streams but can be interlayered with material similar to ground moraine. Often, the distinction that can be made during mapping is due to the presence of excavations into the sediment that reveal the extent of the stream deposited sand and gravel. Outwash sediment is chiefly sand and gravel of moderate to high permeability. However, this sediment unit can be of limited thickness and limited recharge potential to an underlying bedrock aquifer.

III Lower - Areas of impermeable thick till do not easily allow water to penetrate any deeper than the base of the soil profile. These occur along the lower mountain flanks in areas where there are no permeable surficial deposits and where thick till blankets lower valley ridges.

Where there is thick till mantling the Green Mountains lithologies, there is a comparatively thick and relatively impermeable barrier to the infiltration of groundwater through the till into the underlying bedrock. Till is an impermeable sediment and even though the upper surface of the till has weathered and has a more permeable soil developed upon it, beneath the soil there is dense, impermeable unweathered till. Thus, thick till areas are not places where the underlying rock can be easily recharged.

The areas mapped as Holocene (Hft, Hal) sediment are more recent deposits of silt, sand and gravel of variable permeability and typically very limited thickness. In most cases, it is usually true these sediments overlie an eroded surface developed upon older sediment. It is unknown whether the underlying sediment is permeable or impermeable without site specific studies. However, these sediments lie at low elevations adjacent to modern streams and infiltrating groundwater most probably flows through these sediments and discharges into the nearby streams without contributing recharge to any underlying bedrock aquifer.

Wetlands, typically places of groundwater discharge to the surface, do not serve to recharge the underlying rock aquifer.

Town Boundary

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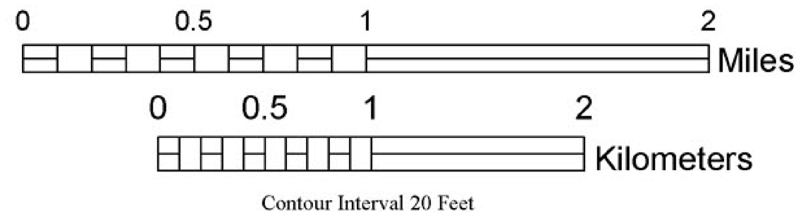
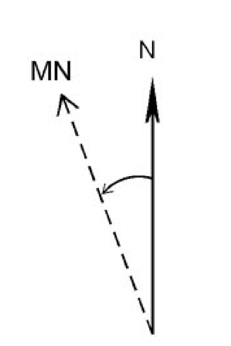


Contour Interval 20 Feet



Magnetic declination
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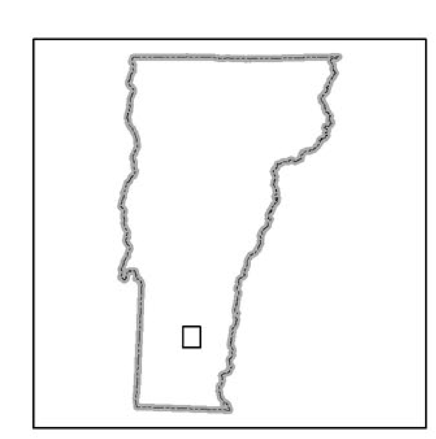

OPEN FILE REPORT - RECHARGE POTENTIAL TO BEDROCK AQUIFER, LONDONDERRY, VERMONT

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