Buried valley aquifers: New data collection for municipal water supply and watershed management, Caledon East, Ontario

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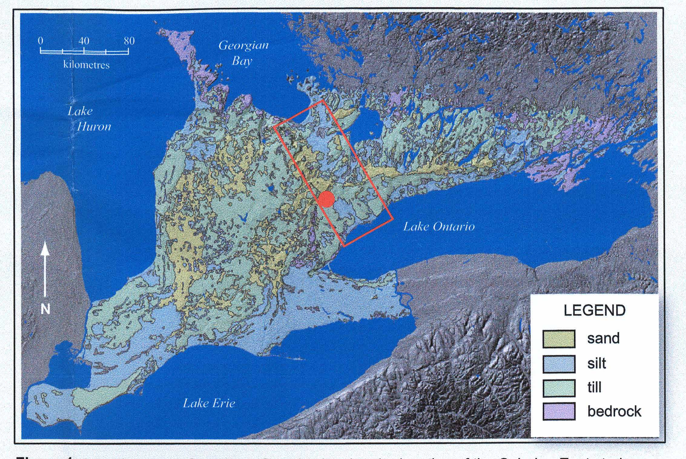

Figure 1. Location map of southern Ontario showing the location of the Caledon East study area (red dot). Geology modified from Barnett et al., 1991.

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Introduction

- Buried-valley aquifers are an important source of water supply in southern Ontario. They are significant to water resource managers as the need increases for source water protection, security of supply, and for constraining estimates of watershed-scale water balances.
- Prospecting methods for this aquifer type have seldom used modern exploration techniques to discover, target, and assess the reservoir potential and flow-system properties. This work outlines the exploration strategy employed near Caledon East in an ~141 km^2 area of the Credit River and Humber River watersheds, southern Ontario.

Regional Geological Setting

- The lithostratigraphic framework of the study area (Karrow, 1967) has been reinterpreted using basin analysis principles and event stratigraphic concepts (Figs. 1, 2; Sharpe et al., 1996). A key result is the mapping of a regional unconformity that is defined by drumlinized Newmarket Till and tunnel channels (Barnett et al., 1998).
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- To permit mapping of the regional stratigraphy using archival data, the lithostratigraphic framework has been simplified to five principal units. They are, stratigraphically upward: 1) Paleozoic bedrock, 2) Lower sediment, 3) Newmarket Till, 4) Oak Ridges Moraine and channel sediment, and 5) Halton Till. Lower sediment (LS) comprises 10 poorly exposed formations representing middle Wisconsinan and older sediment (Fig. 2) described mainly from Scarborough Bluffs (Karrow, 1967; Eyles et al., 1985; Sharpe et al., 1996).

Geological Model

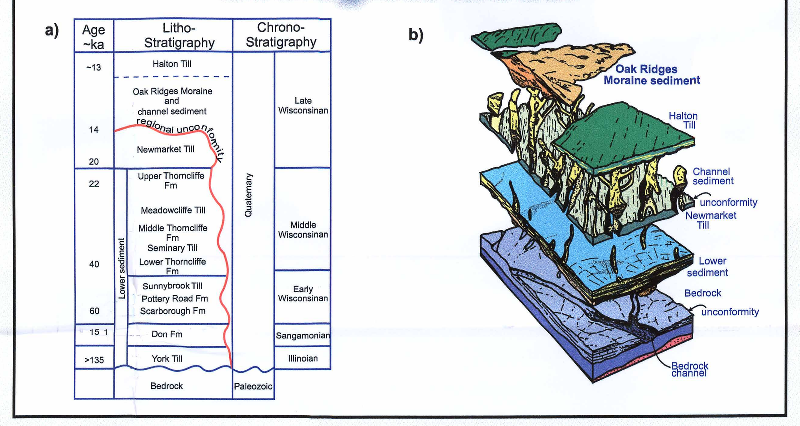


Figure 2. a) Lithostratigraphic framework and b) conceptual geological model of the ORM region.

