Overview

Testifying before the Standing Committee on Agriculture, Environment, Energy and Forestry In February of 2014, Bruce Raymond (whose title at the time was Manager of Watershed and Subdivision Planning) was introduced by the Hon. Janice Sherry (who at time was the Minister of Environment, Labour and Justice and Attorney General). She said:

> "You will be hearing a presentation from Bruce Raymond which provides *background information* about water. This includes the water cycle, groundwater flow patterns and water use. The presentation also outlines the current water extraction permitting policy. The policy considers varying water patterns across the province to both protect streams and aquatic life and provide reasonable *access* to water." (Hansard text pg. 19; bold & italics added)

Deep-well Irrigation, Bruce Raymond (2014), Manager of Watershed and Subdivision Planning, Dept. of Environment, Labour and Justice; Standing Committee on Agriculture, Environment, Energy and Forestry, 13 February 2014, Pope Room, Coles Building, Charlottetown; Hansard transcript, (italics added), http://www.assembly.pe.ca/sittings/2013fall/transcripts/11_2014-13-02-transcript.pdf (35 pgs.)

In addition to Mr. Raymond's oral presentation to the Standing Committee, he submitted (email communication, Raymond, 2019) *background information* that can be accessed at the following link (or, if the Overview Is received as an email, accessed through the attached pdf):

PEI Water Extraction Policy Department of Environment, Labour and Justice, January, 2014,
https://www.princeedwardisland.ca/sites/default/files/publications/pei_water_extration_policy_presentation_with_background_information.pdf (web-accessed 29-09-2019)

In the present paper (the one currently in front of you) that background information will be referred to as **'the policy presentation' (2014)** since part of the link address is 'pei_water_extration_**policy_presentation**_with_background_information'.

Regarding who wrote 'the policy presentation', "The main architect of this would have been Bruce Raymond." (email communication from George Somers, 11 October 2019); and, "A few people in [the 2014 Department of Environment, Labour and Justice]… including [Qing Li]…" (email communication from Qing Li, 11 October 2019). In other words, the principal or coordinating writer was Bruce Raymond, in collaboration with Departmental staff members.

Wanting to better understand what the 'policy presentation' was saying, I began reading the scientific papers listed in the 'References cited' section (pgs. 17a-d). I compared the 'policy presentation' text with the papers, and took notes.

I found that the references cited by the 'policy presentation':

- generally do **not** support the text of the 'policy presentation';
- have **nothing** to do with the text they are supposed to substantiate; or,
- actually **contradict** the 'policy presentation' text they are supposed to substantiate.

As a matter of demonstrable fact, 'the policy presentation' (2014):

- **is not an accurate, reliable, science-based document;**
- **is not reflective of competency; and, it….**
- **conveys misinformation.**

"**misinformation**… wrong information, or the fact that people are misinformed…"
https://dictionary.cambridge.org/dictionary/english/misinformation

"**misinformation**: incorrect or misleading information…" https://www.merriam-webster.com/dictionary/misinformation

"**misleading**…. causing someone to believe something that is not true: 'The instructions were confusing and even misleading in some cases.' …. 'The credit company has been criticized by the Office of Fair Trading for printing misleading advertisements.' …. 'The screens at the stock exchange gave the misleading impression that shares were falling'."
https://dictionary.cambridge.org/dictionary/english/misleading

"**Misinformation** is wrong information which is given to someone, often [but, not always] in a deliberate attempt to make them believe something which is not true…. false information, gossip, disinformation, misleading information, false rumour, bum steer…" https://www.collinsdictionary.com/dictionary/english/misinformation

"**misinformation**…. False or inaccurate information, especially [but, not always] that which is deliberately intended to deceive…"
https://www.lexico.com/en/definition/misinformation (Oxford Dictionary)

The Difference Between 'Disinformation' and 'Misinformation': Misinformation is false information that's given without malice, and **disinformation** is false information, such as government propaganda, that's given with the intention to deceive.
https://www.quickanddirtytips.com/education/grammar/the-difference-between-disinformation-and-misinformation

The 'policy presentation' (2014) misinformed the Standing Committee; served to misinform Islanders during the development of the Water Act; continued to misinform Islanders during the development of the draft Regulations; and, remains on government web-sites - for instance, on a site for people interested in applying for a 'high capacity well' permit.

The 'policy presentation' (2014) remains on government web-sites even though the Standing Committee's fourth recommendation was that "**a thorough review of the scientific basis for our water policies be undertaken as part of the development of the water act**." The fourth recommendation goes on to speak of 'high capacity wells', however, the call for "a thorough review of the scientific basis for our water policies" did not apply *just* to 'high capacity wells':

"A) **Identify and address knowledge gaps**; …. **At the outset of the water act *development* process** it will be important to eliminate weaknesses in our knowledge and understanding of the resource, *otherwise a weak policy will be the result*." (bold, italics, underlining added)

It would seem evident that "a thorough review of the scientific basis for our water policies" was not undertaken. (underlining added)

While the fourth recommendation was a 'recommendation' of the elected representatives of Islanders, out of respect for the spirit of the consultation process, it should not have been viewed as being 'optional'. Therefore, to remove any doubt about whether it 'should' now be implemented: **all of the fourth recommendation must be implemented, not just with regard to high capacity wells, but with regard to all aspects of our water policies.**

The 'fourth recommendation' appears on pages four and five of the present report.

It would be essential for Islanders to have well-merited confidence that our water is being managed in a substantively and meaningfully science-based way; that the spirit and the letter of the Standing Committee's recommendations be respected; and, that Regulations explicitly and unequivocally state a commitment to the spirit of the consultation (as expressed in the following two paragraphs) that led to the Act being written.

The interpretation and application of the Regulations shall be demonstrably and meaningfully based on the *combined application* of the following six *decisive* principles:

- science-based;
- precautionary;
- ecologically sustainable;
- hydrologically sustainable;
- intergenerational equitability; and….
- 'the common good' (with respect to sustainability and equitability).

This may be intuitively understood as being 'like the stewardship of an extraordinarily well-informed, extraordinarily far-sighted, cautious grandparent acting for the greater good of the environment, of the present generation, and of future generations.

In the context of 'grandparenting', 'grandfathering' unsustainable practices would almost certainly not be considered to be 'grandfatherly' (in gender-neutral language: 'grandparently').

In drafting Regulations and in the application of Regulations, any 'benefit of the doubt' must 'benefit' the spirit that led to the development of the Act; must benefit the spirit of the Act.

Decisions to include things in the Regulations *must* be science-based.

Decisions to not include things in the Regulations *must* be science-based.

The resulting Regulations would be a unique and outstanding testament to Island political leadership and to expertise in the enlightened management of water resources; and, would serve to bolster the 'brand' of Prince Edward Island as being an extraordinary place to be.

In the spirit of reconciliation with indigenous/aboriginal/First Nations' Peoples (after consultation with that community), in *addition* to the 'six decisive principles' the term '**The Seventh Generation Principle**' might be used. For instance, rather than having *six* principles, perhaps there might be *seven* principles: 'The Seventh Generation Principle' being the seventh one.

"**The Seventh Generation Principle** is based on an ancient Iroquois philosophy that the decisions we make today should result in a sustainable world seven generations into the future."

What is the Seventh Generation Principle?;Indigenous Corporate Training Inc. (May 29, 2012), https://www.ictinc.ca/blog/seventh-generation-principle (web-accessed 28 Oct. 2019)

True, Lasting Reconciliation - Implementing the United Nations Declaration on the Rights of Indigenous Peoples in British Columbia law, policy and practices, Bain et al. (November 2018); Union of British Columbia Indian Chiefs; The Canadian Centre for Policy Alternatives, British Columbia, https://www.policyalternatives.ca/sites/default/files/uploads/publications/BC%20Office/2018/11/CCPA-BC_UBCIC_TrueLastingReconciliation_full_181126.pdf (28 pgs.)

[Start of scanned document, November 19, 2014 Standing Committee Recommentation # 4]

4. Your committee strongly recommends that a thorough review of the scientific basis for our water policies be undertaken as part of the development of the water act.

Conflicting views were presented to your committee on whether science supports the moratorium on high capacity irrigation wells and the current water extraction policy. Your committee is not in a position to pass judgment on the scientific basis of current policy or determine scientific consensus for future policy. **However, witnesses put forward several suggestions of what a review should include:**

A) identify and address knowledge gaps;

Multiple areas of uncertainty surrounding water use were brought to your committee's attention. For example, what is the effect of high capacity extraction on nitrates distribution in the water supply? Also, is it sustainable to allow the same level of extraction of the mean summer base flow in all PEI streams, or should the level be fine-tuned on a watershed-basis? Experts may have answers in these areas, but in general your committee's investigations yielded more unknowns than certainties. At the outset of the water act development process it will be important to eliminate weaknesses in our knowledge and understanding of the resource, otherwise a weak policy will be the result.

B) use recent data and collect new data where necessary;

It was argued that some studies used in the development of the current water extraction policy are outdated. With a rapidly changing climate and increasing demands on our water supply it is not wise to rely on data and studies that no longer reflect the state of the resource. Ten years was suggested as a suitable threshold for relevance.

C) consult and follow the recommendations of specialists in a wide variety of fields, including but not limited to hydrogeology, climatology, ecology, agriculture, fisheries, forestry and wetlands;

Water is fundamental throughout the natural world and policies on its use should not be based on an isolated view of it. Instead, they must factor in the complexities of the water cycle and the multitude of interactions it has with species, naturally occurring and human-made habitats, and external influences. A wide knowledge base must inform our use and protection of this resource.

D) employ independent scientific peer review;

To be the basis on which our policies rest, the scientific representation of our water resource must be exposed to expert evaluation and criticism. Preliminary data, unpublished reports, and information that has not been subject to the scrutiny of the scientific community should be approached with caution and, at most, only used provisionally until peer review is complete.

E) increase monitoring efforts and commit to maintaining them in the future;

Current monitoring of existing high capacity wells is insufficient. As of 2014 there are 36 high capacity agricultural irrigation wells that were put in place before the 2002

moratorium. The Department of Environment, Labour and Justice has indicated that these have not been monitored on a long-term basis. There are also many more high capacity wells for municipal and industrial/commercial use; the committee is uncertain of the exact number of these or the extent that they are monitored. Management of our groundwater resource requires more monitoring of all high capacity wells across the Island, and consistent monitoring of those wells over time.

F) make data gathered from monitoring publicly accessible;

Your committee recognizes that data from 16 groundwater wells are available on the Department of Environment, Labour and Justice website, as are stream level, pesticide monitoring and water quality data. With increased monitoring, particularly of all forms of high capacity wells, your committee sees no reason not to publish more data on how our shared resource is being used.

G) incorporate flexibility so that new policies can be adjusted in response to our changing climate;

There is no ignoring that our climate is changing and change may be the only constant over this century and beyond. More frequent periods of drought, higher intensity precipitation, sea level rise and ocean acidification are just some of the major changes that are affecting our water supply and will continue to do so. Policies on water use and protection must incorporate our best predictions of the future based on recent trends, and must be adaptable so that the negative effects of climate change can be mitigated. The development of a comprehensive water act is an excellent opportunity to do this work.

H) follow the precautionary principle throughout.

It is clear that current and future actions in regard to PEI's water supply should be guided by the precautionary principle: the lack of scientific certainty or consensus regarding a potential environmental threat is not a reason to avoid taking protective measures against that potential threat.

[End of scanned document, November 19, 2014 Standing Committee Recommentation # 4]

Standing Committee on Agriculture, Environment, Energy and Forestry - First Report of the Fifth Session Sixty-fourth General Assembly, Committee Activities (November 19, 2014), (pg. 2, recommendation #4; bold added; 6 pgs.; web-accessed 06-Oct. 2019. *However*, in late October 2019 this document could not be found through the following link, or through a search of government web-sites,
http://www.assembly.pe.ca/sittings/2014fall/reports/11_2014-19-11-report.pdf (document no longer there)

"**Message from the Environmental Advisory Council - Water Act Consultation Panel**….
Establishing valid criteria for protecting Prince Edward Island's water supply is vital if we are to achieve this goal. **Any decisions regarding water use and management must be based on sound science and, where uncertainty exists, on the exercise of caution**." (text pg. 6)

"**Conclusions**
… **any legislative, regulatory and/or policy framework should be drafted in such a way as to support efforts to**….
• **allow for continuous adaptation** [change; modification] **to water management rules, as science advances**, or natural conditions change; and
• … **make transparent government decision-making**." (text pg. 8)

"… all parties in the discussions asked that the development of **laws, regulations and policies be based on consistent, reliable and scientifically valid data**." (text pg. 27)

"**Transparency** - in a government context implies openness, communication, and accountability. Transparency is **the intentional sharing of information in such a way that all may see what actions are being performed and why**. (text pg. 60)

Water Act Public Consultation Report, March 15, 2016, Appendix 3, Glossary of terms, (bold & underling added), http://www.gov.pe.ca/photos/original/CLE_EAC_WARep.pdf

"**What does a presentation** [before a Standing Committee] **consist of?**
Your presentation (formally, your **testimony**) at the committee meeting will typically consist of a 15-minute verbal statement of your views on the subject at hand."

"**What are my rights and responsibilities as a witness?**
… the refusal to answer questions or to answer truthfully may give rise to a charge of **contempt** of the House, *whether the **witness** has been sworn in or not*. In addition, witnesses who lie under oath may be charged with **perjury**."

Making a presentation to a standing committee: frequently asked questions, Legislative Assembly of Prince Edward Island, http://www.assembly.pe.ca/present (bold & italics added)

"**What does 'science-based' mean**?"
"…. It essentially means that some decision that is made is done in a way that takes scientific methods and/or results into account. If you are going to implement some policy on some issue, you should make sure that scientific research on that issue strongly indicates that your decision is the best one."

Why "Science-Based" Matters - Why the White House's request of the CDC is so troubling,
Geher (Dec 16, 2017), Psychology Today,
https://www.psychologytoday.com/us/blog/darwins-subterranean-world/201712/why-science-based-matters

"Scientific citation is providing detailed reference in a scientific publication, typically a paper or book, to previous published (or occasionally private) communications which have a bearing on the subject of the new publication. The purpose of citations in original work is to allow readers of the paper to refer to cited work to assist them in judging the new work, source background information vital for future development, and acknowledge the contributions of earlier workers."

Scientific citation Wikipedia (2017),
https://en.m.wikipedia.org/wiki/Scientific_citation (bold added; web-accessed 03-Sept.-2019)

"**The number one thing is to dispel misinformation**…. When something is very scientific and it can be easily misinterpreted, and so if you are able to dispel some of that **misinformation** and then give information in ways that people can relate to, it makes it easier for people to all be on the same page." Stephanie Arnold, "a senior researcher with UPEI's Climate Lab". (bold added)

UPEI researcher trains with Al Gore to become a climate reality leader, Kevin Yarr (Nov 04, 2019), CBC News,
https://www.cbc.ca/news/canada/prince-edward-island/pei-stephanie-arnold-climate-reality-leader-1.5346547

Scientific Basis: Checking References

Scrutinizing and untangling misinformation in a science-based way by 'checking references'; comparing scientific papers; deciphering scientific papers; defining the terms/words used in such papers; and, attempting to present that information clearly; is a very time-consuming, cumbersome, frustrating, and tedious process. That is probably why no one else appears to have made a thorough review of the scientific basis of that water policy document.
It is also why *the whole* 'the policy presentation' (2014) has *not* been scrutinized and untangled. However, several examples will be presented, concerning 'recharge time'; the depth of groundwater; and, the question of how much of 'groundwater stores' are palatable and capable of being pumped.

Residence Times

The '*policy presentation*' (2014) on page 4a speaks of 'residence time' which is the amount of time that water has been in the ground at any particular location; reflects the amount of time it takes for 'recharge' water to reach an aquifer; and, is dependent on the hydraulic conductivity/permeability of the aquifer. Paraphrasing Savard and Somers (2007), the 'policy paper' (pg. 4a) quote follows:

> "Samples from a depth of 100 m in the Wilmot [River Watershed] have isotope dates (tritium) indicating they are at least 50 years old… (Savard and Somers, 2007)."

But, what that 2007 article[1] *actually* says is:

> "Tritium analyses on GW [**g**round**w**ater] samples indicate an age younger than 50 years in the HF [high flow] system ['*from the water table to a depth of 18 to 36m'*]. In the shallow LF [low flow] system [below 36 m but above 100m], Carbon-14 analyses on GW samples suggest an age between 5000 to 7000 years." (pg. 56)

In other words, samples from a depth of 100 m are not "at least 50 years old", they are 5000 to 7000 years old. They have 'residence times' (also referred to as 'travel times') of between five thousand to seven thousand years. The difference between what the 'policy paper' implies, and what Savard and Somers (2007) actually say, is absolutely enormous in terms of 'recharge times' and in terms of *the available volume* of *palatable water*.

The pg. 4a quote is also very troubling in that it *clearly does not reflect competence* with regard to the ability of the '*policy presentation*' (2014) authors to properly interpret scientific information and to be 'science-based'.

