MINI-HANDBOOK OF LAMOINE'S GROUNDWATER HYDROLOGY

By

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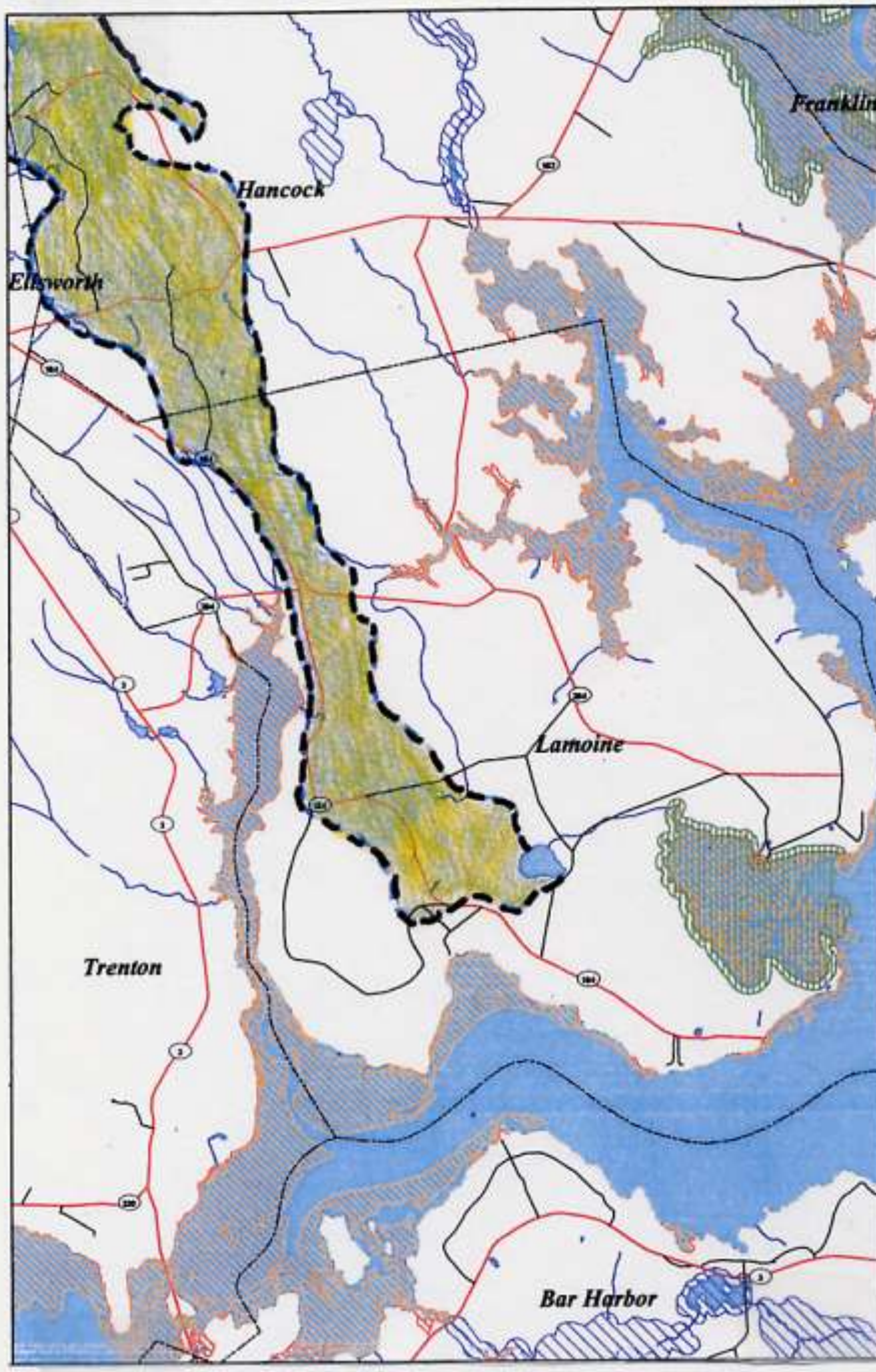

PURPOSE AND SUMMARY

The purpose of this mini-handbook is to serve as background to the Lamoine Conservation Commission's efforts in putting together a pamphlet explaining to the people of Lamoine why the current Building and Land Use Code needs updating to include a comprehensive aquifer protection plan.