Study Area Geology

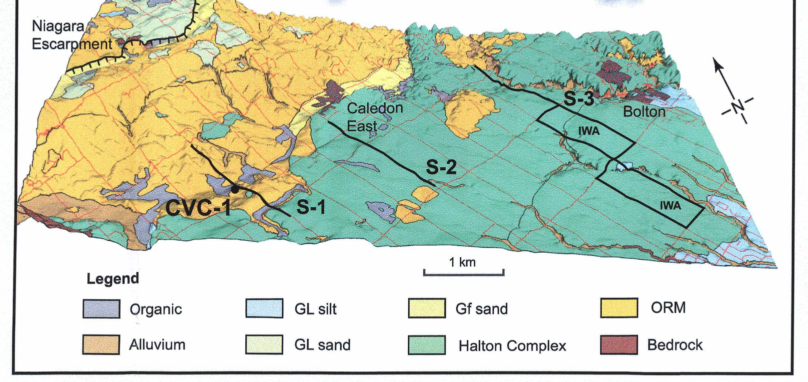


Figure 3. Geological context of study site. a) Digital elevation model (DEM) with a surficial geology drape of the area. Geology from Russell and White (1998). Seismic sections (e.g. S-1) and key borehole sites (CVC-1, IWA (Interim Waste Authority sites) are indicated.

Data

- A continuous cored borehole (CVC-1) was drilled to a depth of 180 m and logged with downhole geophysics (Fig. 4). Sampling was completed for grain-size, total organic carbon, and water content (see Russell et al., 2005).
- Reflection seismic data were collected along 3 profiles, at a spacing of 4-6 km, for a total of ~12 line-kms (Figs. 5).
- Seismic data were collected using a 120 channel array of 40 Hz geophones at 5 m spacing, and an IVI minivib 1(TM) vibratory seismic source (30-300 Hz). The output here is shown as a variable density display (see Pullan et al., 2004, for additional info).
- Geophysical logs obtained in the cased borehole include natural gamma, conductivity, magnetic susceptibility, spectral gamma, temperature and seismic velocity measurements (Fig. 6).