[1]**Consequences of climatic changes on contamination of drinking water by nitrate on Prince Edward Island**; Savard & Somers (Editors) et al. (2007); Report submitted to Natural Resources Canada Climate Change Action Fund: Impacts and Adaptation, Contribution Agreement A881/A843; web-accessed Feb. 8, 2019; http://www.gov.pe.ca/photos/original/cle_WA3.pdf (142 pgs.)

To see the quote in context see pages 9-12, Savard and Somers (2007).

Pages 13-15 include [A]Paradis et al. (2017; pg. 12) who speak of a **ten thousand year travel time** across *part* of the Wilmot River Watershed; and, for context, a map from [B]Liao et al. (2005).

[A] **Multi-scale nitrate transport in a sandstone aquifer system under intensive agriculture**, Paradis, Ballard, Lefebvre, Savard (2017); Hydrogeology Journal · September 2017, (pg. 13; fig. modified), https://www.researchgate.net/publication/320036922_Multi-scale_nitrate_transport_in_a_sandstone_aquifer_system_under_intensive_agriculture (22 pgs.)

[B] **Preliminary results from water-isotope characterization of groundwater, surface water, and precipitation in the Wilmot River watershed, Prince Edward Island**; Liao, Savard, Somers, Paradis, & Jiang (2005); Geological Survey of Canada, Current Research 2005-D4, https://www.researchgate.net/publication/237407130_Preliminary_results_from_water-isotope_characterization_of_groundwater_surface_water_and_precipitation_in_the_Wilmot_River_watershed_Prince_Edward_Island/download (10 pgs.)

Page 16 returns to the discussion of the 'the policy presentation' (2014)

”5000 to 7000 years” residence time.

Consequences of climatic changes on contamination of drinking water by nitrate on Prince Edward Island; Savard & Somers (Editors) et al. (2007); Report submitted to Natural Resources Canada Climate Change Action Fund: Impacts and Adaptation, Contribution Agreement A881/A843; web-accessed Feb. 8, 2019; http://www.gov.pe.ca/photos/original/cle_WA3.pdf (142 pgs.)

“Consequences of climatic changes on contamination of drinking water by nitrate on Prince Edward Island”

Report Prepared by

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Edited by Martine M. Savard & George Somers

EARTH SCIENCE SECTOR
GEOLOGICAL SURVEY OF CANADA

and

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Prince Edward Island CANADA — Environment, Energy and Forestry

Presented March 20, 2007
to

NATURAL RESOURCES CANADA
CLIMATE CHANGE ACTION FUND: IMPACTS & ADAPTATION
Contribution Agreement A881/A843

Natural Resources Canada | Ressources naturelles Canada
Geological Survey of Canada | Commission géologique du Canada

mean annual discharge of the river is 0.92m^3/s (1972-1999) and the mean monthly discharge ranges from 0.45m^3/s in September to 1.88m^3/s in April, during the spring freshet.

Table 5.1. Main characteristics of the Wilmot River Watershed (Flow rates are for the 1972-1999 period recorded at the *01CB004* station located above the tidally influenced portion of the river; Land uses are based on a LANDSAT image for year 2000).

Physiography	
Area	84 km^2
Average width	5km
Average length	17km
Elevation (above sea level)	0-90m
Wilmot River Flow Rate	
Mean annual	0.92 m^3/s
Minimum monthly mean (Sept.)	0.45 m^3/s
Maximum monthly mean (April)	1.88 m^3/s
Land Use	
Agriculture	76%
Forest	11%
Urban, road	9%
Wetland, recreational	4%

Table 5.2. Weather and water balance for the Wilmot River Watershed (Meteorological data are for the 1971-2000 period recorded at the *Summerside A* station).

Weather	
Mean annual total precipitation	1078 mm
Mean annual rain	809 mm
Mean annual snow	269 mm
Mean annual temperature	5.1 °C
Minimum mean monthly temperature	-8.6 °C
Maximum mean monthly temperature	18.4 °C
Water Balance	
Mean annual evapo-transpiration	438 mm
Mean annual runoff	230 mm
Mean annual recharge	410 mm

5.2.2 Hydrogeology

The Wilmot watershed area is almost entirely covered by glacial material defined as permeable unconsolidated sandy tills, a few centimetres to several meters thick (Prest, 1973). That layer is underlain mostly by fine to medium-grained fractured sandstone (80-85%) with some siltstone and claystone forming isolated lenses (Van de Poll, 1983). The sandstone is a fractured porous medium characterized by a well-developed network of fractures and a high porosity matrix (17% on average for sandstone according to Francis, 1989). The aquifer is unconfined, except in small

zones where less permeable mudstone beds alternate with sandstone to form semi-confined conditions. The water table is generally located in the first 20m of the sandstone aquifer and follows the topographic relief. A schematic hydrostratigraphic column of the aquifer is show on Figure 5.2a.

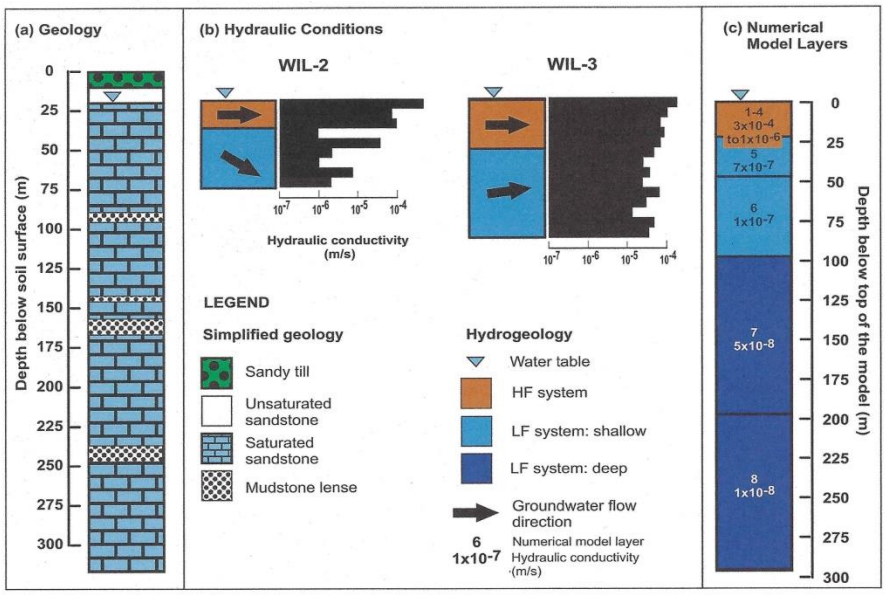


Figure 5.2. Conceptual model of the groundwater flow system and discretization of the numerical model: (a) geology; (b) hydrogeological conditions; and (c) numerical model layers. Locations of WIL-2 and WIL-3 are shown on Figure 5.1.

To support the model development, field work was conducted to evaluate the flow properties of the aquifer. The field characterization was based on three sets of three nested piezometers installed along a transverse section through the watershed (locations of monitoring wells WIL-1, WIL-2 and WIL-3 shown on Figure 5.1. The monitoring wells reach depths between 1 to 100 m below the water table. Profiles of hydraulic conductivity, hydraulic heads, nitrate concentrations and GW age were obtained by isolating boreholes with a 6m interval double-packer.

A hydraulic conductivity measurement using multi-level slug tests for the sandstone unit range from $9x10^{-7}$ to $4x10^{-4}$ m/s. Hydraulic conductivity measured with a laboratory permeameter ranges from 10^{-8} to $5x10^{-7}$ m/s for sandstone and is lower than $5x10^{-10}$ m/s for mudstone (Francis, 1989). Comparison between field and laboratory measurements suggests that fractures play an important role in the rock permeability. Hydraulic conductivity generally decreases with depth, as a result of decreasing fracture aperture and frequency. Typically, hydraulic conductivity profiles show a strong vertical to horizontal anisotropy that ranges from 2 to 3 orders of magnitude due to alternating high and low hydraulic conductivity layers and the predominance of sub-horizontal bedding plane fractures over sub-vertical fractures.

The hydraulic conductivity profiles for monitoring wells WIL-2 and WIL-3 shown on Figure 5.2b indicate that the sandstone aquifer comprises a high flow (HF) and a low flow (LF) system. The HF system extends from the water table to a depth of 18 to 36m, the LF system being under the HF. Groundwater flow within the HF system is mostly horizontal whereas flow inside the LF system is characterized by an important vertical downward gradient near the GW divide that becomes flat toward the middle of the section and upward near the Wilmot River. Hydraulic conductivities in the HF system are always relatively high and average $1.3x10^{-4}$ m/s, whereas in the LF system the average conductivity is an order of magnitude lower at $3.5x10^{-5}$ m/s, and it is also more variable with a range between $8.4x10^{-7}$ and $1.7x10^{-4}$ m/s.

Tritium analyses on GW samples indicate an age younger than 50 years in the HF system. In the shallow LF system, Carbon-14 analyses on GW samples suggest an age between 5 000 to 7 000 years.

Based on the conceptual GW flow model (Fig. 5.2) and GW age dating, it is inferred that GW flow predominantly occurs in the HF system. The HF system is relatively shallow and in good contact with the Wilmot River as will be shown in the next section. Nitrate transported to the aquifer by infiltration of precipitation will first reach the shallow HF system. Nitrate is likely to be transported mostly in the HF system, together with the dominant GW flow. It is thus thought that nitrate found in the Wilmot River is coming predominantly from the HF system. However, it is also likely that a proportion of the nitrate transported in the HF system has also reached the underlying LF system. Considering the reduced GW flow and the mostly large GW ages encountered in the LF system, the nitrate that may be present in the LF system may not have yet reached the Wilmot River. The numerical modelling of GW flow and nitrate transport in the Wilmot Watershed will allow a verification of these hypotheses.

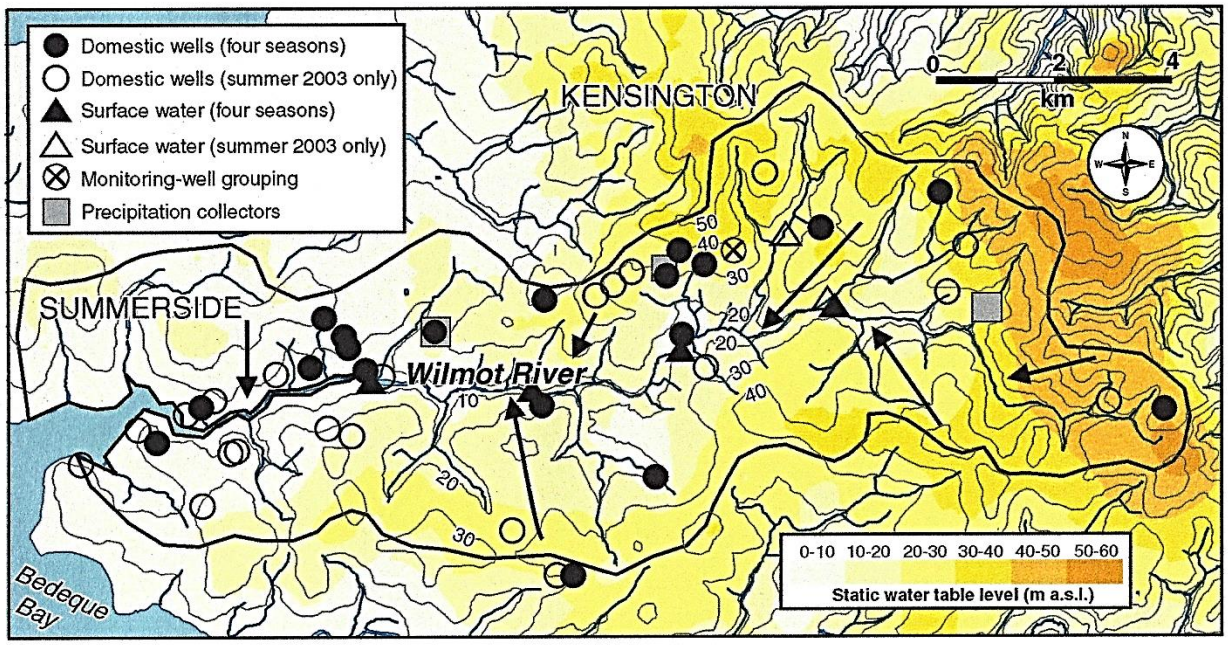
5.2.3 Groundwater and Wilmot River Interaction

Rivers and streams may represent a source of GW or act as a drain depending on their water level relative to the water table in the underlying aquifer. Observation of GW levels and river stages suggests that the Wilmot River gains water from the aquifer, thus acts as a drain most of the year.

Base flow represents water supplied to the river by the aquifer. The streamflow analysis with filters described by Furey and Gupta (2001) was applied to the Wilmot River, showing that base flow accounts for 63% of the mean annual streamflow (38% of the mean annual precipitation). This analysis also shows that base flow may be the only source of water to the river during summer, except immediately after precipitation events. Moreover, seasonal sampling of nitrate performed over a period of two years (2002-2004) in domestic wells (n=107) and in the Wilmot River (n=17) shows similar average nitrate concentrations as well as water and nitrate isotope properties (Savard *et al.*, 2004; this report, chapter 3). These observations indicate a highly effective connection between the aquifer and the river.

5.3 Numerical Modelling of Groundwater Flow and Nitrate Transport

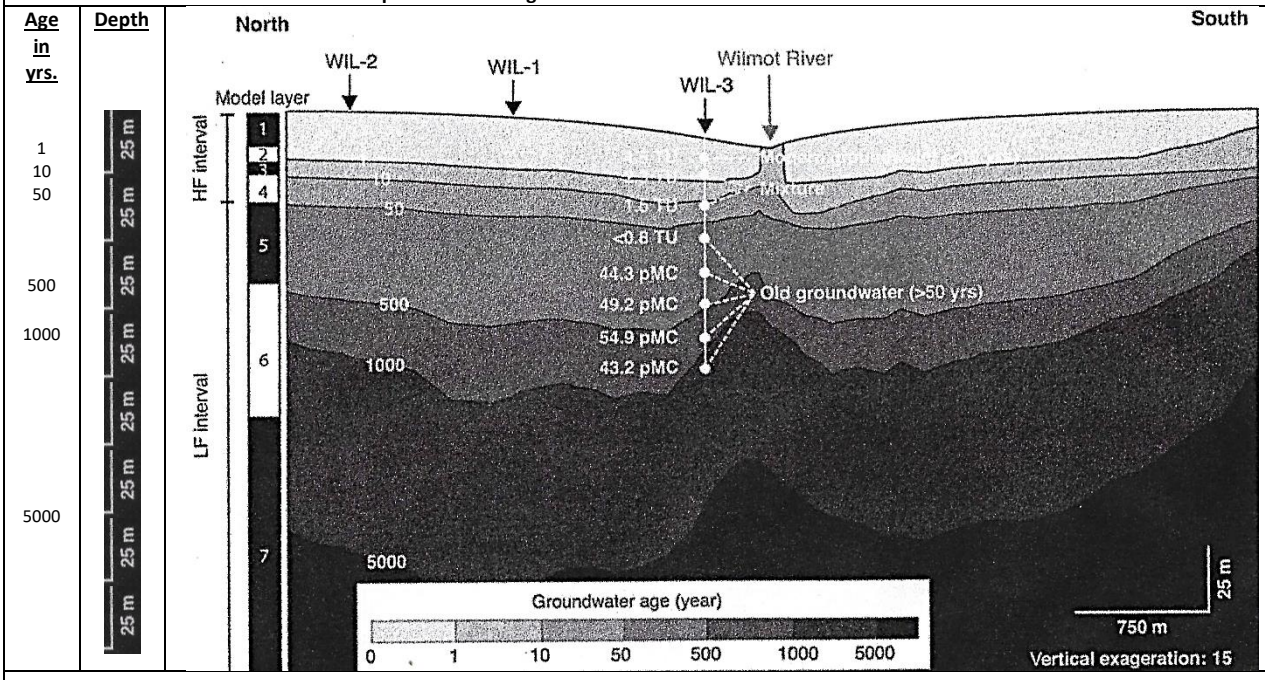
The main objective of the model is to asses the impact of various scenarios of agricultural practices on the future nitrate level in the Wilmot aquifer. The three-dimensional finite element numerical simulator FEFLOW (Diersch, 2004) was used to reproduce the GW flow system and to simulate nitrate transport in the aquifer.