Most if not all of Lamoine is underlain by 'water-bearing' fractured bedrock. The word 'water-bearing' is a literal translation of the Latin word 'aquifer'. Practically all Lamoiners tap into this bedrock for a source of fresh water. Exceptions are the few people getting their water from dug wells or from the Cold Spring Water Company. The quantity of available water is generally sufficient for domestic water supply wells. Yields of 5 gallons per minute are common at moderate depths. Also the quality is generally good but the concentrations of iron can sometimes be somewhat elevated.

The water-bearing bedrock in most places is overlain by the 'overburden' (surficial geology), and can consist of a variety of deposits, all of glacial origin. The most prominent of these deposits are the sand and gravel deposits of western Lamoine, mostly straddling route 184, and till and glacio-marine deposits covering pretty much the rest of Lamoine.

These overlying deposits play a significant role in the 'natural recharge' of the underlying bedrock. Precipitation infiltrates and percolates through this overburden, thus the need to protect this part of the 'hydrologic cycle', to prevent groundwater pollution.

The most vulnerable areas for pollution are the sand and gravel deposits, also referred to as the Lamoine Sand and Gravel Aquifer or 'Esker' and depicted by the green area on the map of the front cover of this mini-handbook. These deposits are up to 85 feet thick in places and are very permeable, and therefore absorb a lot of rainfall, close to half of the 45 inches of average annual precipitation. They are an easy pathway for pollution. This is particularly true in areas were the thickness of the deposits has been significantly reduced by mining activities.

Protecting the good quality of a town's water resource, thus groundwater in the case of Lamoine, is tantamount and central to the well-being and good health of the citizens of the town… (liberally translated from De Jussieu, 1733, in *"Histoire de l'Académie Royale des Sciences"*). From this quote we learn that a town's water resources, throughout history, have been considered a communal issue, a common, not a commodity.

PRECIPITATION, EVAPOTRANSPIRATION AND GROUNDWATER RECHARGE

Groundwater comes from precipitation, which includes rain and snow. Only a fraction of it will naturally recharge the groundwater system. The rest will run off or evaporate from surface water bodies and soils, or will be transpired by plants. The combined process of evaporation and transpiration is called ‘evapotranspiration”. Some snow will also evaporate, a process referred to as sublimation.

The average annual precipitation for Lamoine is 45 inches, but can vary greatly from year to year. Historical records for the area list annual average precipitation as low as 28 inches and as high as 60 inches. Throughout the year the precipitation is fairly uniformly distributed, but variations are possible. Normally, monthly precipitation is greatest in November, gradually decreases to a low in August, followed by a gradual increase to November. On average for this region, about 45 % of the precipitation is returned to the atmosphere as evapotranspiration.

Good estimates of natural recharge of groundwater are hard to come by because of the great variability of soil type, soil cover (type of vegetation), slope and seasonal effects. Good guesstimates have been obtained from hydrologic water balance studies and groundwater modeling studies for a large variety of conditions. For the sand and gravel aquifer of the Lamoine area, a reasonable estimate of natural groundwater recharge is about 50 % of annual precipitation. There is indeed little surface water runoff in that area as indicated by lack of streams, but some of the recharged groundwater re-emerges as spring water and wetlands alongside the aquifer boundaries. Natural recharge in the areas covered by dense glacial till and glaciomarine deposits is much less and is in the range of 5 to 15 % of precipitation.

There is a seasonal fluctuation of groundwater levels, with lowest levels reached toward the end of the growing season in September. This lowering is fundamentally due to the seasonal effect of evapotranspiration which reaches its peak during the peak of the growing season, and lower precipitation rates towards end of summer. Groundwater levels recover during the fall and early winter, but decline again from January to mid March, when most precipitation falls as snow, and the soil is much less permeable due to frost, inhibiting infiltration. Water levels begin to rise again in spring fed by snowmelt and rainfall. Significant differences in fluctuations from year to year will be caused by wet and dry conditions.

SURFICIAL GEOLOGY

Surficial geology, as opposed to subsurface geology, deals with the soil materials deposited at or near the surface. In the case of Lamoine these soils are all of glacial origin laid down during the last period of continental glaciation which covered Maine from 22,000 to 13,000 years ago with a snow and ice sheet of more than a mile thick, called glacier. At the peak of glaciation, the land surface was depressed over 200 feet compared to the current elevation, while ocean water levels were at their lowest. Melting started around 17,000 years ago, but rapid melting took place from 13,000 to 10,000 years ago while 'dumping' enormous amounts of material and creating significant melt water channels within the retreating glaciers. Most of the material left behind was unsorted (till) but some was sorted by the flowing water (eskers). As the glaciers melted, ocean levels gradually rose again so that at the end of the ice age all land below approximately 270 feet was covered by the ocean, which covered all land below 270 feet with a coat of marine silts and clays. Subsequently, the land surface gradually rebounded (iso-static rebound) washing away much of the marine sediments leaving behind only a patchwork of marine clays and silts. A brief description of the four major surficial geologic units of Lamoine follows (see Surficial Geology Map, Figure 1).