Sediment Log

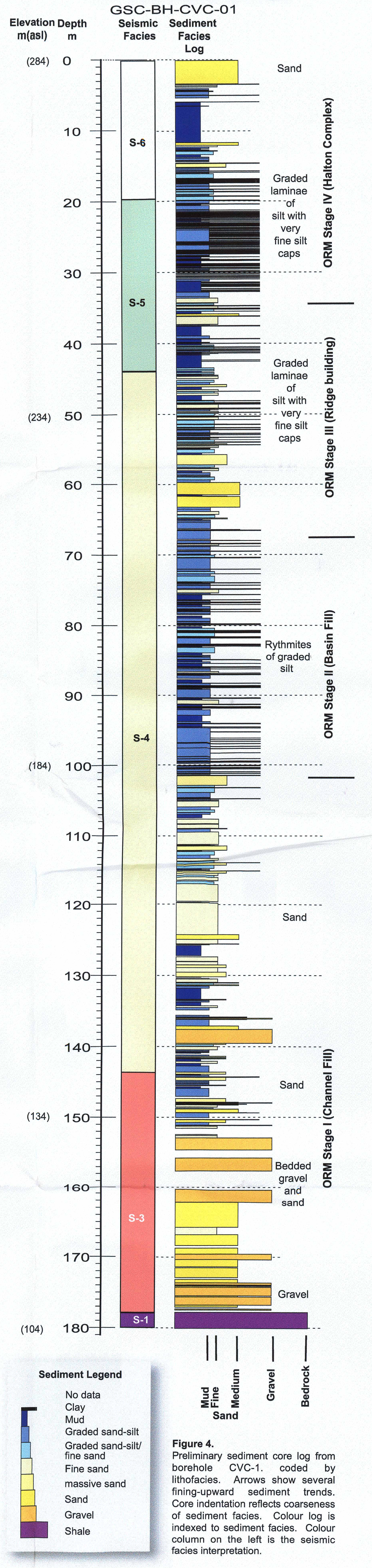
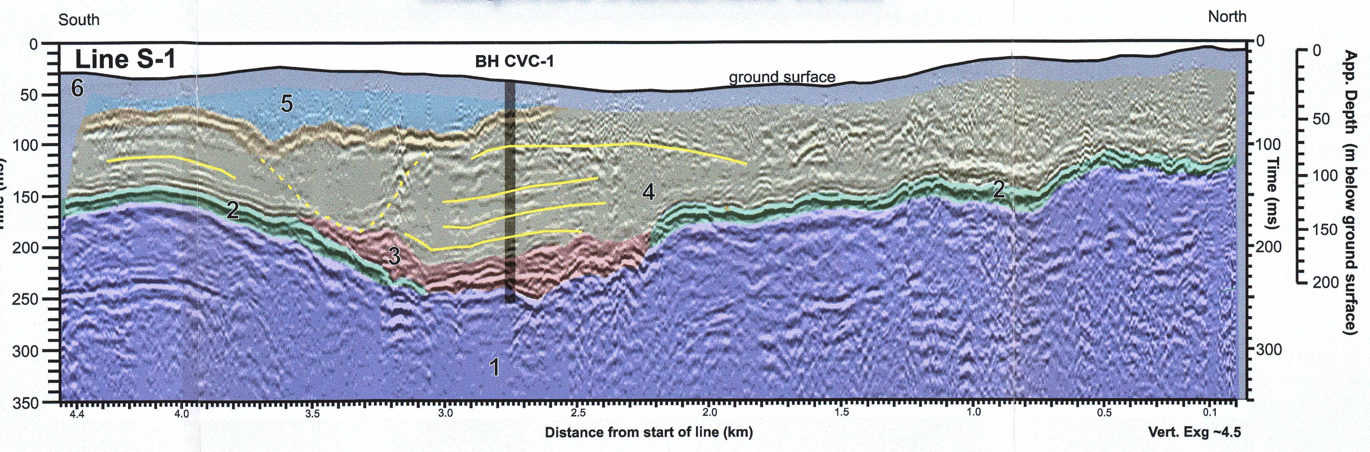


Figure 4. Preliminary sediment core log from borehole CVC-1, coded by lithofacies. Arrows show several fining-upward sediment trends. Core indentation reflects coarseness of sediment facies. Colour log is indexed to sediment facies. Colour column on the left is the seismic facies interpretation.

- Bedrock is intercepted at 178 m and is Georgian Bay Formation.
- The 178 m sediment log fines upward from basal gravel and sand to mud recording a decrease in flow energy in the fill succession and a change in depositional environments.
- Secondary, smaller fining-upward cycles (5-6) record temporal variations in depositional processes (Fig. 7) and control various scales of aquifer heterogeneity.
- The coarsest basal sediment is within the buried valley (below 100m depth, Fig. 5) and has not been previously recorded in water well records from the area.
- Detailed sediment descriptions allow for improved hydrogeological correlation, characterization and groundwater modeling.