"Figure 3. Wilmot watershed… water-table levels, topographic contours (10 m interval), and sampling sites. Solid black line defines the watershed boundaries. Arrows indicate the direction of groundwater flow. Topographic contour values in metres." (text pg. 3) [1]

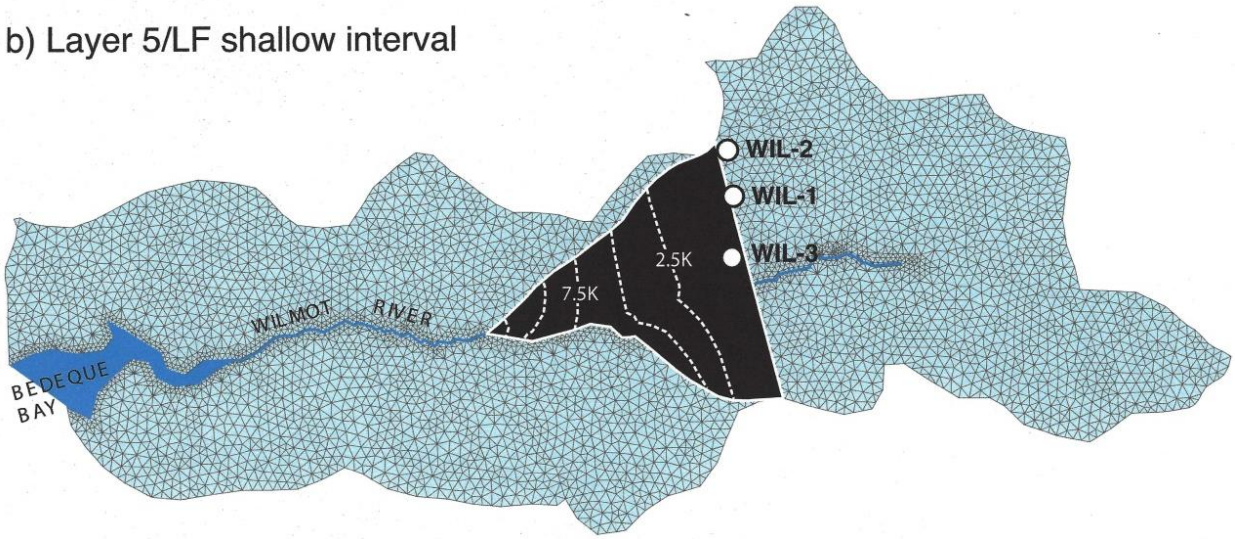
Ma s.l.: metres above sea level

North is at the top of the above figure.

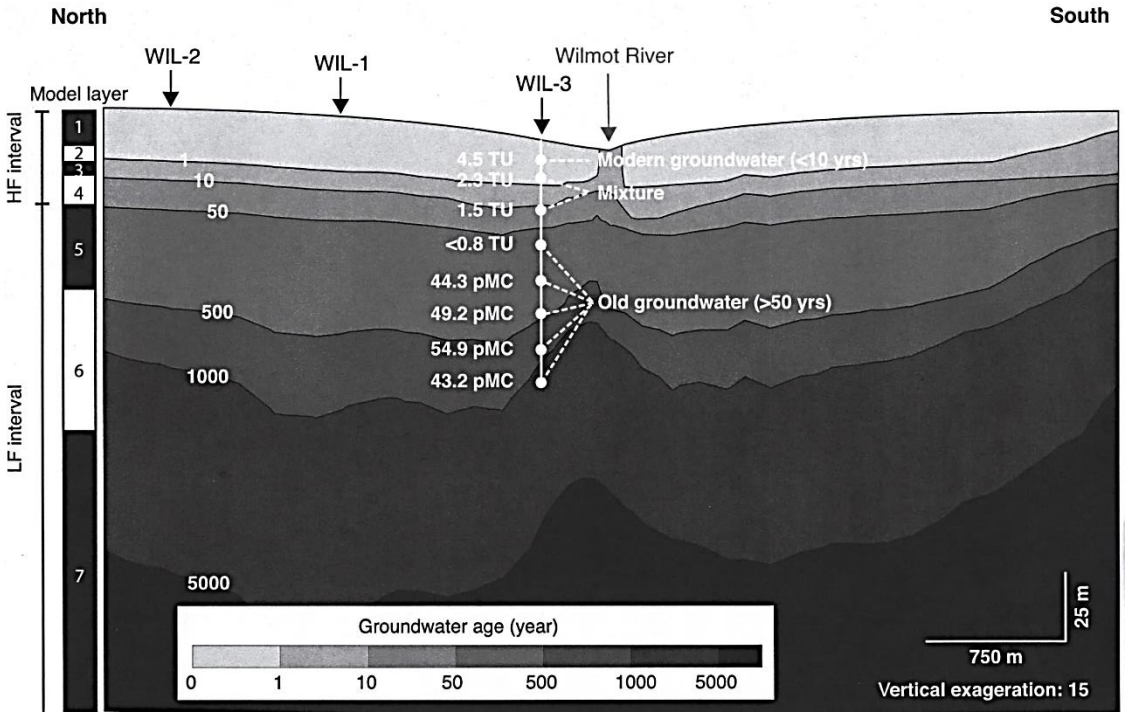


"Fig. 4 - Simulated groundwater ages… in the Wilmot River watershed…. [The] top four samples are based on… **t**ritium **u**nits (**TU**)… the four deeper sampling points… [are] expressed in **p**ercent **m**odern **c**arbon (**pMC**). The second and third sampling points from the surface are inferred to represent mixtures…) of modern (< 50 years) and old (> 50 years) groundwaters." [2]

1	**Preliminary results from water-isotope characterization of groundwater, surface water, and precipitation in the Wilmot River watershed, Prince Edward Island**; Liao, Savard, Somers, Paradis, & Jiang (2005); Geological Survey of Canada, Current Research 2005-D4, https://www.researchgate.net/publication/237407130_Preliminary_results_from_water-isotope_characterization_of_groundwater_surface_water_and_precipitation_in_the_Wilmot_River_watershed_Prince_Edward_Island/download (10 pgs.)
2	**Multi-scale nitrate transport in a sandstone aquifer system under intensive agriculture**, Paradis, Ballard, Lefebvre, Savard (2017); Hydrogeology Journal · September 2017, (pg. 13; fig. modified), https://www.researchgate.net/publication/320036922_Multi-scale_nitrate_transport_in_a_sandstone_aquifer_system_under_intensive_agriculture (22 pgs.)



"**Fig. 7** Particles tracking for… **b** the low flow (LF) shallow interval (layer 5)…. Particles were released from a transect crossing **WIL-1 to WIL-3** [**less than 3 km**]. The figure shows the envelope of particle tracks…" (pg. 16; fig. format modified)



"Fig. 4 - Simulated groundwater ages… in the Wilmot River watershed…." (pg. 13)

"The LF shallow interval (model layer 5; **Fig. 7b**) is also connected to the Wilmot River… and takes **a travel time of up to 10,000 years** [at rate of roughly **0.3 metres <u>per year</u>**] to reach the river…." (pg. 13; 3,000 m ÷ 10,000 yrs.)

Multi-scale nitrate transport in a sandstone aquifer system under intensive agriculture, Paradis, Ballard, Lefebvre, Savard (2017); Hydrogeology Journal · September 2017, (pg. 13), https://www.researchgate.net/publication/320036922_Multi-scale_nitrate_transport_in_a_sandstone_aquifer_system_under_intensive_agriculture (22 pgs.)

Page 13 scan, with **<u>arrow</u> pointing to "travel time of up to 10,000 years"** from WIL-1 to WIL-3.

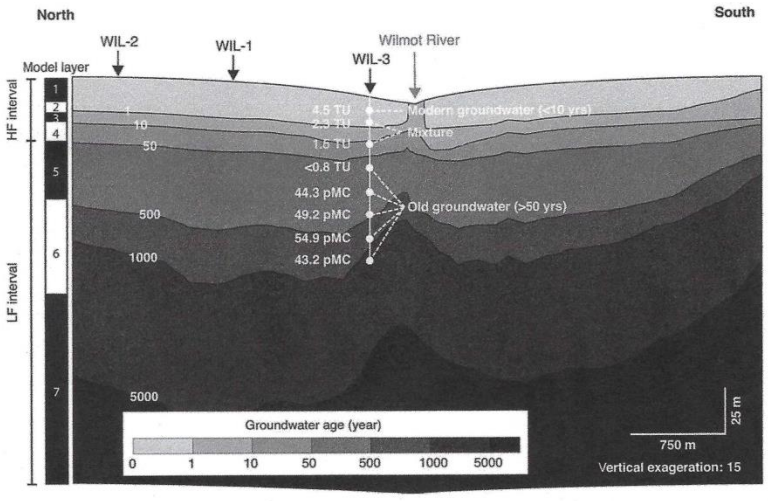


Fig. 4 Simulated groundwater ages at a transect crossing observation wells (WIL-2, WIL1 and WIL-3) in the Wilmot River watershed compared to qualitative isotopic groundwater ages measured at WIL-3 (see Fig. 1 for the transect location). Isotopic groundwater ages for the top four samples are based on tritium concentrations in tritium units (TU), whereas ^{14}C was used for the four deeper sampling points. ^{14}C is expressed in percent modern carbon (pMC). The second and third sampling points from the surface are inferred to represent mixtures (mix) of modern (< 50 years) and old (> 50 years) groundwaters

concentrations observed in the Wilmot River (Fig. 5). This appraisal agrees with an independent estimate suggesting that 87–96% of soil-N annually available to leaching as nitrate is reaching groundwater in PEI (De Jong et al. 2008), which suggests a very low denitrification rate in the soil layer. The simulated yearly trend from 1973 to present is in good agreement with nitrate concentrations measured in the Wilmot River (Fig. 5). Even though there is only a slight bias in simulated and observed nitrate concentrations, r and C_D are the weakest compared with other calibration parameters. This could be attributed to the nitrate concentration measured in rivers that may show higher variability due to a varying degree of dilution with runoff water at different sampling periods. So, diluted samples would lead to lower nitrate concentration.

Calibration of local-scale seasonal fluxes from nitrate sources

Figure 6 shows that total and individual concentrations simulated for each nitrate source with the shallow model nicely compare with observations in domestic wells. Simulated concentrations are averaged for the five layers of the model, weighted by layer transmissivities at the 16 observation points where sampled domestic wells are located. These calibrated results were obtained by iteratively adjusting the magnitude and timing of nitrate mass fluxes as well as model parameter values for n and S_y; the best fit was obtained for n and S_y of 2 and 1.5%, respectively (Table 4). The S_y value used was previously obtained through calibration with baseflow recessions and a modification of this value did not provide a better match. The K_h profile was also modified to better match the nitrate mass flux timing. In comparison with the deep model, the overall transmissivity for the same interval was similar and only the general vertical trend was modified. Thus, in spite of simplification of physical processes and uncertainty in hydraulic parameter values and spatial variability, calibration results suggest that the numerical models can be used to adequately represent the main nitrate transport mechanisms in the Wilmot aquifer.

Groundwater nitrate transfer to river and distribution within the aquifer

Figure 7 presents particle tracking carried out through the WIL-1 to WIL-3 transect for three different depths within the deep model providing an appreciation of the link between the aquifer and the Wilmot River. Based on the small travel path envelope and the short travel time (less than 20 years), it appears that the HF interval (model layer 1; Fig. 7a) is well connected to the Wilmot River and that groundwater mostly flows directly to the river within this interval. The LF shallow interval (model layer 5; Fig. 7b) is also connected to the Wilmot River but it provides much less contribution and takes a travel time of up to 10,000 years to reach the river, while ← particle tracking for the LF deep interval (model layer 7; Fig. 7c) suggests that the aquifer is draining much farther downgradient and closer to the estuary. Moreover, the simulated nitrate concentrations for year 2000 within the Wilmot aquifer at a transect crossing WIL-1 to WIL-3 show that the concentrations are homogeneously distributed (Fig. 8), owing to the homogeneous flux and parameters used in the model. The highest concentrations are found in the HF interval (model

Depth of Groundwater

The much greater length of this section (compared to the previous section) is not because the topic is any more important. The greater length reflects the challenge of presenting what the references cited by the 'policy paper' *actually say* or *do not say*, as compared to what the 'policy paper' *says that they say*.

"One of the things that's particularly difficult for people to understand is just how much water we have in groundwater. In PEI, away from the shoreline, **the fresh water-groundwater resource** which is in the pores in between the rock, and actually in the pores inside the rock as well, **extends down hundreds of metres. Maybe 800 metres is a reasonable distance to think about how far down it goes**. Our productive wells are only in the upper part of that, approximately the top 200 metres or so." (text pg. 24)

Deep-well Irrigation, Bruce Raymond (2014), Manager of Watershed and Subdivision Planning, Dept. of Environment, Labour and Justice; Standing Committee on Agriculture, Environment, Energy and Forestry, 13 February 2014, Pope Room, Coles Building, Charlottetown; Hansard transcript, http://www.assembly.pe.ca/sittings/2013fall/transcripts/11_2014-13-02-transcript.pdf (35 pgs.)

That testimony strongly implies that:

- it's particularly difficult for people to understand that the fresh water resource (all over P.E.I., away from the shoreline) can reasonably be thought of as extending down maybe 800 metres;
- our productive wells are only in the upper 200 metres or so; and….
- productive wells could be sunk to a depth of 800 metres. After all, it's reasonable to think that "the fresh water-groundwater resource" is capable of being pumped, because:
    - Mr. Raymond begins his testimony by saying that it is particularly difficult for people to understand "just how much water we have" - i.e. presumably water that is ***accessible*****,** capable of being pumped, extending down 800 metres or so.
    - It would be meaningless to call it 'an 800m deep resource' unless that water was in an aquifer, and capable of being pumped from that depth; and….
    - The 800m depth of the geological formation would be irrelevant unless that water was in an aquifer, and capable of being pumped.

The '*policy presentation*' (2014) notes (on pg. 5b) that "The formation that makes up PEI's aquifer is at least 800m thick (Van de Poll, 1983, Francis 1989)", but it would not be scientifically accurate to say that "the formation that makes up PEI's aquifer is 800m thick" unless the *entire* 800m thickness is an aquifer (as defined below). Since the *entire* 800m thickness is not an aquifer, the 'policy presentation' statement is (at the very least) misleading.

"**Aquifer**: A formation, group of formations, or part of a **formation that contains sufficient saturated, permeable material to yield <u>significant</u> quantities of water** to wells and springs."

Aquifer Basics, U.S. Geological Survey (2016), (bold & underlining added) https://water.usgs.gov/ogw/aquiferbasics/

"**Aquifer** - is an underground layer of **permeable** rock, gravel or sediment that contains or transmits water." (text pg. 58) [i.e. if a layer is not permeable, it's not an aquifer]

Water Act Public Consultation Report, March 15, 2016, Appendix 3, Glossary of terms, (bold added), http://www.gov.pe.ca/photos/original/CLE_EAC_WARep.pdf

"**Aquifers** are defined as **geological formations <u>that yield</u>** [that can release] **useable quantities of groundwater**."

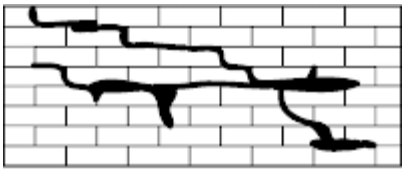
Water Extraction Permitting Policy Department of Environment, Labour & Justice January 2013, (text pg. 4; bold & underlining added), https://www.princeedwardisland.ca/sites/default/files/publications/water_extraction_permitting_policy_2013.pdf

Porosity and Permeability

"The pore space of an aquifer is the spaces or voids between the solid material. The porosity of the aquifer is the volume of void space to the total volume, typically expressed as a percentage.

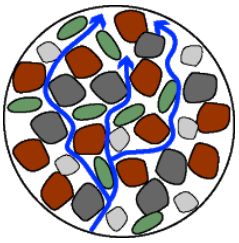
Effective porosity is the space available for fluid to flow, and is calculated as the volume of interconnected void space to the total volume, typically given as a percentage."

Secondary Porosity



[e.g. Fractures/cracks in sandstone]

"Porosity can be deemed either primary or secondary. Void spaces in primary porosity formed at the time the geologic material was created. Void spaces in secondary porosity formed after the rock was created. Examples of secondary porosity include fractures, solution-created channel ways, etc."



"Permeability is the ease in which water flows through the rock's pore structure. **A rock may be highly porous, but if the pore spaces are not connected, it is not permeable**. The… diagram [at left] represents hypothetical flow paths through a porous media"

Porosity and Permeability, Groundwater Geek, Maria Gibson, Graduate Research Assistant, Hydrogeology, Oregon State University, http://www.groundwatergeek.com/groundwater/porosity (web-accessed 06-Oct. 22019)

- "**Total Stored Groundwater** in a basin is the total volume of groundwater below the water table and above the impermeable geologic materials [the confining layer] that form the bottom of the basin." (text pg. 2-24)
- "**Usable Stored Groundwater** is a subset of total stored groundwater and reflects limitations imposed by well depths, well locations, seawater intrusion threats, *aquifer layering*, etc." (text pg. 2-25)
  ['*Aquifer layering*' is the occurrence (typical on the Island) of different types of aquifers layered/stacked one on top of another.]

"… most of the Usable Stored Groundwater is in the shallowest portion of most basins because **unconfined aquifers have more storage capacity**." (text pg. 2-25; underlining & italics added)

Basin Management Action Plan, Seaside Groundwater Basin Monterey County California; Hydrometrics Inc., Consulting Scientists and Engineers; prepared for Seaside Groundwater Basin Water-master, 2009, http://www.seasidebasinwatermaster.org/Other/BMAP_FINAL_5-Feb-2009.pdf (web-accessed 15 Oct. 2019)

"14.1 Groundwater and Aquifers"

"Groundwater is stored in the open spaces within rocks and within unconsolidated sediments. Rocks and sediments near the surface are under less pressure than those at significant depth and therefore tend to have more open space. For this reason, and because it's expensive to drill deep wells, most of the groundwater that is accessed by individual users is within the first 100 m of the surface. Some municipal, agricultural, and industrial groundwater users get their water from greater depth, but deeper groundwater tends to be of lower quality than shallow groundwater, so there is a limit as to how deep we can go."