Eskers or glacial stream deposits, Qg. Lamoine's sand and gravel aquifer is a typical esker, having the morphology or form of a 'beaded' ridge, that is, not continuous. Eskers consist of sorted and stratified sand and gravel material deposited by melt water streams contained by the glacier. When the glacier has melted it will leave behind a ridge of sediments on the topography. In Maine these ridges are frequently referred to as 'horsebacks'. Esker materials are obviously very permeable. The thickest deposit in Lamoine is 85 feet. Local widenings of Lamoine's esker appear to be **submarine fan deposits,** also consisting of sand and gravel but somewhat finer grained than esker deposits. These deposits may have formed beneath a floating ice shelf, some 150 to 200 feet below what was then sea level.

Glacial till, Qt. Till is the poorly sorted material either deposited at the base of the glacier (lodgment till, very compact and dense) or 'dumped' by the glacier (ablation till, less dense). It is a heterogeneous mixture of silt, sand, gravel and boulders. It is several orders of magnitude less permeable than esker material. Roughly 25 % of Lamoine is covered by till.

Glacio-marine silts and clays, Qp Referred to as the Presumpscot Formation, these deposits consist of layered silts, clayey silts and clays, sometimes containing shells. Glacier movement was grinding up rocks into 'rock flour' which washed off into the ocean, flocculated and settled down at the bottom during the period of marine submergence. These marine deposits are often covered by coarser materials and may thus be found frequently at shallow depths, but large patches remain at the surface of the Skillings River flats of northern Lamoine.

Raised beach deposits, Qb. These deposits consist of well-sorted medium to coarse sand generally occurring as blanket deposits on wave-cut terraces, probably derived from nearby stratified drift deposits. Two of these deposits are near Lamoine Beach, two in east Lamoine and two in Lamoine village.