Seismic Stratigraphy

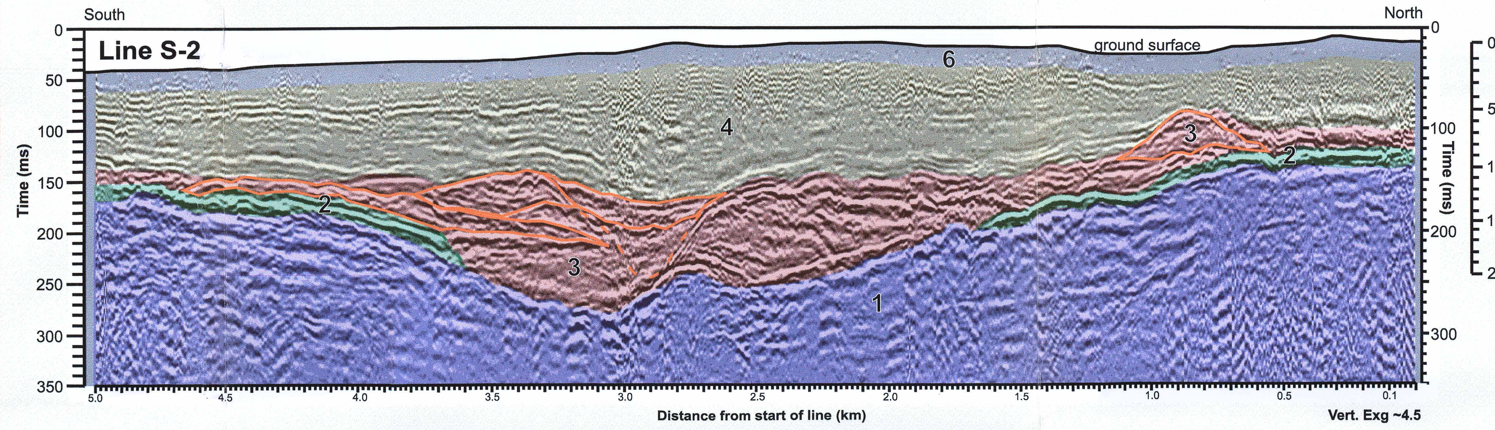
Interpreted Subsurface Strata



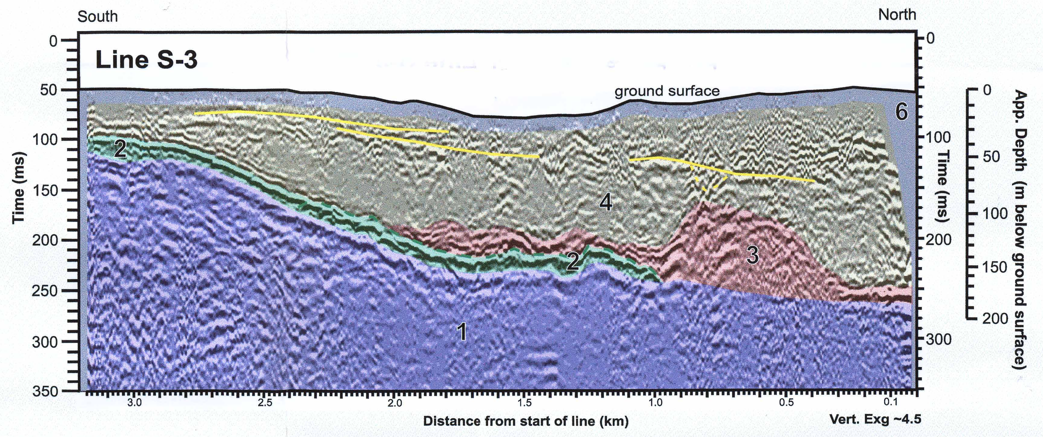
- (S-1) Bedrock valley is ~70 m deep and > 1.5 km wide. To the north the bedrock slope rises toward the Niagara Escarpment. The sediment succession is predominantly seismic facies 4. From core data seismic facies 4 is inferred to fine upward from sand to silt. Isolated sand and gravel beds occur within the upper silt rich part of the succession. (see figure 4).

Colour legend indexed to colours on seismic section.

- **6. Shallow zone of no data return.**
- **5. Silt:** A < 40 m thick, low-amplitude, weakly planar, discontinuous seismic facies. Interpreted only along line 1 where borehole control exists.
- **4. Sand and Silt:** An 80-100 m thick, low-amplitude, weakly planar seismic facies. It is interpreted to be sand and silt.
- **3. Sand and Gravel:** A <100 m thick seismic facies of high-amplitude, less continuous, truncated and inclined reflectors that is interpreted to be stacked sand and gravel sets with cut-and-fill and cross-bedding structures. This seismic facies is inferred to represent high-energy deposition from a subglacial fluvial system.
- **2. Diamicton/Gravel:** Overlying bedrock is a continuous, relatively coherent high-amplitude facies ~10 m thick that is interpreted to be diamicton or coarse gravel.
- **1.Georgian Bay Shale:** A basal, semi-continuous, high-amplitude reflector seismic facies that is interpreted as shale and limey bedrock of the Georgian Bay Formation.