"Porosity is a description of how much space there could be to hold water under the ground, and permeability describes how those pores are shaped and interconnected. This determines how easy it is for water to flow from one pore to the next. Larger pores mean there is less friction between flowing water and the sides of the pores. Smaller pores mean more friction along pore walls, but also more twists and turns for the water to have to flow-through. A permeable material has a greater number of larger, well-connected pores spaces, whereas an impermeable material has fewer, smaller pores that are poorly connected. Permeability is the most important variable in groundwater. Permeability describes how easily water can flow through the rock or unconsolidated sediment and how easy it will be to extract the water for our purposes. The characteristic of permeability of a geological material is quantified by geoscientists and engineers using a number of different units, but the most common is the hydraulic conductivity. The symbol used for hydraulic conductivity is K. Although hydraulic conductivity can be expressed in a range of different units, in this book, we will always use m/s [meters per second]."

Physical Geology, Earle (2015), BCcampus [British Columbia] Open Textbook project, https://opentextbc.ca/geology/chapter/14-1-groundwater-and-aquifers/ (web-accessed 06-Oct.-2019)

Again regarding the page 4b quote from the 'policy presentation' (2014): "The formation that makes up PEI's aquifer is at least 800m thick (Van de Poll, 1983, Francis 1989)":

- Van de Poll (1983) is about the geology of P.E.I., but says absolutely nothing about water or aquifers. (two formats - with identical content - of Van de Poll (1983) are available through the P.E.I. library system).
- Francis (1989) mentions (text pg. 8) a 'red bed' geological formation that is 850m deep (text pg. 8); but, he says absolutely nothing about an aquifer being that deep.

Therefore, the '*policy presentation*' gives a scientific basis for *the geological formation* being at least 800m thick, but it gives no scientific basis for it being *an aquifer*. It is not an aquifer.

Once again regarding the quote:

"The formation that makes up PEI's aquifer is at least 800m thick (Van de Poll, 1983, Francis 1989), however:

- **Permeability**, the ability to transmit water, mostly through fractures, declines with depth due to reduced fracture frequency and size (Francis, 1989, Paradis et al. 2007).
- As a consequence, relative water yields to wells decline with depth and highly productive portions of the aquifer are generally limited to the upper 200 m of the formation (Jiang and Somers, 2008)." (pg. 5b)

In other words, 'relative productivity' declines with depth.

Therefore, the '*policy presentation*' *somewhat* clarifies Mr. Raymond's testimony in that **if** "*highly productive* portions of the aquifer are generally limited to the upper 200 m" (italics added), then (presumably) wells below 200m would also be productive, but they would be *relatively less productive*.

The statement that "highly productive portions of the aquifer are generally limited to the upper 200 m of the formation" gives its supposed scientific basis as being Jiang and Somers (2008). However, that paper In **no** way, shape, or form says, suggests, or even implies that the upper 200 m of the formation are *highly productive*. There Is no valid scientific basis given for that statement.

What Jiang and Somers (2008) **do** say, is on the following page.

What Jiang and Somers (2008) **do** say, is the following:

"**Aquifer geology**

…. Field observations and drilling in the central portion… of the watershed… **confirm that geologically WRW** [**W**ilmot **R**iver **W**atershed] **is similar to the other parts of the island**.

Aquifer properties
The *uppermost portion* of the red bed formations plus the saturated till forms an **unconfined/semi-confined fractured-porous aquifer <u>across the island</u>**….. A detailed hydrogeological investigation conducted by Francis (1989) in the Winter River watershed… suggested that the aquifer has… significant fracture permeability dominated by horizontal bedding plane fractures, in addition to intergranular porosity. Horizontal layering of the aquifer along with the predominance of horizontal bedding plane fractures leads to a stratified aquifer with a **v**ertical hydraulic conductivity (K_v) ranging from one to three orders of magnitude less than **h**orizontal values (K_h or K_r [**r**elative conductivity]). K_h [horizontal hydraulic conductivity/permeability] **decreases with depth due to the reduction of fracture frequency and openings**." (pg. 4)

Clarifying the previous paragraph phrase "one to three orders of magnitude less" means that ***v**ertical hydraulic conductivity* is one-tenth to one-thousandth of whatever the *horizontal conductivity* is. It does <u>not</u> drop ***by*** $1/10^{th}$ to $1/1{,}000^{th}$: it drops ***to*** $1/10^{th}$ to $1/1{,}000^{th}$.

> Francis (1989) describes (text pgs. 46[A], 111[B], 62[C]) the general trend:
> "….an **average reduction in hydraulic conductivity of an order of magnitude for each 60 m depth**." [A]; "Total rock mass **hydraulic conductivity decreases by an order of magnitude for each 60 m depth**." [B]; "**the aquifer could be said to confine itself…**" [C]

"The distribution frequencies of well depth and casing length based on 594 domestic wells indicate that **sampled water primarily originates from the shallow portion of the aquife**r (i.e. **from water table to less than 30 m below the land surface**)." (pg. 5)
[Regardless of the depth of the well.]

The 'shallow portion of the aquifer' is "… layer 1 (thickness=22 m)…" (pg. 6)

"**At depth of 220–240 m the bedrock is assumed impervious**." (pg. 7) As Francis (1989) might put it, by that depth the aquifer has virtually fully confined itself: it is virtually impervious to hydraulic conductivity.

[Note that in that paper, Somers is identified as being with the Water Management Division, Department of Environment, Energy and Forestry, P.E.I.]

Modeling effects of nitrate from non-point sources on groundwater quality in an agricultural watershed in Prince Edward Island, Canada, Jiang & Somers (2008), Hydrogeology Journal DOI 10.1007/s10040-008-0390-2, http://www.gov.pe.ca/photos/original/cle_WA20.pdf (18 pgs.)

A paper by Savard & Somers (Editors) et al. (2007) notes that the geological formation is virtually impervious by the depth of 200 metres:

"… hydraulic conductivity of the aquifer generally decreases with depth (Paradis et al. 2006), which agrees with previous findings by Francis (1989). **From the viewpoint of water supply, the permeability of the bedrock decreases to near negligible[1] levels at depths of 200 m**." (pg. 42)

Consequences of climatic changes on contamination of drinking water by nitrate on Prince Edward Island; Savard & Somers (Editors) et al. (2007); Report submitted to Natural Resources Canada Climate Change Action Fund: Impacts and Adaptation, Contribution Agreement A881/A843; web-accessed Feb. 8, 2019; http://www.gov.pe.ca/photos/original/cle_WA3.pdf (142 pgs.)

[1] "**negligible** - insignificant, not worth bothering about"

https://en.oxforddictionaries.com/thesaurus/negligible

"Obviously one is very likely to encounter open fractures in the 0-50 m zone…. the reduction in fracture frequency and fracture aperture [cross-section, diameter] with depth [i.e. the reduction in hydraulic conductivity/permeability]… probably continues to depths of at least 150 m." (text pg. 47)

"Linear regression analyses were conducted to examine the variation of hydraulic conductivity with depth…. clearly show…. the consistency of hydraulic consistency trends… across the [Winter River watershed] basin…. an **average reduction hydraulic conductivity of an order of magnitude for each 60 m depth**." (text pg. 46)

"Total rock mass **hydraulic conductivity decreases by an order of magnitude for each 60 m depth**." (text pg. 111)

In other words, the ability of that water to be pumped, reduces by an order of magnitude for every 60 metres of depth (Francis, 1989): 1/10 the permeability at 60m; 1/100 the permeability at 120m; 1/10,000 the permeability at 180m. By a depth of 150 metres the geological formation is so impermeable that groundwater is 'confined'/trapped in rock pores and *cannot* be utilized for water supply: "**the aquifer could be said to confine itself**". (text pg. 62)

"The permeability data lead one to conclude that development of high capacity wells will be most successful in areas of high water table **where the upper, most permeable zone is saturated and can be utilized for water supply**. Any contamination of the upper-most portion of the aquifer could have serious implications for both the potential yield of the aquifer and the cost of water supply if deeper, lower capacity wells need be constructed. **Drilling wells to depths beyond 75-100 m in hope of increasing well yields is not likely to be cost effective**." (text pg. 49)

"… **the aquifer could be said to confine itself**, the degree of 'confinement' increasing with depth as the vertical interconnection of the various horizontal strata [layers] decreases." (text pg. 62)

[Note that in that paper, Francis is identified as being with the Dept. of the Environment, P.E.I.]

Hydrogeology of the Winter River Basin - Prince Edward Island, Francis (1989), P.E.I. Dept. of the Environment, Water Resources Branch, http://www.gov.pe.ca/photos/original/cle_WinterR.pdf (200 pgs.; web-accessed 06-Oct. 2019)

"Groundwater is the collective* water [the entire amount of water] that exists in porous rock formations and/or unconsolidated sediments, such that this water fills in the void spaces in what is known as the saturated zone. The top surface of the **groundwater** is called the **water table** or piezometric surface of the saturated zone. Above the water table, the rock formations through which rain water may percolate downwards to recharge the water table is known as the unsaturated zone, or the zone of aeration."

* ["Definition of **collective**…. 1.2 Taken as a whole; aggregate." Lexico Dictionary.com & Oxford University Press (2019), https://www.lexico.com/en/definition/collective (web-accessed 06-Oct.-2019)

"The **collective** mass of water found on, under, and over the surface…"
Water, Wikipedia (2019), https://en.wikipedia.org/wiki/Water (web-accessed 06-Oct.-2019)]

"…. Groundwater does not move in the way that surface water does because the path is not smooth - groundwater must wind a very slow, twisting path between void spaces in porous rock or unconsolidated sediment. However**, groundwater may not always be retrieved from water-bearing rocks or sediments; it is not enough for a rock to contain void spaces (porous); the pore spaces must be interconnected** [for the water in the pores of the rock to be extractable]."

"**Rock formations containing extractable ground water are known as aquifers**." [Water contained in rock pores that are not interconnected, is simply called 'groundwater'; and, the rock formation is simply called a geological formation – it is not called an 'aquifer'.]

"…. The rate of groundwater flow through a rock formation is called the permeability. Aquifers have relatively high permeability…" [Rock formations (geological formations) that contain water in rock pores that are not interconnected, have low permeability]

Surface Water & Groundwater – Groundwater, Tong (2002), Earth Science Faculty, Oakton Community College, Chicago, Illinois, (asterisk & definitions of 'collective' added; bold & underlining added), https://www.oakton.edu/user/4/billtong/eas100/surfaceandgroundwater.htm (web-accessed 04-Oct.-2019)

Once again, returning to the 'policy presentation' (2014):

"Groundwater storage (ie total volume of groundwater available) is a function of the porosity (% void spaces) of *the aquifer*. The porosity of PEI's aquifer is 15%.... Thus every cubic metre of the aquifer contains about 150 litre of ground water." (pg. 5b; italics added)

Regarding "*the aquifer*", P.E.I. does not have *just one* aquifer. The Island has *many* aquifers. It also has several *types of aquifer*, each of which behaves very differently (with regard to recharge, pumping, and vulnerability to contamination): unconfined aquifers, semi-confined/'leaky' aquifers, and confined aquifers. In addition, these aquifers tend to be 'stacked', one on top of another. Again, that is why the Regulations must define 'aquifer' and the three types of aquifer.

Regarding porosity, 'groundwater *storage*… is a function of the porosity', but groundwater *availability* is a function of permeability (hydraulic conductivity). Thus "every cubic metre of the aquifer contains about 150 litres of ground water" but the ability of that water to be pumped reduces by an order of magnitude for every 60 metres of depth (1/10 the permeability at 60m; 1/100 the permeability at 120m; 1/1000 the permeability at 180m; etc.). Although it may be comforting to say that there are very large amounts of groundwater 'stored' beneath the surface, it is very largely ***permanent* storage**: it is virtually irrelevant.

'**Groundwater *storage* is a function of porosity, but groundwater *availability* is a function of permeability (hydraulic conductivity). The amount of groundwater stored is virtually irrelevant unless it available, unless it would be capable of being pumped.**

Generalizations about typical P.E.I. aquifers

The '*policy presentation*' (2014) says: "While the general geology, physiography and hydrology of the Province is relatively similar, there are some regional differences…. Even on a local scale hydrogeological conditions can vary significantly." (pg 14)

Evidently, however, regional differences and local variations are not great enough to have prevented the '*policy presentation*' (2014) from making general statements describing the aquifer system.

The scientific papers referenced by the 'policy presentation' very often refer to Island-wide hydrogeological conditions being similar enough, that generalizations can be made.

For instance, over the course of a 142 page paper by Savard & Somers (Editors) et al. (2007), five times it is noted that Island-wide generalizations can be made about P.E.I. aquifers:

- "The hydrogeological characteristics and general behaviour of these [groundwater flow] systems is **similar throughout the Province** because of its relatively uniform physiographic, geological and climatic conditions." (pg. 16)
- "The hydrogeological conditions of the Wilmot watershed-aquifer system are **representative of most of PEI**." (pg. 17)
- "… Harrington Experimental Farm… is representative of the… overall physiographic and hydrogeological characteristics of the Province…. [as is] the Wilmot watershed, a watershed/aquifer system… which is also hydrogeologically **representative of most of the province**…" (pg. 19)
- "Field observations and drilling confirm that, hyrogeologically, the Wilmot River watershed **bears strong similarities to the other parts of the island**." (pg. 42)
- "The Wilmot watershed… was selected for the study because it is **representative of the relatively uniform geology, the typical watersheds will small streams and basins and of the hydrogeological conditions of PEI**…." (pg. 52)

Consequences of climatic changes on contamination of drinking water by nitrate on Prince Edward Island; Savard & Somers (Editors) et al. (2007); Report submitted to Natural Resources Canada Climate Change Action Fund: Impacts and Adaptation, Contribution Agreement A881/A843; web-accessed Feb. 8, 2019; http://www.gov.pe.ca/photos/original/cle_WA3.pdf (142 pgs.; web-accessed 23-09-19)

"Though the province doesn't monitor the whole groundwater system, Mr. Somers said the geology is, for the most part, similar across the Island. So, the 13 monitoring stations they do give a good picture of what is going on."

Dried-up spring baffles Eldon man and experts, Eastern Graphic, Dec 4, 2013, (web-accessed 23-09-19), http://www.peicanada.com/eastern_graphic/news/article_e9fb3884-3809-5eb5-83de-da0fd918b2e7.html

"The Wilmot watershed…. basin is **representative of the relatively small streams and basins present over PEI that has a relatively uniform geology** (Prest, 1973; Van de Poll, 1983) and hydrogeological conditions (Francis, 1989)."

Impact of agricultural activities on nitrates in ground and surface water in the Wilmot watershed, PEI, Canada; Paradis, Ballard, Savard, Lefebvre, Jiang, Somers, Liao, & Rivard (2006); 7th Joint CGS/IAH-CNC Groundwater Specialty Conference, Vancouver, 2006, https://www.academia.edu/20699366/Impact_of_agricultural_activities_on_nitrate_in_ground_and_surface_water_in_the_Wilmot_Watershed_PEI_Canada (8 pgs.)

While generalizations can be made about Island aquifers, such generalizations must compare similar *types* of aquifers (e.g. comparing a 'confined aquifer' to another 'confined aquifer'); and, similar aquifer *depths* must be compared. For example, pumping water from an unconfined aquifer at a depth of twenty metres, is very different from pumping water from a confined aquifer at a depth of eighty metres. Regulations must reflect the necessity to characterize each particular well location with regard to what *type* of aquifer is being pumped and from what *depth* water is being pumped.

'One-size-fits-all' draft regulations are totally inadequate.

Let us have Regulations

that are a unique and outstanding testament

to Island political leadership and

to expertise in the enlightened management of water resources;

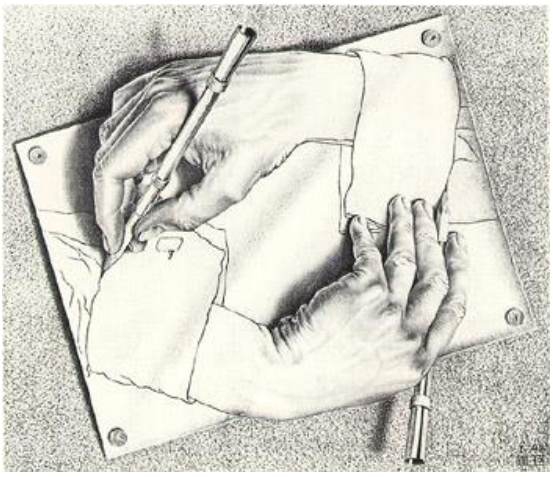
and, that serve to bolster the 'brand' of Prince Edward Island

as being an extraordinary place to be.

More Disinformation Debunked:

A Brief Review of the Physical Characteristics of PEI's 'Redbed Aquifer'

P.E.I. Dept. of Environment, Water & Climate Change, *On The Level*, https://www.onthelevelpei.ca/redbedaquifer



Drawing Hands by Escher (1948), https://www.aaronartprints.org/images/Paintings/4597.jpg

Disinformation draws on other disinformation to bolster the illusion

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Since the '*On The Level'* document attempts to 'conjure up' '*alternative* facts',

A B*rief* R*eview of the* P*hysical* C*haracteristics of* PEI*'s '*Redb**ed A**quifer*'**

'**A B R P C P E I R B A**'

Will, for the most part, subsequently be referred to as being:

'**A b r a c a d a b r a**'

its author/authors referred to, for the most part, as 'author/s'.