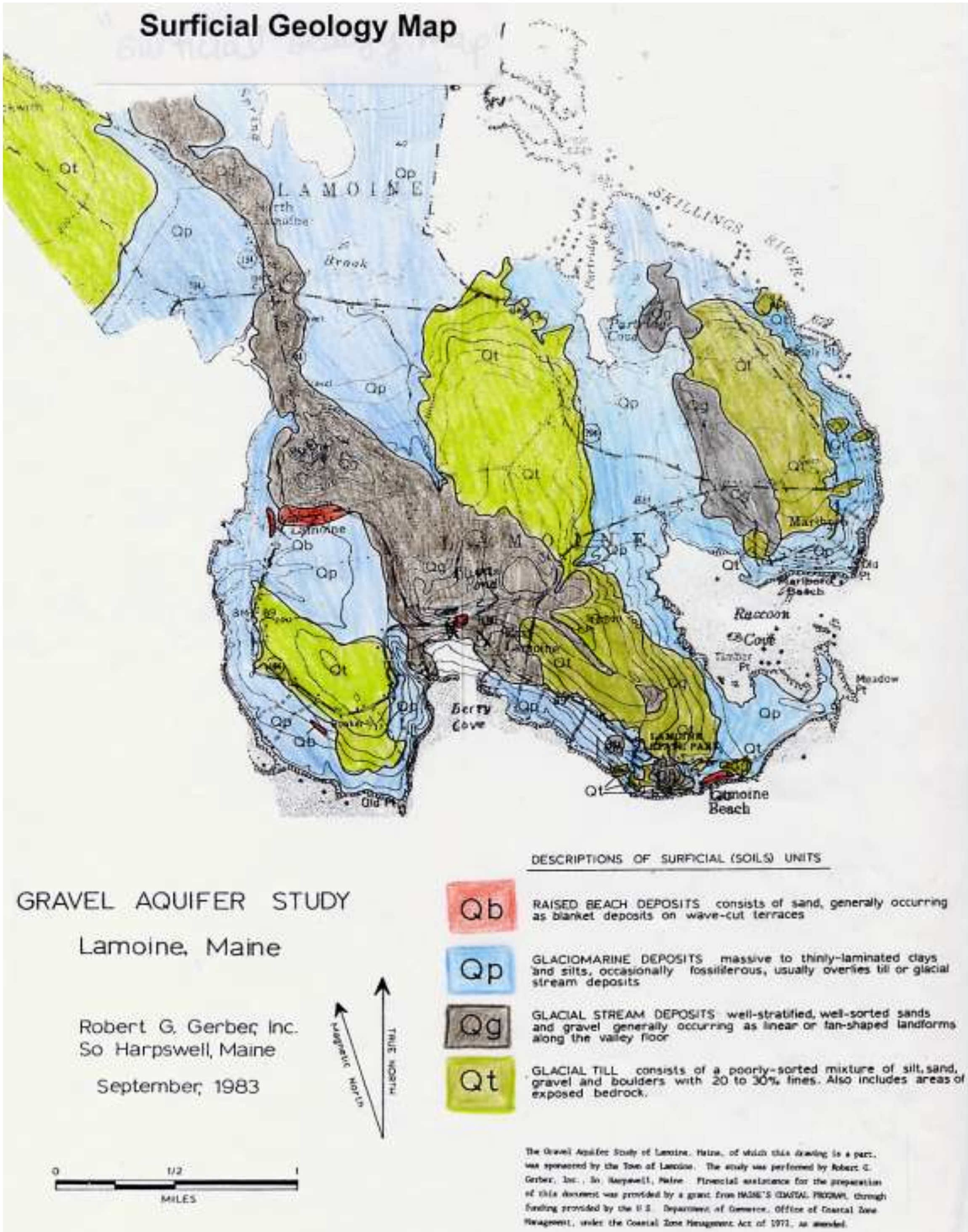

Figure 1. Surficial Geology Map

GROUNDWATER FLOW IN THE SAND AND GRAVEL AQUIFER

To explain groundwater flow in Lamoine's sand and gravel aquifer, two sketches have been prepared for that purpose. One sketch (Figure 2) consists of a water table contour map within the confines (boundaries) of the sand and gravel deposits. The thicker lines are water table contours, and the thinner lines are land surface contours. Superimposed on that map are directions of groundwater flow, indicated by the red arrows. Groundwater flow lines are perpendicular to the water table contours in a downward direction, just like a marble put on a hill rolling down along the steepest path, that is, perpendicular to the contours. The second sketch (Figure 3) shows a typical east-west cross-section across the aquifer. Observe that the vertical scale is exaggerated compared to the horizontal scale. Because of the large permeability of the aquifer, precipitation infiltrates and percolates readily downward toward the water table which is usually far below land surface, up to 35 feet and more in the middle. Groundwater is seen to recharge the underlying fractured bedrock but is also seen to flow sideways and may re-emerge as a spring or as a swampy area. Several such springs, some with pretty good flows, are known to exist along the aquifer boundaries. What does one learn from these two sketches?

- It is incorrect to envision this aquifer as a subterranean stream, flowing swiftly from north to south, and being affected by activities much farther north of Lamoine. In fact, as can be observed in Figure 2, most flow lines leave the aquifer sideways, or are reversed flowing northward as for example just south of the Rt. 184/204 intersection, where there is a northward component of flow in the aquifer. Groundwater flow is rather slow. Velocities of a few feet per day are considered to be a dynamic groundwater system. Much smaller velocities are usually the case and depend on the permeability of the aquifer and the slope of the water table.
- As water reaches the water table, part of it is constantly diverted sideways because of the water table topography, while another part is recharging the underlying bedrock.
- Because of this slow movement, issues of groundwater quality are very much a local issue, but tend to slowly spread (disperse) with time.
- Groundwater availability is predominantly governed by nearby recharge conditions. Although it is correct that there is plenty of rainwater constantly recharging both the sand and gravel and the bedrock aquifers in Lamoine, it is incorrect to assume that all this water is readily accessible wherever one lives.

Note. The water table contour map was produced by Robert G. Gerber Inc. (1983), generated by a groundwater flow model and constrained by groundwater level measurements of that time. Since this was a steady state approach using average hydrologic conditions, a similar contour map would be obtained today. Figure 2 only represents the northern portion of this map.