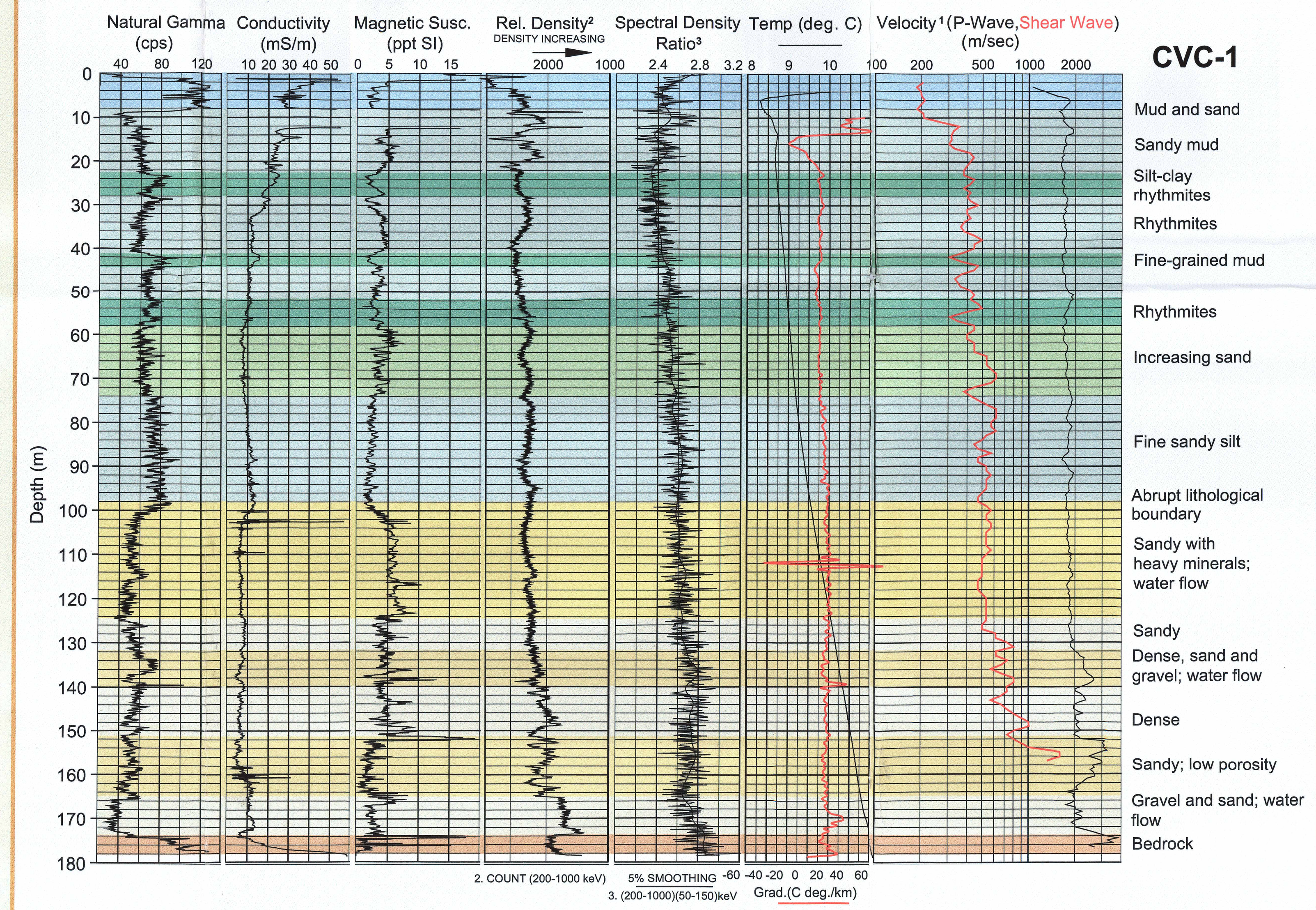
- (S-2) Seismic facies (3) is up to 100 m thick and completely fills the buried valley. Interpreted to be sand and gravel it forms ~35% of the sediment succession along this line.