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Abracadabra invokes much of the same disinformation found in the following publication:

PEI Water Extraction Policy,
Department of Environment,
Labour and Justice, January, 2014
(33 pgs.)
(web-accessed 10-Jan-2021)

https://www.princeedwardisland.ca/sites/default/files/publications/pei_water_extration_policy_presentation_with_background_information.pdf

Which, for brevity, will subsequently be referred to as being
~~https://www.princeedwardisland.ca/sites/default/files/publications/pei_water_extration_~~
policy_presentation_~~with_background_information.pdf~~

the '**Policy Presentation' (2014)**.

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For Island aquifer system information that *actually is* science-based… browse on.

Testifying before the Standing Committee on Agriculture, Environment, Energy and Forestry In February of 2014, Bruce Raymond (whose title at the time was Manager of Watershed and Subdivision Planning) submitted *background information* that can still be accessed at the link appearing in the box at the bottom of the previous page. That background information will be referred to in the following paragraphs as 'the Policy Presentation' (2014).

A critique (an 'Overview') of 'the Policy Presentation' (2014) was presented by Bourdon at the following meeting:

Attendees, Nov. 7th 2019 meeting, Shaw Building, concerning: **1. draft regulations of the Water Act** 2. **briefing notes 'Overview' about the "PEI Water Extraction Policy Presentation (January 2014)"**	
Brad Colwill,	Deputy Minister, Environment, Water and Climate Change.
Bruce Raymond,	Manager of Water and Air Monitoring.
George Somers,	Manager of Drinking Water and Wastewater Management.
Qing Li,	Hydrogeologist, Environment, Water and Climate Change.
Kate McQuarrie,	Director, Forests, Fish and Wildlife Environment, Water and
	Climate Change.
Karalee McAskill,	Coordinator, Cornwall and Area Watershed Group.
Ron Bourdon,	Director, Cornwall and Area Watershed Group.

The 'Overview' (document attached) presented the case that, as a matter of demonstrable fact, **'the Policy Presentation (2014)':**

- **is not an accurate, reliable, science-based document;**
- **is not reflective of competency; and, that it….**
- **conveys misinformation.**

At the time of writing (Jan. 2021) the paper that is currently in front of you, 'the Policy Presentation' (2014) remains on the provincial government web-site. The case has already been made (November, 2019; in the attached 'Overview') that even the *references* ***cited*** **by** 'the Policy Presentation' (2014), conclusively demonstrate that **most of what the 'presentation' presents, simply is not true. That misinformation now very appropriately qualifies as being disinformation. Worse yet, that disinformation has for the most part been repeated in 'Abracadabra' which, therefore, can also appropriately be called disinformation.**

Scrutinizing and untangling disinformation in a science-based way by 'checking references'; comparing scientific papers; deciphering scientific papers; defining the terms/words used in such papers; and, attempting to present that information clearly; is a very time-consuming, cumbersome, frustrating, and tedious process. Therefore, the reader is directed to the 'Overview' attachment which is even more relevant and applicable today than it was a year ago, in debunking the disinformation *repeated* in 'Abracadabra'.

One aspect of the Overview (attachment) that will be repeated here are the recommendations of the **Standing Committee on Agriculture, Environment, Energy and Forestry - First Report of the Fifth Session Sixty-fourth General Assembly, Committee Activities** (November 19, 2014). Since that document was removed from the provincial government web-site in November of 2019, a scanned copy of the relevant pages appears on the following two pages.

The Standing Committee's fourth recommendation was that "**a thorough review of the scientific basis for our water policies be undertaken as part of the development of the water act**." The fourth recommendation goes on to speak of 'high capacity wells', *however*, the call for "a thorough review of the scientific basis for our water policies" did not apply *just* to 'high capacity wells':

> "A) **Identify and address knowledge gaps**; …. **At the outset of the water act *development* process** it will be important to eliminate weaknesses in our knowledge and understanding of the resource, *otherwise a weak policy will be the result*."
> (bold, italics, underlining added)
>
> **"to eliminate weaknesses in our knowledge and understanding of the resource, *otherwise a weak policy will be the result*" …. such as Abracadabra's *'*On The Level' *bizarrely slanted assertion* that the Island has only one aquifer.**

'The Policy Presentation' (2014) disinformation presented to the Standing Committee in 2014, remains on the provincial web-site; most of the same disinformation appears in the 'Abracadabra' (found at the On The Level web-site); but, the 2014 Standing Committee's recommendation calling for "a thorough review of the scientific basis for our water policies" was *removed* from the provincial web-site in November 2019. A scanned copy of the relevant pages of the Standing Committee's recommendations follows on the next two pages.

Following that, will be a critique of 'Abracadabra', including quotations from scientific papers that describe the many aquifers and types of aquifers found on the Island.

"***What is the opposite of* 'on the level'**? …"					
dishonest	deceitful	perfidious	unprincipled	mendacious	untrustworthy
unprincipled	shady	untruthful	unethical	false	dishonourable
Word Hippo, https://www.wordhippo.com/what-is/the-opposite-of/on_the_level.html#C0-2					

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"**footnote** 1.	a note at the bottom of the page….
2.	a piece of additional information that is *not very important* but is interesting or helps you understand something"
[e.g. something in the next few pages, may be put into perspective by this footnote.]	
Longman Dictionary of Contemporary English, https://www.ldoceonline.com/dictionary/footnote (italics & underlining added)	

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[Start of scanned document, November 19, 2014 Standing Committee Recommentation # 4]

4. Your committee strongly recommends that a thorough review of the scientific basis for our water policies be undertaken as part of the development of the water act.

Conflicting views were presented to your committee on whether science supports the moratorium on high capacity irrigation wells and the current water extraction policy. Your committee is not in a position to pass judgment on the scientific basis of current policy or determine scientific consensus for future policy. **However, witnesses put forward several suggestions of what a review should include:**

A) identify and address knowledge gaps;

Multiple areas of uncertainty surrounding water use were brought to your committee's attention. For example, what is the effect of high capacity extraction on nitrates distribution in the water supply? Also, is it sustainable to allow the same level of extraction of the mean summer base flow in all PEI streams, or should the level be fine-tuned on a watershed-basis? Experts may have answers in these areas, but in general your committee's investigations yielded more unknowns than certainties. At the outset of the water act development process it will be important to eliminate weaknesses in our knowledge and understanding of the resource, otherwise a weak policy will be the result.

B) use recent data and collect new data where necessary;

It was argued that some studies used in the development of the current water extraction policy are outdated. With a rapidly changing climate and increasing demands on our water supply it is not wise to rely on data and studies that no longer reflect the state of the resource. Ten years was suggested as a suitable threshold for relevance.

C) consult and follow the recommendations of specialists in a wide variety of fields, including but not limited to hydrogeology, climatology, ecology, agriculture, fisheries, forestry and wetlands;

Water is fundamental throughout the natural world and policies on its use should not be based on an isolated view of it. Instead, they must factor in the complexities of the water cycle and the multitude of interactions it has with species, naturally occurring and human-made habitats, and external influences. A wide knowledge base must inform our use and protection of this resource.

D) employ independent scientific peer review;

To be the basis on which our policies rest, the scientific representation of our water resource must be exposed to expert evaluation and criticism. Preliminary data, unpublished reports, and information that has not been subject to the scrutiny of the scientific community should be approached with caution and, at most, only used provisionally until peer review is complete.

E) increase monitoring efforts and commit to maintaining them in the future;

Current monitoring of existing high capacity wells is insufficient. As of 2014 there are 36 high capacity agricultural irrigation wells that were put in place before the 2002

moratorium. The Department of Environment, Labour and Justice has indicated that these have not been monitored on a long-term basis. There are also many more high capacity wells for municipal and industrial/commercial use; the committee is uncertain of the exact number of these or the extent that they are monitored. Management of our groundwater resource requires more monitoring of all high capacity wells across the Island, and consistent monitoring of those wells over time.

F) make data gathered from monitoring publicly accessible;

Your committee recognizes that data from 16 groundwater wells are available on the Department of Environment, Labour and Justice website, as are stream level, pesticide monitoring and water quality data. With increased monitoring, particularly of all forms of high capacity wells, your committee sees no reason not to publish more data on how our shared resource is being used.

G) incorporate flexibility so that new policies can be adjusted in response to our changing climate;

There is no ignoring that our climate is changing and change may be the only constant over this century and beyond. More frequent periods of drought, higher intensity precipitation, sea level rise and ocean acidification are just some of the major changes that are affecting our water supply and will continue to do so. Policies on water use and protection must incorporate our best predictions of the future based on recent trends, and must be adaptable so that the negative effects of climate change can be mitigated. The development of a comprehensive water act is an excellent opportunity to do this work.

H) follow the precautionary principle throughout.

It is clear that current and future actions in regard to PEI's water supply should be guided by the precautionary principle: the lack of scientific certainty or consensus regarding a potential environmental threat is not a reason to avoid taking protective measures against that potential threat.

[End of scanned document, November 19, 2014 Standing Committee Recommentation # 4]

Standing Committee on Agriculture, Environment, Energy and Forestry - First Report of the Fifth Session Sixty-fourth General Assembly, Committee Activities (November 19, 2014), (pg. 2, recommendation #4; bold added; 6 pgs.; web-accessed 06-Oct. 2019. *However*, in late October 2019 this document could not be found through the following link, or through a search of government web-sites,
http://www.assembly.pe.ca/sittings/2014fall/reports/11_2014-19-11-report.pdf (document no longer there)

Change of direction:

"**Aquifers are** defined as **geological formations that yield *useable* quantities of groundwater**."

Water Extraction Permitting Policy Department of Environment,
Labour & Justice, January 2013, (text pg. 4),

https://www.pngjoy.com/pngm/217/4230869_goodbye-change-ahead-png-hd-png-download.png https://www.princeedwardisland.ca/sites/default/files/publications/water_extraction_permitting_policy_2013.pdf

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What is an aquifer?

The pictures below are not of streams flowing over the tops of cliffs. Water is flowing out of fractures / cracks / fissures in the rock and from between the rock layers. Some rock layers store water and allow water to move through them much more easily than others. Those are called '**aquifers**' and they are what well-drillers look for.

Often aquifers are 'sandwiched' (above and below) by layers of rock that prevent much water from moving downwards into the aquifer to 'recharge' it, or downwards out of the aquifer. Those aquifers are called '**confined aquifers**', and the water from them is under pressure. Aquifers that are 'semi'-confined are 'semi'-pressurized.

When an aquifer is not *confined* in that way (although it still has some soil and rock above it), it's called an '**unconfined aquifer**'. Water in those aquifers is not under pressure; and, they tend to contain much more water than confined aquifers do.

Confined aquifers can be stacked one on top of another, with a semi-confined aquifer or an unconfined aquifer being the top layer. The top picture below is *probably* of water flowing from an unconfined aquifer.

How easily an aquifer gets 'recharged'; the effect that pumping has on it; and, how easily it can become contaminated; depends on the type of aquifer.

https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.pinterest.co.uk%2Famp%2Fpin%2F273735102236567 59%2F&psig=AOvVaw0c1jbYRLPtcq1E0FEvi6nI&ust=1611935777441000&source=images&cd=vfe&ved=0CAIQjRxqFwoTCJDW7fX-vu4CFQAAAAAdAAAAABAD

https://photojeepers.com/calf-creek-falls-hiking-guide/?epik=dj0yJnU9RTZPRXVJMndhbDN4Q1oyUGF2RGwwT0RGZGk4Y3d0SDQmcD0wJm49QkZKVHBZNnNfeGthdmtYYkpUUTY0ZyZ0PUFBQUFBR0FTMzk4

"… the cliffs are "painted" by minerals dissolved by underground springs… that then drip down the sides of the sandstone. The color indicates the mineral: white is calcite, **orange is iron**, gray is dolomite, blues and greens are copper, black is manganese."

https://erinbartels.com/2017/06/23/the-unsurpassed-beauty-of-pictured-rocks-national-lakeshore/

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A Brief Review of the Physical Characteristics of PEI's 'Redbed Aquifer' (Abracadabra):

"The Department's current approach *to assess groundwater allocation* proposals was recently reviewed by an independent party [[o] MacQuarrie, 2014]. The goal of the review was to provide an independent, scientific opinion regarding *the* [*groundwater allocation*] *methodologies*…. In particular, the focus… was on *the science basis for groundwater extraction assessments and groundwater quantity estimates*. ([o] MacQuarrie, 2014)." (text pg. 3, para. 4)

Regrettably, it seems evident from the above quote, and from MacQuarrie's (2014) *eight pages of comments*, that:

- reviewing the **appropriate and consistent use of terminology**; or…
- reviewing the **appropriate use of scientific citations**; or…
- reviewing the **familiarity of Departmental staff *with their very own* research papers**; or…
- reviewing the **familiarity of staff with the other research papers** they cite; …

was <u>not</u> part of his mandate or 'terms of reference'.

Also, the above quote (text pg. 3, para. 4) *seems to suggest* or *to allude to* the MacQuarrie (2014) review being a response to the (19 Nov. 2014) **Standing Committee on Agriculture, Environment, Energy and Forestry, First Report of the Fifth Session Sixty-fourth General Assembly, Committee Activities, recommendation 4.A) - 4.H) (**Refer to previous pages 4 & 5). *If <u>that</u>* is what the author/s may be *implying*, then evidently many critical aspects of the Standing Committee's recommendations (e.g. **4.A 'Identify and address knowledge gaps')** do <u>not</u> appear to have been part of the MacQuarrie (2014) mandate either.

[o] **Review of Groundwater Assessment Methodology (Province of Prince Edward Island)**; MacQuarrie (2014); Dept. of Environment, Labour & Justice Province of Prince Edward Island; (11 pgs.; 8 pages of comments), https://www.princeedwardisland.ca/sites/default/files/publications/review_of_groundwater_assessment_methodology_0.pdf

"PEI… water supply, needs… are met by <u>a single bedrock aquifer underlying the Province</u>. <u>It is hoped that the following</u> [A Brief Review of the Physical Characteristics of PEI's 'Redbed Aquifer'] <u>review</u> of… this aquifer <u>provides *a sound scientific basis* for discussion</u>

- about the Province's groundwater resources and
- [about] whether concern is warranted." (Introduction, pg. 2, para. 2)

'Abracadabra' is soundly and arrogantly <u>not</u> scientific. There is a solid basis warranting dire concern about the apparent ineptitude of (*at the very least*) its author/s, who should have absolutely nothing to do with managing aquifers they don't even acknowledge exist.

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'Abracadabra' asserts: "<u>In a comment</u> <u>on a report</u> <u>on groundwater mapping</u> in Canada, it [the CC A (2009)] notes **'since there is a single sandstone aquifer covering the province, further aquifer mapping is unnecessary from a <u>geological</u> perspective'**." (pg. 5, para. 1; bold & underlining added)

But, checking the Abracadabra 'References Cited' and the source document, **the CCA did *not* make** "*a comment on a report on groundwater mapping*". **It made *a footnote* at the bottom of a page**, ***below a table partly about* mapping** (see footnote close to bottom of this page). Citing footnote[19] (below) as the scientific basis, the author/s of A Brief Review of the Physical Characteristics of PEI's 'Redbed Aquifer' claim the Island has only one aquifer; and, essentially advise researchers and Islanders in general, **not to bother looking for *other I*sland aquifers**.

CCA (2009) - The Sustainable Management of Groundwater in Canada; Report of the Expert Panel on Groundwater (2009); Council of Canadian Academies, (text pg. 75); For brevity, most province entries were removed from the scan of the original table; bold, italics, underlining, added),

http://www.cec.org/wp-content/uploads/wpallimport/files/17-1-sub-appendix_ix_-_expert_panel_on_groundwater_-_sustainable_management_of_groundwater_-_2009.pdf (270 pgs.)

Table 4.2

Summary of Aquifer Mapping and Groundwater Monitoring Programs (August, 2007)

Province	Does the province have an inventory of aquifers?	Does the province have a program to measure groundwater levels in a monitoring network?
Prince Edward Island	No (only one main aquifer)[19]	Yes — 13 wells are monitored in a partnership agreement with the federal government; data are accessible over the web.
British Columbia	Yes — inventory of some 900 aquifers — not necessary to delineate the full extent of the aquifer (e.g., could be delineated on the basis of a number of wells using same unit).	Yes — 163 wells are monitored; data are available on a website.

[Above comment beside Prince Edward Island heading says: "No. (only one main aquifer)[19]" Note the superscript [19] which refers to the footnote at page bottom]

[Above: the B.C. comment above says that there is an "inventory of 900 aquifers" in B.C. and that an inventory is "not necessary to delineate the full extent of the aquifer". It seems obvious that the use of the singular term 'aquifer' refers to an 'aquifer *system*'.]

19 In Prince Edward Island, since there is a single sandstone aquifer covering the province, further aquifer mapping is unnecessary from a geological perspective.

From a *geological* perspective further mapping *may or may not* be necessary; but, from a ***hydro*-geological perspective, further aquifer mapping might be a fine idea… particularly since the Abracadabra author/s seem to have misplaced our aquifers**:

"The study of water flow in aquifers and **the characterization of aquifers is called hydrogeology** [not 'geology']."