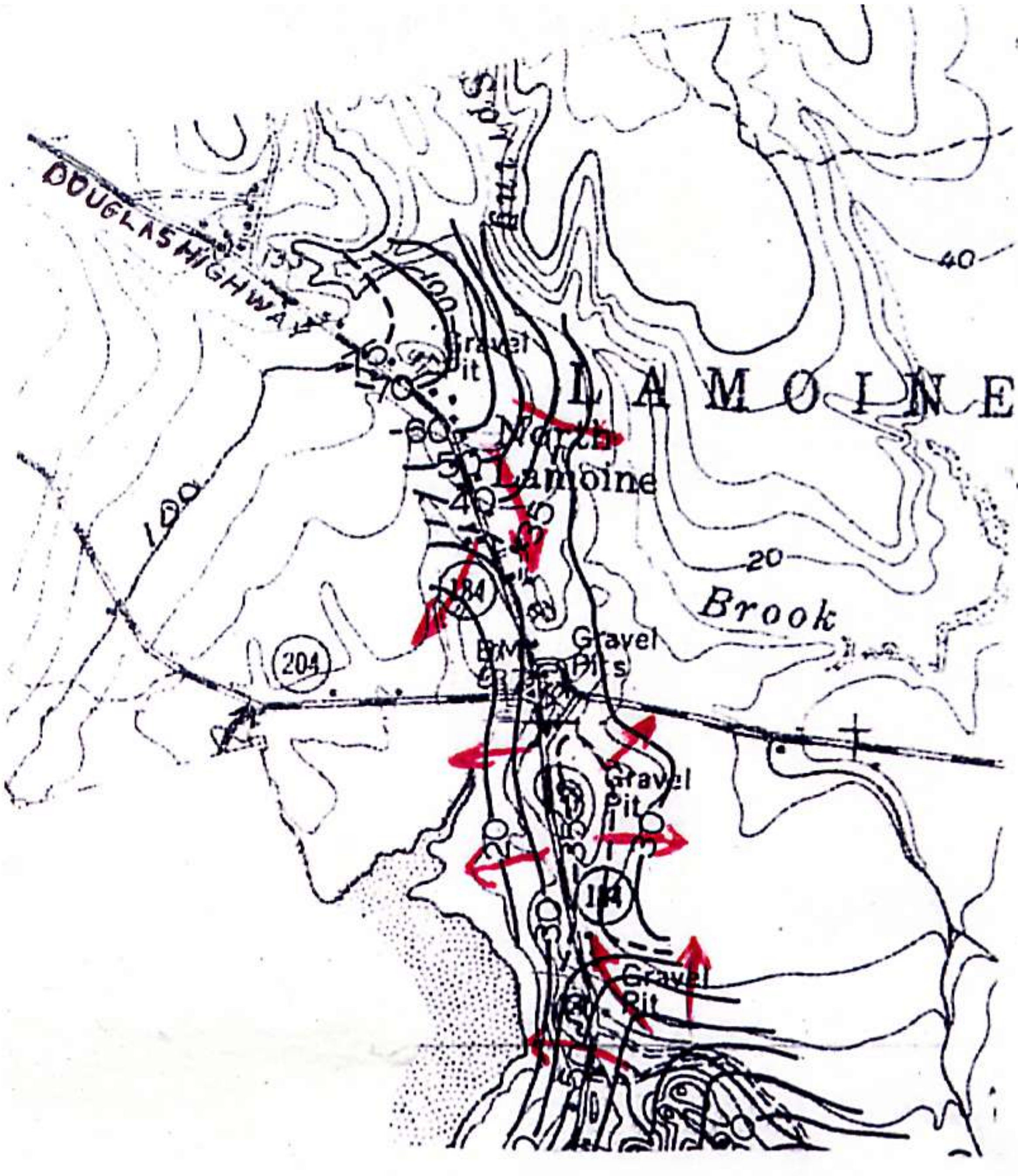

Figure 2. Water Table Contour Map of Northern Portion of Lamoine Aquifer

The above map is showing the intersection of Rt. 204 with Rt. 184 (Douglas Highway) in the center of the map. The thicker black lines are water table contours, and the thinner black lines are surface elevation contours. A contour is a line of equal elevation. The red arrows indicate the direction of shallow groundwater flow.