- (S-3) The bedrock valley is broadening and only the southern margin is observed on this seismic line. Seismic facies 3 (sand and gravel) is less extensive and seismic facies 4 (sand and silt) is appreciably thicker.

Figure 5. Reflection seismic data displayed as south to north profiles. Location of respective lines is shown in figure 3. Seismic reflection patterns are correlated with sediment facies identified in borehole CVC-1 (Fig. 4). Five main seismic facies are identified. Horizontal scale of lines is in kilometres, vertical scale is in milliseconds (left side) and metres below ground surface (right side).

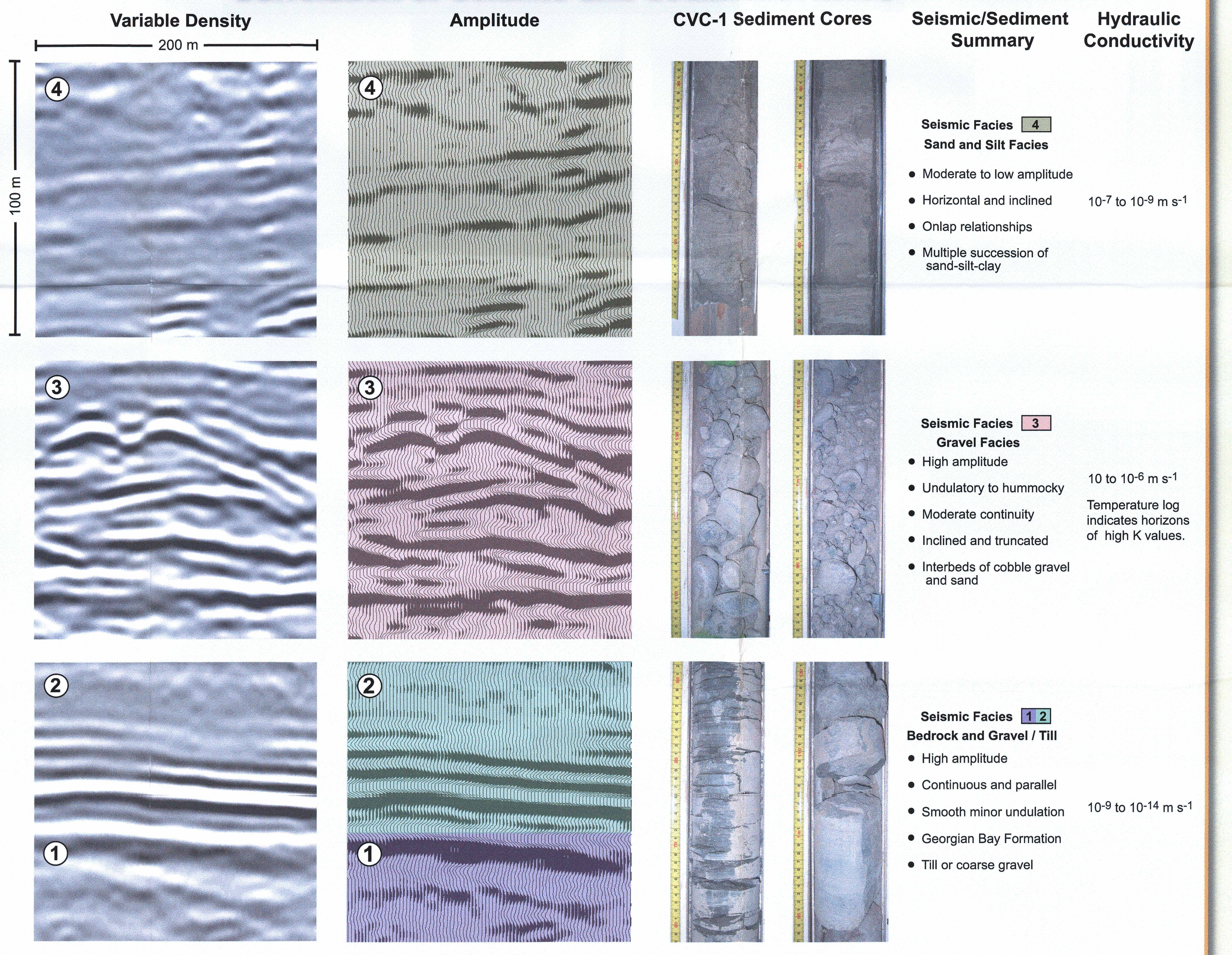
Borehole Geophysics



- Borehole logging assists with mapping aquifer extent and properties across the bedrock valley.