A Status Review of the Hydrological Characterization of the Basement Complex Aquifers in Taraba State, N.E. Nigeria, Okeke & Omoko (2017); Dept. of Geology, Federal University of Technology, Owerri, Nigeria; IJRDO-Journal of Applied Science, Volume-3 | Issue-5 | May,2017 | Paper-1; (text pg. 1); (26 pgs.),
https://www.google.ca/url?sa=i&url=https%3A%2F%2Fmail.ijrdo.org%2Findex.php%2Fas%2Farticle%2Fdownload%2F1276%2F1204%2F&psig=AOvVaw0UK7aD0rKLTgAkm4VVtBVX&ust=1608207554273000&source=images&cd=vfe&ved=0CA0QjhxqFwoTCJCctpy-0u0CFQAAAAAdAAAAABAU

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A simplistic but very effective way to shut down debate		
Consider the ***credibility* of footnote[19]**, by comparing it with another comment made *on the <u>same page</u>*; and, a third comment made on a different page of that CCA (2009) publication:		
(1)	"PEI is **essentially** <u>one aquifer</u>… composed of sedimentary rock formations dominated by sandstone." (text pg. 127; bold & underlining added)	• **Essentially**, more-or-less, in effect, some people might agree… • But, it is <u>not</u> *entirely* true (as the following pages will show).
(2)	"No (only ***one*** <u>*main* aquifer</u>)[19]" (Table 4.2, text pg. 75; bold, italics, underling added)	• Since a P.E.I. respondent evidently reported there was one ***<u>main</u>*** aquifer, there must be <u>*more* than one</u> aquifer. • How does comment **(2)** go from being " ***one*** <u>*main* aquifer</u> " with a footnote, to being " ***<u>a single</u>*** <u>*sandstone aquifer*</u> " in the footnote?
(3)	"[19] In Prince Edward Island, since there is ***<u>a single</u>*** <u>*sandstone aquifer*</u> covering the province, further aquifer mapping is unnecessary from a <u>geological</u> perspective." (Footnote to Table 4.2; bold & underlining added)	How does the description shift from being: • "essentially one aquifer"… to • "one main aquifer"…to • "there is a single sandstone aquifer"?
In **a single publication**, **on only <u>two</u> pages**, the CCA (2009) gives essentially ***<u>three</u> different* descriptions of how many aquifers P.E.I. has**: **(1)** "*essentially* one" **(2)** "one *main* aquifer" **(3)** "*a single*… aquifer".		
Why did the author/s of *A Brief Review of the Physical Characteristics of PEI's 'Redbed Aquifer'* decide (pg. 5, para. 1) to go with the third one, the footnote: **"… since there is a single sandstone aquifer covering the province, further aquifer mapping is unnecessary from a *geological* perspective." ?**		

Kilroy https://commons.wikimedia.org/wiki/File:KroySquare.jpg was here below

Claiming P.E.I. has <u>only *one* aquifer</u>, denies the existence of *other* aquifers and of other *types* of aquifers. It would be ***a simplistic* <u>but</u> *very effective way* to shut down debate:**

Pointless raising concerns about *<u>other</u>*** aquifers or ***<u>other</u>* <u>types of</u> aquifers…**

when our water managers say there's only one aquifer….

***Pointless even looking* for *other* aquifers…**

Let's look anyway!

'Salt Water Well Study - Prince Edward Island, Jacques Whitford and Associates':

"**2.4 Hydrogeology** - T*he entire bedrock aquifer* in Prince Edward Island is a classical example of a fractured porous media, in which the hydraulic conductivity is due almost entirely to fractures and the storativity is dependant upon the intergranular porosity of the rock…." (text pg. 9)

"**Hydraulic conductivity** is… the ability of the material to transmit fluid through pore spaces and fractures in the presence of an applied hydraulic gradient ['water pressure' difference]."
[i.e. it is the ability of water to flow/transit/travel/'be *conducted* through' the aquifer]

Open Energy Information,
https://openei.org/wiki/Definition:Hydraulic_Conductivity#:~:text=Wikipedia%20Definition,through%20pore%20spaces%20or%20fractures

"**Hydraulic conductivity**:
- k_h measured in horizontal direction
- k_v measured in vertical direction
- k_r measured in repacked (disturbed) sample"

The Stratigraphy and Hydraulic Properties of Tills in Southern New England; Melvin, de Lama, & Stone (1992); U.S. Geological Survey Open-File Report 91-481; U.S. Environmental Protection Agency, Waste Management Division, Region 1; (text pg. 19),
https://pubs.usgs.gov/of/1991/0481/report.pdf (57 pgs)

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[The way that the following paragraph speaks of *numerous aquifers* and of *multiple layered (stacked) aquifers,* clarifies that the **previous paragraph's reference to "the entire bedrock aquifer"** (which might appear to be saying that there is only *one* aquifer on the Island), would actually be a **reference to '*the entire bedrock* aquifer *system*'** composed of numerous aquifers.]

"…. Prince Edward Island is typified by **horizontally-stratified, multiple-layered confined and leaky** [semi-confined] **aquifers** of relatively high transmissivity. Recharge areas to many of these [aquifers] sub-crop beneath the sea, suggesting the promise for salt water development if vertical *leakage from fresh water zones is minimal* [i.e. if confining layers minimize leakage of fresh-water into the **salt-water aquifers**]. The numerous saline [salt-water] estuaries… permit high tides to carry sea water a long way inland. This increases… the potential for sea water intrusion in wells." (text pg. 10; hyphen added to 'sub-crop'; underlining, bold, & italics added)

"**OUTCROP** (portion of a water-bearing rock unit [aquifer] exposed at the land surface).
SUBCROP (portion of a water-bearing rock unit existing below other rock units) [sub-surface]"

Texas Well Owner Network Well Owner's Guide to Water Supply; Uhlman et al. (no date); footnote to 'Major aquifers of Texas' (web-pg. 2); B-6257 11/12; The Texas A & M University,
https://twon.tamu.edu/media/358238/lowres.pdf (96 pgs.; bold & underlining added)

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> "The surface extent [area], or **outcrop**, of each aquifer is **the area in which the host formations are exposed at the land surface**. This area **corresponds to the principal recharge zone** for the [fresh-water] aquifers. Groundwater encountered within this area is normally under unconfined… conditions and is most susceptible to contamination."
>
> **Texas Aquifers**, Texas Water Development Board, TWDB Report 380, (bold & underlining added), https://www.twdb.texas.gov/groundwater/aquifer/index.asp

"It is probable that the dominant [main] direction of regional [Island-wide] groundwater flow is northward in the direction of bedrock dip, creating a greater seaward movement [flow] of fresh water along [towards] the north coast than the south coast. The uplifted and exposed bedrock units [formations] along the south coast provide greater horizontal hydraulic continuity [connection] between sea water and the permeable formations [on land] …. This implies a greater likelihood of successful **salt water wells** [or, of salt-water intrusion] in strata sub-cropping beneath the sea, on the south coast [see the following quotes], than strata dipping beneath the sea, on the north coast." (text pg. 11; bold, & underlining added)

Salt Water Well Study - Prince Edward Island, Project No. 5424, Report to (1) P.E.I. Dept. of Environment, (2) P.E.I. Dept. of Industry, (3) Atlantic Canada Opportunities Agency; Jacques Whitford and Associates Ltd. (March 1990). (**Not available on line: perhaps because it contradicts the current apparent disinformation strategy**.)

'Salt Water Intrusion in the Summerside Area, P.E.I.':

"… Summerside, ground-water supplies are… from ***an* aquifer** hydraulically connected with the sea. Over the past ten years [1963-1973], there has been progressive…. salt water intrusion…. aided by the relatively high transmissivity [permeability permitting flow of water] of the fractured… sandstone… **semiconfined aquifer**. Two separate zones of salt water contamination exist… **an upper [aquifer] zone** from a depth of 0 to 80 feet caused by a landward hydraulic gradient [higher pressure of the sea compared to the 'water pressure' of fresh-water] due to heavy pumping; and, **a second** [likely **confined, aquifer**] **zone** at a depth of 350 to 400 feet due to intermittent pumping resulting in a raising and thickening of the zone of diffusion [zone of brackish/salty water]."

Salt Water Intrusion in the Summerside Area, P.E.I.; Tremblay, D'Cruz, & Anger (March 1973; issued on line 06 July 2006); National Groundwater Association; (Abstract; *'; and,'* & punctuation added), https://ngwa.onlinelibrary.wiley.com/doi/epdf/10.1111/j.1745-6584.1973.tb02962.x

"PEI is entirely underlain by an **unconfined** *or* **semi-confined** fractured-porous **aquifer** [system]." (text pg. 7) Logically, the aquifer system must consist of **unconfined aquifers at some locations,** and **semi-confined aquifers at other locations**. **See the top of the next page**.

Nitrogen Loading Criteria For Estuaries In Prince Edward Island; Bugden, [1]**Y. Jiang**, van den Heuvel, Vandermeulen, **MacQuarrie**, Crane, [2]**B.G. Raymond** (2014); Canadian Technical Report of Fisheries and Aquatic Sciences 3066; [1]Agriculture and Agri-Food Canada; [2]P.E.I. Dept. of Environment, Labour & Justice, (52 pgs.) https://www.princeedwardisland.ca/sites/default/files/publications/nitrogen_loading_criteria_for_estuaries_in_prince_edward_island.pdf

	The Island aquifer system			
				The Island road system has **clay roads** *or* **paved roads**. By definition and common sense, at any one location **a road can be** *either* **clay** *or* **paved**: **it can't be both**.
The Island aquifer system has **unconfined aquifers** and **confined** or **semi-confined aquifers**. By definition and common sense, *at any one location* ***and*** *depth*, **aquifers can be** ***either*** **unconfined or semi-confined, but** ***not*** **both**.				

'**Case Study: Simulating Saltwater Intrusion in a Changing Climate, Summerside, PEI':**
"**Vertical hydraulic gradients suggest a recharging environment in both coastal and inland wells with the exception of well 5, due to the presence of a clay-stone *confining layer* and horizontally occurring fractures associated with bedding planes** [layers of the geological formations]." (text pg. 37)

"Hydrological analyses suggest the aquifer behaves in an **unconfined**, **semi-confined** manner ['with the exception of well 5, due to the presence of a clay-stone confining layer']…"
(text pg. 34)

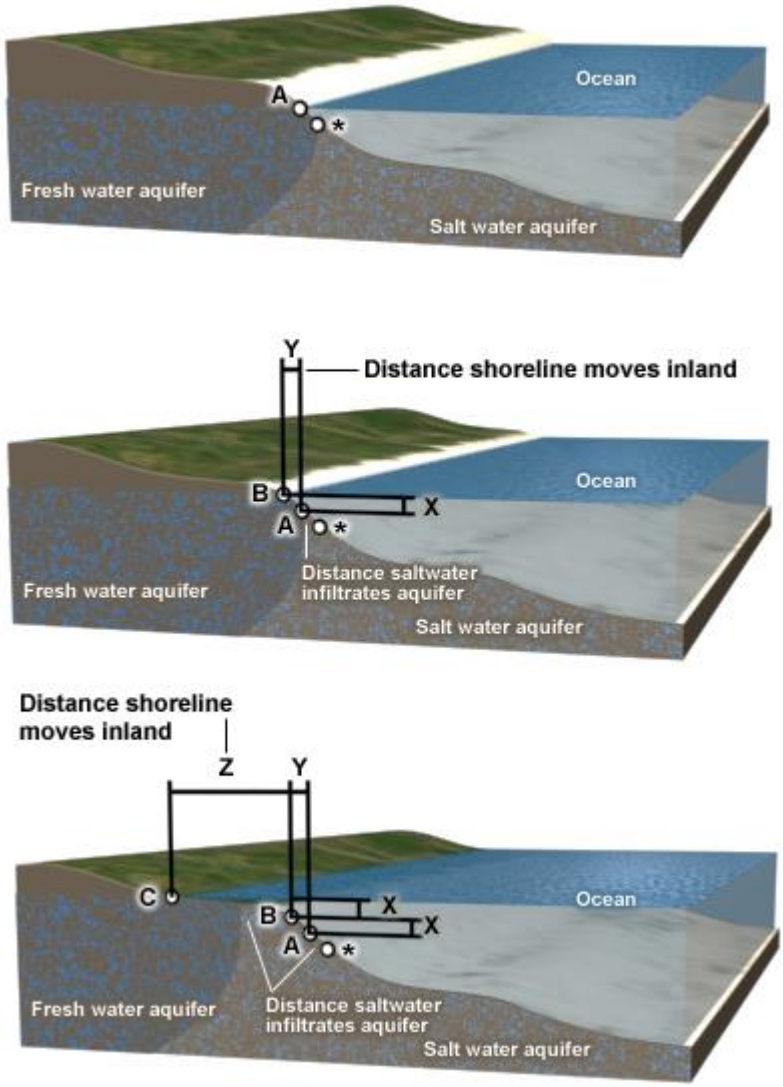
"3.2…. The ***uppermost portion*** **of the island's red bed formation forms an unconfined / semi-confined aquifer… across most of the province**." (text pg. 37)

"… similar to that of previous investigations in the region. Important geological features… pertain to saltwater intrusion are the presence of horizontal fractures and fractured bedding plains associated with clay-stone [confining] layers. These conduits [**confined above & below and acting like a pipeline**] can provide direct pathways for the lateral encroachment [intrusion] of saltwater, and therefore, increase the susceptibility **of the** [confined] **aquifer** to saltwater contamination. The influence of these fractures on hydrogeological processes is exhibited in the strong **tidal signal** [tide-induced rise & fall of water in the well] observed in **well 5**. If pumping was to commence in this well or any similar well, the presence of these fractures would rapidly lead to saltwater contamination." (text pg. 40)

Case Study: Simulating Saltwater Intrusion in a Changing Climate, Summerside, PEI; **Hansen**[1] & Ferguson[2] (2012); [1]Dept. of Earth Sciences, Saint Francis Xavier University, Nova Scotia; [2]Dept. of Civil & Geological Engineering, University of Saskatchewan; **Managing Groundwater Resources - Assessing the impact of climate change on salt-water intrusion of coastal aquifers in Atlantic Canada**, **Somers** & **Nishimura** (eds.); P.E.I. Dept. of Environment, Labour and Justice; November 2012, [bold, underlining, italics added], http://www.gov.pe.ca/photos/original/cle_WA2.pdf

https://ih1.redbubble.net/image.1320501568.7118/st,small,507x507-pad,600x600,f8f8f8.jpg →

Salt-water Aquifer



↓

"The diagram [at left]… illustrates how coastal areas may experience a 'tipping point' for salt water

←

infiltration [salt-water intrusion]….. Sea level begins at '**A**' and the aquifer interface [fresh-water salt-water interface] begins at the point marked with the star [*]. As the sea rises one unit (**x**), the **saltwater aquifer** interface moves to

←

'**A**' and the shoreline moves in a distance (**y**). But when the sea again rises the same amount (**x**), the coast advances a much greater distance, **z**, *and the saltwater infiltrates the aquifer much further* as well."

←

Coastal Climate Change - The Coast to Come, The Point of No Return;
University Corporation for Atmospheric Research (2011), (single quotation marks, bold, & arrows added),
http://kejian1.cmatc.cn/vod/comet/climate/coastalclimate/navmenu.php_tab_3_page_6.3.0.htm

Abracadabra says the situation is covered… but it doesn't look it.

The Emperor's New Clothes - Character, Education, Economics, Fairy Tales, Science, Social Studies;
Lee Harper (2013); FreshPlans; http://www.myfreshplans.com/2010/07/the-emporers-new-clothes/ (caption: Bourdon)

"**The <u>uppermost</u> portion** of the bedrock formations forms an **unconfined/semi-confined** fractured-porous aquifer." (Introduction) The "uppermost portion" must be composed of **more than one aquifer: at some locations unconfined; at other locations semi-confined**. *<u>Below</u>* the "uppermost portion" there may be confined aquifers.