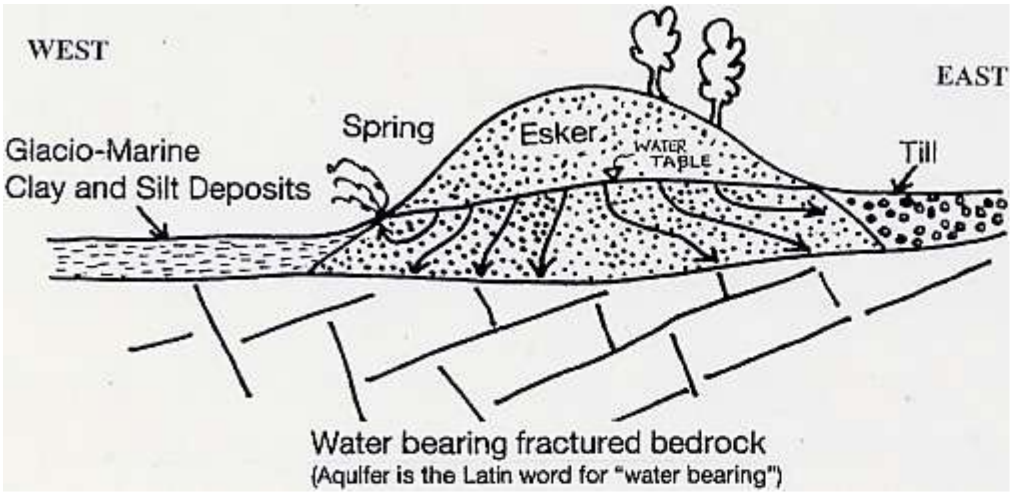

Figure 3. Typical East-West cross-section of Lamoine Esker, also referred to as The Sand and Gravel aquifer.
Note: Vertical scale is exaggerated

WHAT IF THE AQUIFER BECOMES POLLUTED?

It is better to prevent than to heal.

- Once an aquifer is polluted, it is next to impossible to remediate.
- No polluted aquifer has been successfully remediated.
- Remediation is very expensive.

The few public dollars that are available are better used to prevent, or to contain in case of pollution.

CAN LAMOINE'S SAND AND GRAVEL AQUIFER SUSTAIN COMMERCIAL WATER EXTRACTION?

To a limited degree, the potential is there. If a gravel-packed well were to be developed into Lamoine's aquifer, the nearby flow lines leaving the aquifer would now reverse towards the well (see Figure 3), but long-term sustainability of such a well would depend on local recharge from precipitation. Assuming a zone of influence with a radius of 1200 feet, and an annual recharge from precipitation of 22 inches (average hydrologic conditions), one could conceivably achieve a sustainable yield of 120 gallons per minute (gpm) or better, roughly 50 % of the time. In other words, 120 gpm could be equaled or exceeded 50 % of the time. A well field of 3 to 4 such wells spaced a few hundred feet apart, thereby increasing the zone of influence, could easily sustain a combined pumping rate of more than 120 gpm, say 150 to 175 gpm, because one well continuously pumped at 120 gpm would constantly shut down caused by excessive drawdown in the well bore, whereas several wells pumped intermittently would not. The ideal location, if it exists, would be where the aquifer is wide with a low in the bedrock topography forming a 'bowl'. A pumping rate of 150 gpm amounts to 216,000 gallons per day, which is 864,000 one-quart bottles of water a day! It is to be understood that the above flow rates are based on balancing withdrawal with recharge under average hydrologic conditions, and on a rough estimate of the zone of influence. One of the uncertainties in this calculation is the recharge rate. Also, it is a fact that the integrity of Lamoine's sand and gravel aquifer is compromised to some extent by past, present and future sand and gravel mining activities, causing a significantly reduced saturated thickness of the aquifer, which in turn results in reduced storage capacity of the aquifer and increased risk of pollution. Lastly, as a caveat, riparian well owners will be impacted by this activity, and springs and wetlands may dry up.

WHAT ABOUT SEAWATER INTRUSION?

Seawater intrusion is a natural phenomenon whereby saltwater occurs as a 'wedge' below freshwater in coastal aquifers. Freshwater being lighter than saltwater will 'float' as a 'bubble' on top of saltwater in the aquifer near the shore according to the hydraulic principle of buoyancy (remember Archimedes' "Eureka"?). During extended periods of drought this wedge moves farther inland because of a lower water table (smaller fresh water bubble).   If, for example, the water level in one's well near the shore is 10 feet above MSL (Mean Sea Level), then, on average, one will encounter saltwater at a depth below MSL of forty times the difference between the water table and MSL, thus at a depth of 400 feet below MSL. In groundwater hydrology this is called the Ghyben-Herzberg relationship. As long as a well is only moderately deep, say less than 150 to 200 feet, seawater intrusion for most domestic wells near the shore is seldom an issue. Moreover, a domestic well withdrawing about 250 gallons per day barely 'skims off' some of the water of the freshwater bubble. In contrast, commercial groundwater extraction will have a much greater impact on lowering the water table than a domestic well would, thereby aggravating seawater intrusion with potential 'upwelling' of saltwater in nearby domestic wells.