Figure 6. Downhole geophysics for borehole CVC-1 showing geophysical logs and preliminary interpretation. The pronounced change in gamma and magnetic susceptibility data at 98 m depth corresponds to a distinct upward change in core character from sand to silt.

Correlation of Seismic and Sediment Facies



- Seismic patterns (facies) linked to sediment type (facies) supports hydrogeological(groundwater) predictions in this buried valley.

Figure 7. Correlation of the four principal seismic facies with sediment facies and illustration of representative seismic signature and core photos. Estimated hydraulic conductivity of sediment are from the literature (Freeze and Cherry, 1979).

Bedrock Valley

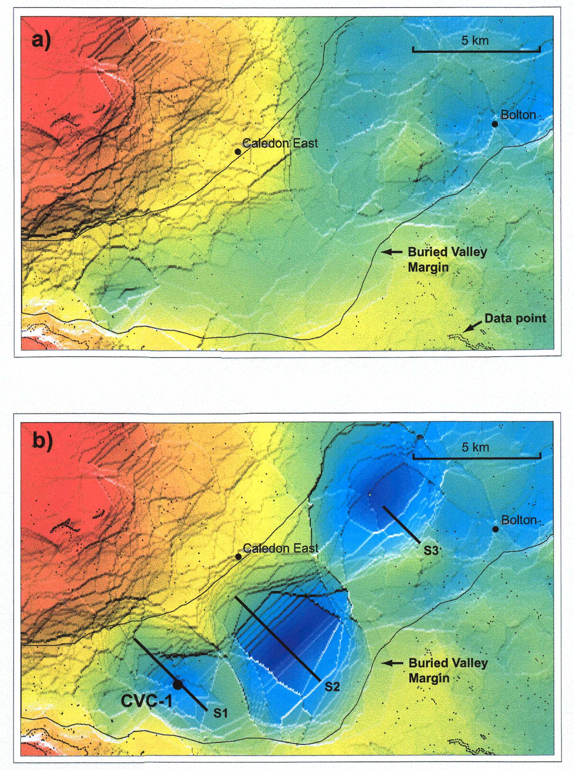


Figure 8. Interpolated bedrock surface from archival data (a) and including new data (b). Note interpolative artifacts between seismic lines.