Modeling Nitrate Transport in Groundwater in the Wilmot River Watershed on Prince Edward Island, Canada; Jiang, Somers, et al. (2012), P.E.I. Dept. of Environment, Energy & Forestry,; (underlining added), http://en.cgs.gov.cn/achievements/201601/t20160112_35554.html

"… **residence time**… the amount of time a moving element [e.g. a water molecule] has spent in a hydrologic system [i.e. in the ground]… **Alternative names** for residence time include **transit time**, **travel time**, **age**, and **exposure time** [i.e. it is the amount of time it takes (due to the level of conductivity) for water to flow/transit/travel through]…"

Residence time distributions for hydrologic systems: Mechanistic foundations and steady-state analytical solutions; Leray et al. Journal of Hydrology, Elsevier, 2016 (text pg. 3; 77 pgs.; bold added) https://core.ac.uk/download/pdf/48158253.pdf

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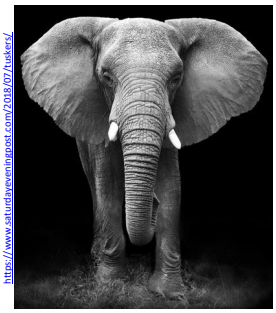

https://www.saturdayeveningpost.com/2018/07/tuskers/

To "**go rogue**: to begin to behave in an independent or uncontrolled way that is not authorized, normal, or expected." https://www.**merriam-webster**.com/dictionary/rogue

To go rogue: "Behave erratically or dangerously, especially by disregarding the rules or the usual way of doing something." https://www.**lexico**.com/definition/go_rogue

"The earliest known citations for '**going rogue**' all dealt with **elephants**…" https://www.**merriam-webster**.com/words-at-play/were-going-rogue

"The expression… [ignoring] '**the elephant in the room'**… is… an… enormous topic… or controversial issue that is obvious… but no one mentions or wants to discuss because it makes at least some [people]… uncomfortable or is personally, socially, or politically embarrassing, controversial, inflammatory, or dangerous." https://en.**wikipedia**.org/wiki/Elephant_in_the_room

"Prince Edward Island…. <u>Surficial</u> [surface] <u>deposits</u> [e.g. till; sand] are <u>not *significant* **aquifers**</u> [plural]. However, the uppermost portion of the sandstone formation forms a fractured-porous aquifer…. **unconfined** [**aquifer**], <u>except in local areas</u> where less permeable mudstone beds alternate with sandstone to generate **semi-confined** [**aquifer**] conditions…. Water flows <u>in the uppermost part of the aquifer</u>, which is strongly fractured and <u>constitutes **a fast path layer for groundwater flow**</u>. [<u>**the aquifer** **is a fast path for** **ground-water flow**</u>] Groundwater flow follows surface topography and decreases with depth due to lower fracturing causing lower hydraulic conductivity [lower flow rates]."

Prince Edward Island regional bedrock aquifer; Groundwater Information Network (2014), https://gin.gw-info.net/service/api_ngwds:gin2/en/data/standard.hydrogeologicunit.html?id=215

'Multi-scale nitrate transport in a sandstone *aquifer system* under intensive agriculture':
"… nitrate reaches the more permeable **shallow aquifer** through fractures in weathered sandstone that represent only 1% of the total porosity (17%) [which means that the actual porosity of the confining weathered sandstone is 0**.**17%]. Some of the nitrate reaches **the underlying aquifer**, which is less active in terms of groundwater flow…. **Groundwater** in the **underlying aquifer**, which **has long residence times**, is also largely influenced by the diffusion of nitrate in the porous sandstone matrix." (Abstract, text pg. 2)

"**2.2 Hydrogeological characteristics of the Wilmot aquifer** - **The sandstone aquifer in the Wilmot Watershed** is both fractured and porous…" (text pg. ~ 4)

"… there is strong… evidence for **an aquifer system** having two intervals (**HF** [**H**igh **F**low] and **LF** [**L**ow **F**low]) with significantly different magnitudes [volumes] of groundwater flow." (text pg. 6)

"At the scale of **the watershed *aquifer system***, slowly migrating nitrate in the fracture system diffuses into the porous matrix, which retards nitrate migration and leads to a large accumulation of nitrate mass in the porous matrix of the aquifer. The nitrate mass discharging with groundwater into the Wilmot River thus has a large time lag with variations in the nitrate flux from the soil to the aquifer. Nitrate reaching the Wilmot River represents a mixture of nitrate having migrated with groundwaters of various residence times, **which have flowed through different parts of the aquifer *system***." (text pg. ~ 19)

Multi-scale nitrate transport in a sandstone *aquifer system* under intensive agriculture; Paradis[1], Ballard[2], Lefebvre[2], & Savard[1] (2017); [1] Geological Survey of Canada; [2] Institut national de la recherche scientifique; Hydrogeology Journal 26(2):1-21; (21 pgs.; bold added), https://www.researchgate.net/publication/320036922_Multi-scale_nitrate_transport_in_a_sandstone_aquifer_system_under_intensive_agriculture

"The Province relies entirely on **GW** [**g**round-**w**ater] supplied from **a *series*** [plural] **of unconfined**, fractured sandstone **aquifers** [plural] as a source of potable water." (text pg. 1255)

Considerations for the mitigation of nitrate contamination: stable isotopes and insights into the importance of soil processes; **Somers** & Savard (2011); Water Science & Technology | 64.6 | 2011, http://www.gov.pe.ca/photos/original/cle_WA17.pdf (7 pgs.)

Ignore Me

https://www.google.ca/url?sa=i&url=https%3A%2F%2Fwww.istockphoto.com%2Fphotos%2Felephant-rear-end&psig=AOvVaw2PKeOL5IBagaLBy2wHcdpq&ust=1615672199607000&source=images&cd=vfe&ved=0CAIQjRxqFwoTCKj_oJ7eq-8CFQAAAAAdAAAAABAz

'Canada's Groundwater Resources':
"Till is thin, but widespread and adequately transmits water to permit significant recharge to bedrock aquifer systems since bedrock outcrops are rare…. Of concern in Prince Edward Island… is **saltwater intrusion** which, even in the absence of extraction [pumping], can migrate landward [further inland] ~ [approximately] 500 m **beneath a thin surface freshwater lens** because **land to sea gradients** *are low* [water-table elevations (above sea level) are relatively low]… In addition, sea levels have been rising for thousands of years, and fresh groundwater may occur in **deeper aquifers**, essentially trapped beneath intruding seawater in **shallower aquifers** (Van der Kamp, 1981). [i.e. aquifers are layered/stacked]" (text pg. 294)

> "In low relief [low-lying topography] landscapes, it is primarily freshwater flow [head; water pressure] that limits the movement of saline [salty] water inland, against the intuitive ***land-to-sea gradient*** [relatively low difference in head/'water pressure' exerted by the height (elevation) of the water-table counter-balancing the pressure exerted by the ocean pushing salt-water intrusion inland]." (text pg. 2)
>
> **Evaluating the effects of land-use change and future climate change on vulnerability of coastal landscapes to saltwater intrusion;** Bhattachan et al. (2018); Elementa Science of the Anthropocene, 6: 62. DOI: https://doi.org/10.1525/elementa.316; (11 pgs.)

Canada's Groundwater Resources; compiled & edited by Alfonso Rivera (2014), Chief Hydrogeologist, Geological Survey of Canada; published by Fitzhenry & Whiteside; (bold, italic, & underlining added), (824 pgs.)
https://geoscan.nrcan.gc.ca/starweb/geoscan/servlet.starweb?path=geoscan/fulle.web&search1=R=293431

'Groundwater response to the tide in wetlands: Observations from the Gillman Marshes, South Australia': The relevance of the following is not the research findings, but that it refers to a data set from **11 confined *coastal* aquifers on Prince Edward Island**:

"Two historical data sets are also suitable for a single constituent tidal analysis. Firstly, at Sizewell... in the United Kingdom… where the geology consists of a highly permeable sand sequence overlying bedrock…. [and,] Secondly, in the **confined coastal aquifers** on **Prince Edward Island**, Canada, data were collected (*__Carr and van der Kamp, 1969__) around Charlottetown in a region where the groundwater moves through fractures between sandstone and siltstone facies. Here, the tidal analysis indicated that for 4 out of **11 aquifers**, the… parameter… varies…" (text pg. 225)

> **[*__Carr**, P.A., **van der Kamp**, G.S., 1969. **Determining aquifer characteristics by the tidal method**. Water Resources Research 5, 1023–1031.]

Groundwater response to the tide in wetlands: Observations from the Gillman Marshes, South Australia; Bye [A] & Narayan [B] (2009); [A] School of Earth Sciences, University of Melbourne, Australia; [B] Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia's national science agency, CSIRO Land and Water, Canberra, Australia; Estuarine, Coastal and Shelf Science, 84 (2009) 219–226, (8 pgs.; bold & underlining added)
Groundwater response to the tide in wetlands: Observations from the G illman Marshes, South Australia (uol.de)

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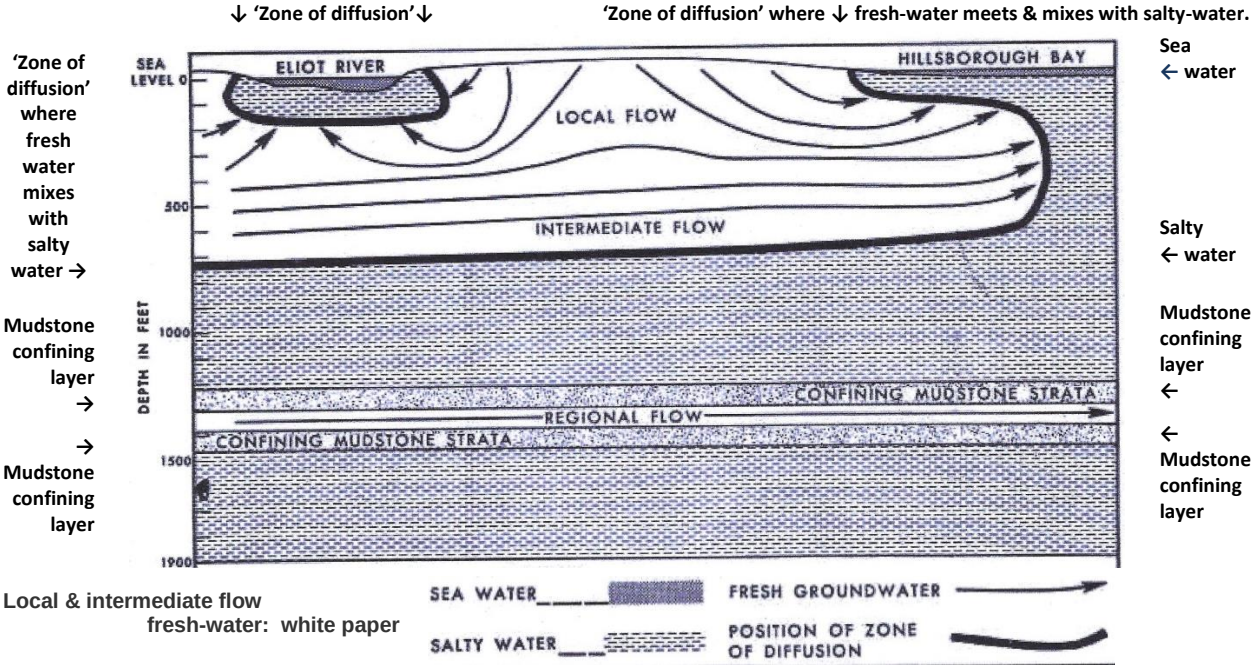
'Salt-water intrusion in Prince Edward Island': 'a layered system of aquifers'.

"Zones of diffusion occur in **aquifers** situated along sea coasts. They are a mixture of fresh groundwater flowing out to the sea and sea water flowing into the aquifer." (text pg. 63)

"In well number 4, salt water was encountered at depths of 150 [46 m], 400 [122 m], and 490 ft. [149 m] below sea level, and considerable flows of fresh groundwater were encountered at 860 [262 m], 900 [274], 1380 [421 m] and 1600 ft. [488 m] below sea level. The latter footage [1600 ft. / 488 m] is the greatest known depth of fresh groundwater occurrence in these rocks. The **fresh groundwater invariably** [without exception] **occurred in the sandstone strata** [layer] **rather than in mudstone**. Since the fractures in the mudstone at this depth are probably closed due to the weight of the overlying strata, they **act as confining beds**, *separating the fresh water from the salt water*…." **A confined, layered aquifer**, implicitly. (pg. 73; italics & underlining added)



"Fig. 9. Composite sketch of fresh and salty water in bedrock aquifers along the coast of Prince Edward Island."

[Above, note that Carr is describing (**a layered system of aquifers plural**)↑]

Salt-water intrusion in Prince Edward Island; Carr (1968), Inland Waters Branch, Dept. of Energy, Mines & Resources, Ottawa, Canada; (Pg. 73 fig. 9 reformatted with added labels) cle_WA6.pdf (gov.pe.ca)

"3.2.4 It should be noted that hydraulically **single aquifers** seldom exist in nature. An aquifer is generally part of a system of two or more aquifers, which is more complex….. **hydraulic and hydrogeologic parameters… are used to characterize an aquifer system**…"

Indian Council of Agricultural Research (2014), [bold & underlining added], http://ecoursesonline.iasri.res.in/mod/page/view.php?id=1814#:~:text=Aquifer%20thickness%2C%20hydrac%20head%2C%20Darcy,to%20characterize%20an%20aquifer%20system.

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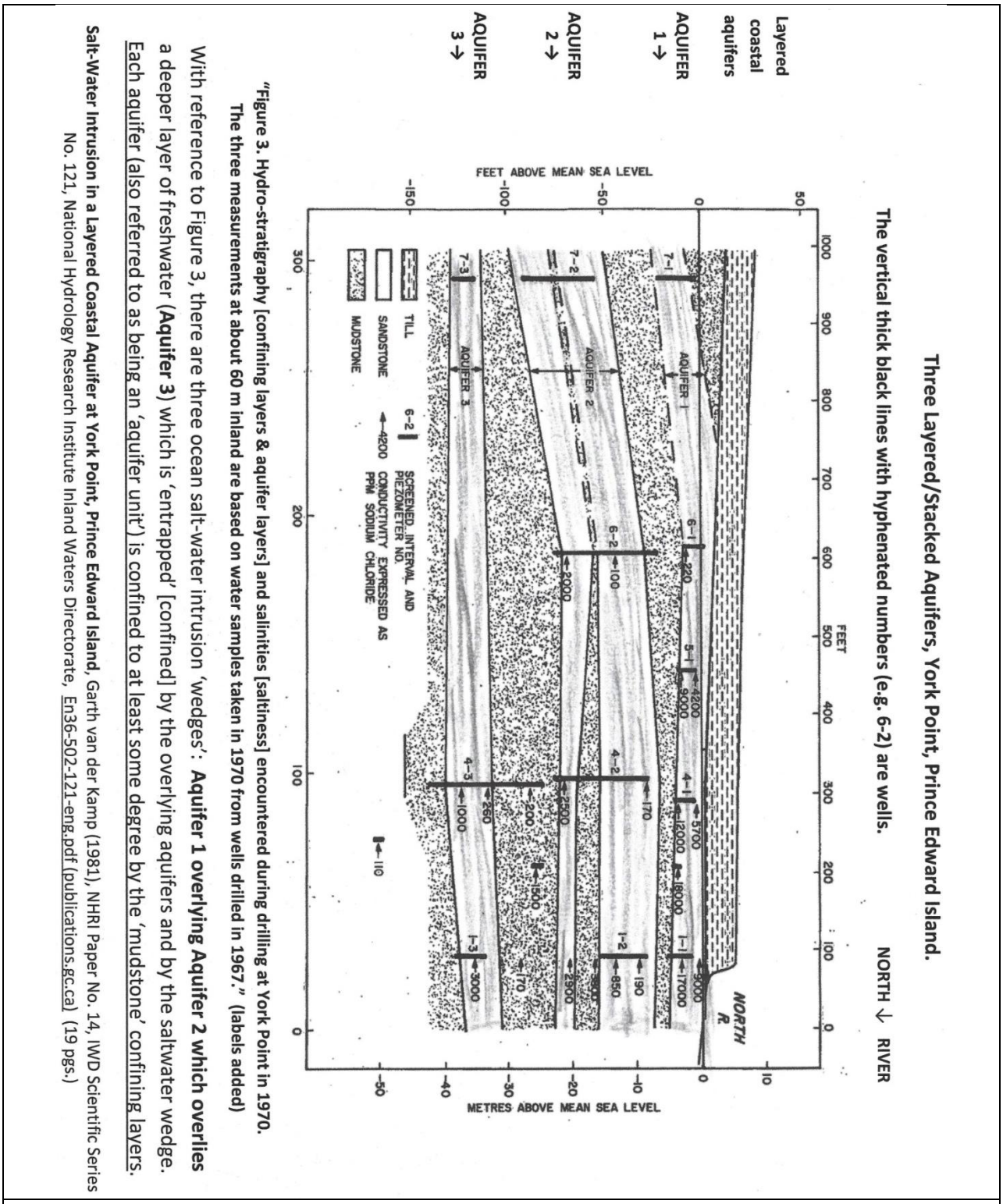

"Figure 3. Hydro-stratigraphy [confining layers & aquifer layers] and salinities [saltiness] encountered during drilling at York Point in 1970. The three measurements at about 60 m inland are based on water samples taken in 1970 from wells drilled in 1967." (labels added)

With reference to Figure 3, there are three ocean salt-water intrusion 'wedges': **Aquifer 1 overlying Aquifer 2 which overlies** a deeper layer of freshwater (**Aquifer 3**) which is 'entrapped' [confined] by the overlying aquifers and by the saltwater wedge. Each aquifer (also referred to as being an 'aquifer unit') is confined to at least some degree by the 'mudstone' confining layers.

Salt-Water Intrusion in a Layered Coastal Aquifer at York Point, Prince Edward Island, Garth van der Kamp (1981), NHRI Paper No. 14, IWD Scientific Series No. 121, National Hydrology Research Institute Inland Waters Directorate, En36-502-121-eng.pdf (publications.gc.ca) (19 pgs.)