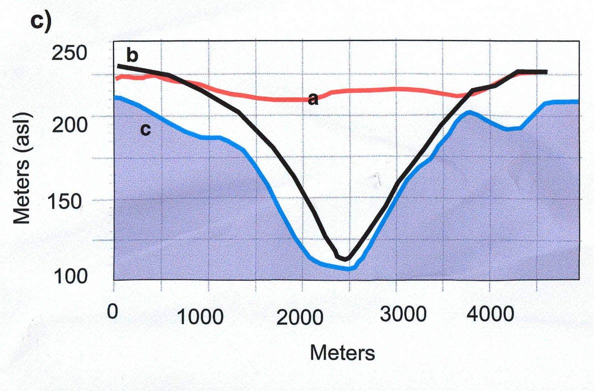
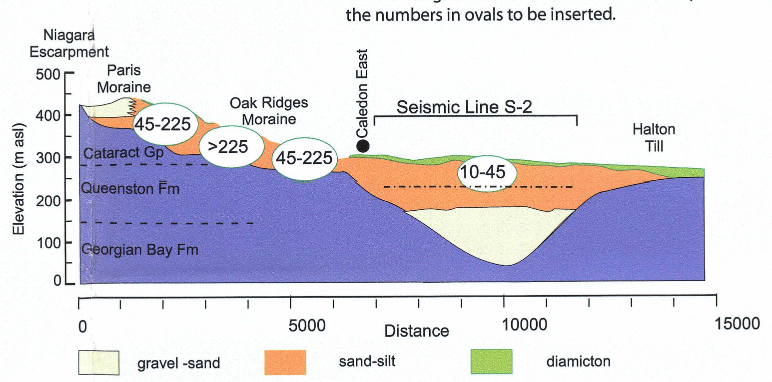


Figure 9. Graph of interpolated valley cross-section at position of CVC-1. Valley geometry from a) archival data, b) addition of CVC-1, and c) addition of seismic profile S-1.

Hydrogeological Implications

Vertical exageration needs to be increased to permit the numbers in ovals to be inserted.



Caledon East is off line 1 km to the northeast (into page).

Elevation of bedrock contacts are schematic

Approximate location of bedrock surface prior to drillhole and seismic data collection. This is slightly deeper than the deepest layers modelled by Dames and Moore, Canada (1996).

(45-225) General well yields are from Dames and Moore, Canada (1992), Figure 9.

Figure 10. Schematic cross-section extending from the Niagara Escarpment toward the southeast along a continuation of the Caledon East seismic line 2.

- New seismic reflection data and the CVC-1 borehole data has increased the known volume of the previously poorly defined buried valley at Caledon by ~40 %.
- Locally the buried valley fill may consist of up to 100 m of interbedded sand and gravel with hydraulic conductivity values in the range of 10^{-2} to 10^{-5} m s^{-1} (values from Freeze and Cheery, 1979).
- New data provides a framework for strategic hydraulic testing of this buried-valley aquifer.
- Buried valleys are poorly identified from water well records where shallower sediment yield adequate potable water for domestic water supply. For example, Dames and Moore (1992, 1996) used water well records and had no means of assessing this buried valley.
- Buried valleys (bedrock or sediment hosted) are important aquifers regionally and currently supply water to municipalities at Aurora, Newmarket, Uxbridge, Nobleton, Inglewood, and Cheltanham.
- The Caledon East area illustrates the need for new, high-quality, subsurface data (i.e. seismic profiles and cored boreholes) to discover and assess previously unknown aquifer potential.
- This buried valley east of the Forks of the Credit is one example of a possible relationship that may exist between re-entrants along the Niagara Escarpment and buried valleys to the east (e.g. Hockley, Sheldon, Limehouse).
- Geoscience expertise and methods available from geological surveys provides an important complement to the water resource management skills of conservation authorities, and municipal governments.

Summary

- New borehole and seismic data collected within a buried valley has increased the known valley volume by 40 %
- Seismic facies analysis indicates that the valley fill may contain up to 100 m of sand and gravel
- 60 % of the valley fill (prior to data collection) was interpreted to be Oak Ridges Moraine (ORM) sediment. New data collection indicates a greater percentage of the fill is ORM sediment.
- New data indicates that the buried valley probably contains a coarse grained aquifer that has not been previously intercepted by water well records.
- The thickness and lateral continuity of the seismic facies interpreted as sand and gravel suggests an aquifer that could possibly provide municipal-scale water supply.

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Acknowledgments

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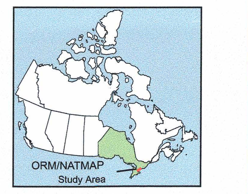

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