Layered/Stacked Aquifers, York Point, Prince Edward Island

Salt-Water Intrusion in a *Layered* Coastal Aquifer at York Point, Prince Edward Island, Garth van der Kamp (1981), NHRI Paper No. 14, IWD Scientific Series No. 121, National Hydrology Research Institute Inland Waters Directorate; En36-502-121-eng.pdf (publications.gc.ca) (19 pgs.; bold, underlining, & italics added)

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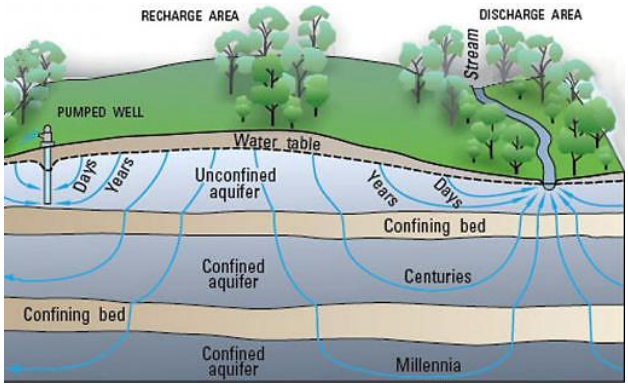
'Technical Information for Lot 11 and Area Watershed Managers':

"**About Groundwater [and, about the layering/stacking of aquifers]**

… water trickles through the zone of aeration [above the water table] until it reaches the aquifer at a boundary called the *water table*. This process… is called *recharge*. The aquifer has a lower boundary also, which may be clay or bedrock. Usually there is another aquifer **below this *uppermost* *aquifer*** called a ***secondary aquifer*** or a ***confined aquifer***…. When the elevation of the land dips below the elevation of the water table we see *surface water* (river, stream, pond, lake, etc.)."

"…. A topographical region where the rain recharges a specific **uppermost aquifer** is closely related to the topographical region that drains to a specific river (watershed) in our small, divided systems on PEI…."

"….The water in the **confined aquifers** [below the 'uppermost' aquifer] will become contaminated at a slower rate than in the **uppermost aquifer**. However, once contaminated, the **confined aquifer** may take centuries to regenerate."



https://d2gne97vdumgn3.cloudfront.net/api/file/4dfLc7nVQ0OYB0kOQ8bT

Technical Information for Lot 11 and Area Watershed Managers; prepared by Mark Bishop, Chairperson, Lot 11 and Area Watershed Management Group; acknowledging the P.E.I. dept. of Environment, Energy and Forestry, and Darren Bardati, Director of Environmental Studies, U.P.E.I.;

(text pg. 8; bold & underlining added; the graphic at left is in the Bishop article but was copied from another source); (71 pgs.)

http://mark-bishop.net/environmental/wsTech.pdf

About the above graphic and 'ground-water flow systems': "… the **volumetric flux** [the volume of movement/change] of groundwater through the regional flow system is very small compared to the local or intermediate systems because of the **much lower hydraulic conductivity** [much lower ability-of-water-to-flow-through] **values** at depth [*deeper than 100 m*]. **Consequently, the residence time** ['travel time'; 'recharge time'] **of groundwater in the regional flow system may be many *hundreds* or *several thousands of years***. These results suggest that when constructing wells in the lower half of the watershed near the river, one should be aware of the possibility of encountering less suitable, high sodium [salty] groundwater *at depth* [*deeper than 100 m*]." (pg. 108) The deeper the ground-water flow, the more *excruciatingly* slow the flow is.

Hydrogeology of the Winter River Basin - Prince Edward Island, Francis (1989), P.E.I. Dept. of the Environment, Water Resources Branch, http://www.gov.pe.ca/photos/original/cle_WinterR.pdf (200 pgs.; web-accessed 23-09-2019)

'Watershed Evaluation of Beneficial Management Practices (WEBs) in the Souris River Watershed, Prince Edward Island: Site Hydrogeology':

"The uppermost portion of the red bed formations forms an unconfined *or* semi-confined fractured-porous aquifer across the island." The geology at the Souris site "… is similar to the regional geology....": an uppermost 'overlying layer' "acts as a confining layer for…. the [underlying red sandstone] *confined* bedrock *aquifer*…"

"3. Regional Hydrogeology

The uppermost portion of the red bed formations forms an **unconfined** or **semi-confined** fractured-porous **aquifer** across the island." [*At any one particular given location and depth*, an aquifer can be *either* unconfined or semi-confined, but not both (by definition). Therefore, there would have to be more than one aquifer: at some locations unconfined; at other locations semi-confined; and, underlying the 'uppermost portion' would be **confined aquifers**.]

"Site Hydrogeology

4.1 Site 1…. Brownish-red clay till was encountered from the ground surface to a depth of 7.6 m and red sandstone with lesser amounts of siltstone and claystone was encountered at 7.6 m to the bottom of the borehole. Groundwater was not encountered until drilling penetrated the till/bedrock interface at a depth of 7.6 m….. The water level stabilized at 5.8 m below ground surface (i.e., ~2 m above the till/bedrock interface), indicating that **the clay till acts as a confining layer**. The second well…. When drilling penetrated the till and reached the bedrock formation, the water level immediately rose above ground surface [due to pressure from the confined aquifer below], suggesting **the till acts as a confining layer**. The third well…. Brownish-red clay till was encountered from ground surface to a depth of 13.1 m and red sandstone was present from 13.1-13.4 m. Similar to [the second well], the water level immediately rose above the ground surface [under pressure] when drilling penetrated the till/sandstone interface."

"4.2 Site 2… In contrast to Site 1, the till does not act as a confining at this site, and the bedrock formation behaves as a fracture-dominated aquifer…."

"5. Conclusion

The two experimental sites are underlain by a red sandstone formation overlain by a layer of glacial till with a thickness of 5-13 m. **The site geology is similar to the regional geology.** At Site 1, **the till mainly consists of clay and acts as a confining layer** for the bedrock aquifer. The creek between the two tested fields **is fed by springs likely originating from** isolated spots **within the *confined* bedrock *aquifer***…" (Conclusion)

Watershed Evaluation of Beneficial Management Practices (WEBs) in the Souris River Watershed, Prince Edward Island: Site Hydrogeology, **Jiang** & **Somers** (2011),
https://www.researchgate.net/publication/267958182_Watershed_Evaluation_of_Beneficial_Management_Practices_WEBs_in_the_Souris_River_Watershed_Prince_Edward_Island_Site_Hydrogeology/link/564c848e08ae020ae9fab15f/download

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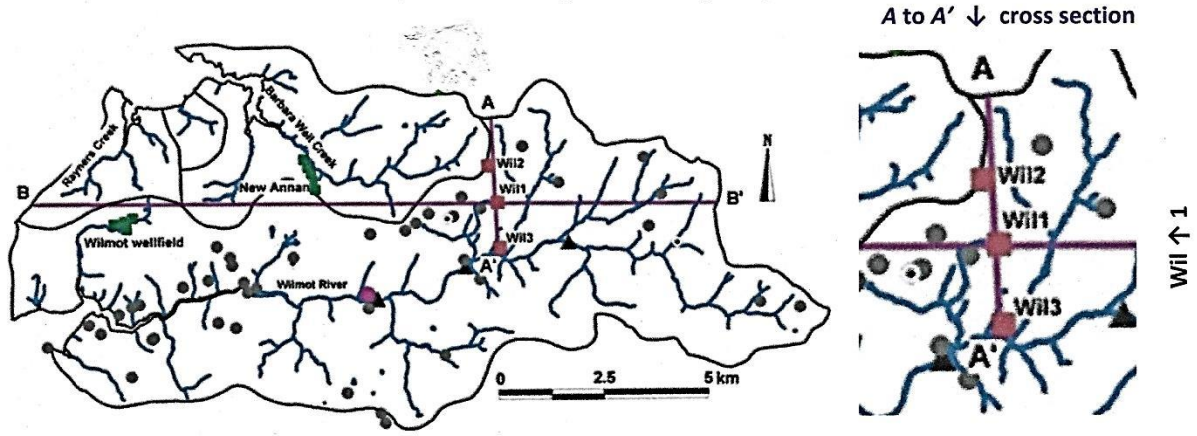
'Modeling effects of nitrate from non-point sources on groundwater quality in an agricultural watershed in Prince Edward Island, Canada' Jiang & Somers (2009)



"Fig. 1. Location map of Wilmot River watershed"

It is ambiguous & misleading to say that there is *an* (just one) unconfined/semi-confined fractured-porous aquifer across the island.

The text below makes that case while paraphrasing the bulleted quotes below it:

In the smaller map (above right) note the arrow pointing left towards **Wil1**:

'At point Wil1 (between the watershed boundary **A** and the flow-system-discharge-point **A'** at the stream) the **shallow *uppermost* 'layer 1' extends from *the water-table to 22 m below the land surface***. It is an **unconfined aquifer** that probably **accounts for both the local and intermediate flow systems.** *Underlying* that, is *a confining layer* **preventing 84% of recharge from moving into the deeper aquifer layers**; and, underlying that, therefore, is **a semi-confined aquifer.** The fractured-porous ***aquifer system*** is similar across the island.'

- "... the top layer is relatively thick (**22 m**)..." (text pg. 5, para. 5)
- "at the shallow depth (**Wil1S**)..." (text pg. 13, para. 4)
- "... groundwater in **shallow** (**S**)... portions of the aquifer at a selected profile (**Wil1**), mid-way (Fig. 1) between the watershed boundary and the discharge point of the flow system at the stream... from water table to **22 m** (**Wil1 S**)... **measured from land surface**..." (text pg. 11, para. 4)
- "... recharge becomes horizontal flow when entering the aquifer, and primarily migrates in **layer 1 (thickness = 22 m**) with a small component ["only 16 %"] moving into the deeper layers due to the significant contrast between K_h and K_v [i.e. **a confining layer prevents 84% of the recharge from moving into the deeper aquifer layers**].... **layer 1** [22 m thick]... **accounts for both the local and intermediate flow systems.**" (text pg. 6, para. 5)
- "The *uppermost* portion of the red bed formations plus the saturated till forms an **unconfined**/semi-confined fractured-porous aquifer across the island..." (text pg. 3)
- **By definition & logically: at any given time, precise location, and depth an aquifer can be either unconfined *or* semi-confined, but it *can't* be both.**

Hydrogeology Journal 17, no. 3: 707–724. http://www.gov.pe.ca/photos/original/cle_WA20.pdf (18 pgs.)

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'Long-term simulations of nitrate leaching from potato production systems in Prince Edward Island, Canada'; **Jiang**, Zebarth, & Love (2011):

<u>Something about the description of the depth of the unconfined, semi-confined, and confined aquifers is obviously wrong</u>

Table 4 – Hydraulic and geometric parameters of MODFLOW model

[Middle section of table omitted so as to focus on layer thickness]

Layer	Thickness (m)
1	10–65
2	25–30
3	25
4	25
5	25
6	25

Adding the thicknesses in the right-hand column: **195 m**.

Adding the overlay of *"a thin veneer of till (5–10 m)"* brings the thickness to around **200 m**.

"the aquifer plus till" adds up to 200 m.

A →

"PEI is entirely underlain with a… sandstone formation (known as 'red beds')….
overlain by *a thin veneer of till (5–10 m)*.
The upper portion (0–200 m) of the formation plus the saturated till forms the unconfined and semi-confined aquifer"
(*text pg. 9, para. 2)*

← <u>Table 4</u> layers add up to a thickness of around 200 m, which is the <u>total</u> thickness mentioned in the above quote "*the upper portion (0 - 200 m)"* which "*forms the unconfined and semi-confined aquifer*".

<u>BUT</u>

text on *pg. 8, para. 2* says:
"Vertically, **the aquifer plus the till** [a total of 200 m] was divided into 6 layers (**Layer 1 was assumed unconfined** and **Layers 2–6 confined**)."

B →

<u>Either</u>:	"the upper portion (0–200 m) [layers 1 to 6] of the formation plus the saturated till forms the **unconfined and semi-confined aquifer**" [which would not seem to make sense at all]
<u>Or</u>:	"**Layer 1** [**is**] assumed **unconfined** and **Layers 2–6 confined**" [which seems far, far more likely]

In effect, what quotes **A** & **B** (above) *seem* to be saying is that:

'**P.E.I. is entirely *overlain* by** a combination of **unconfined aquifers** <u>*and*</u> **semi-confined aquifers**, ***underlain*** by **confined aquifers'**.

Nutrient Cycling in Agroecosystems, DOI 10.1007/s10705-011-9463-z,
http://www.gov.pe.ca/photos/original/cle_WA18.pdf (19 pgs.)

[Intentional gap to prevent different text boxes from merging]

Stable Isotopes of Nitrate Reveal the Important Role of Soil Organic Matter in Mediating Nitrogen Transfer to Groundwater with Implications for the Consequences of Climate Change:

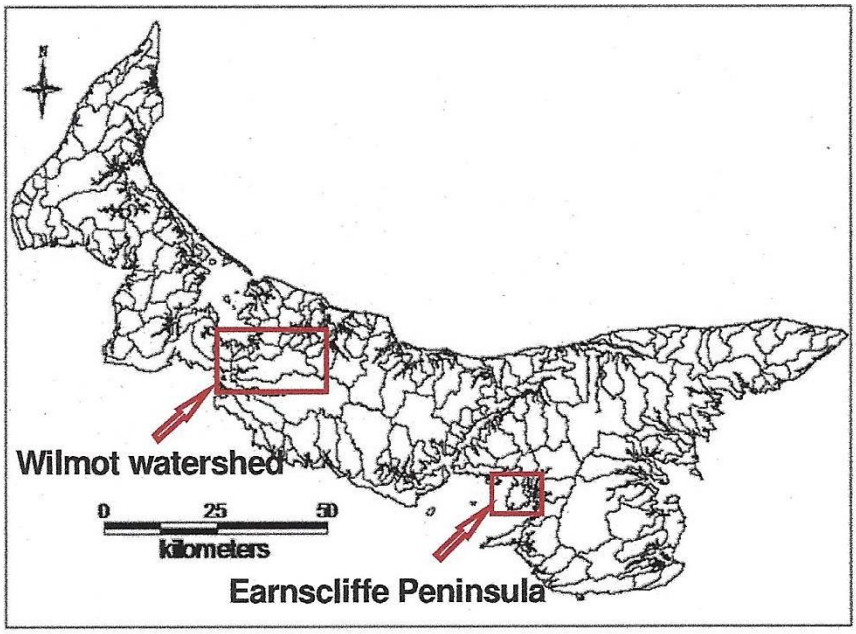


Figure1. Study area locations: Wilmot watershed and Earnscliffe Peninsula

"… we examine… **GW** [**g**round-**w**ater]… in two… agricultural settings… with the intent of shedding additional light on… nitrate… transport to underlying **aquifers** [plural]." (text pg. 1515)

"Groundwater resources across the Province are essentially limited to a sequence of 'red bed' sediments… overlain by a thin veneer of generally sandy glacial till, and the main geological and hydrogeological features of both study areas are essentially the same.… The formation can be characterized as a fractured porous **semi-confined aquifer** with near horizontal bedding plane fractures dominating the fracture network. Groundwater flow is dominantly lateral [horizontal], with the ***uppermost portions of the aquifer*** *being the most active* and responsive to seasonal recharge…" (text pg. 1516)

"The recharge rate of **the red bed aquifers are** high [plural]… **Jiang and Somers** (2008) estimated that approximately 80% of this base-flow is derived from shallow depths of the aquifer, consistent with the dominantly lateral flow regime in **the red bed aquifers of PEI** [plural]." (text pg. 1516)

"… **both aquifers** [plural] are responding rapidly to recharge events and are sensitive to significant seasonal changes in the flux [movement] of N [nitrogen] from soils to **the aquifer system** [aquifer system]…. **each aquifer** [there is more than one aquifer] responds rapidly to seasonal recharge…" (text pg. 1518)

"… the… characteristics of nitrate in GW and principle N sources… are used to estimate the relative contributions… to **the underlying aquifers** [plural]." (text pg. 1519)

"… important processes… between agricultural soils and **aquifers** [plural]…" (text pg. 1520)

Stable Isotopes of Nitrate Reveal the Important Role of Soil Organic Matter in Mediating Nitrogen Transfer to Groundwater with Implications for the Consequences of Climate Change; **Somers** & Savard (September 2009); Conference paper for the 62nd Canadian Geotechnical Conference & 10th joint GCS/IAH-CNC Groundwater Conference GeoHalifax2009, (8 pgs.),
https://www.researchgate.net/publication/237010279_Stable_Isotopes_of_Nitrate_Reveal_the_Important_Role_of_Soil_Organic_Matter_in_Mediating_Nitrogen_Transfer_to_Groundwater_with_Implications_for_the_Consequences_of_Climate_Change/link/0c96051ae30ff9aa26000000/download

'Modeling effects of nitrate from non-point sources on groundwater quality in an agricultural watershed in Prince Edward Island, Canada':

"**Aquifer** properties - The *uppermost* portion of the red bed formations plus the saturated till forms an **unconfined/semi-confined** fractured-porous **aquifer across the island**." (text pg. 3)

"Vertically, the aquifer is divided into 15 layers…. The bottom 14 layers range in thickness from 6 to 26 m, while the top layer is relatively thick (22 m)…" (text pg. 5)

"**Groundwater flow pattern** - … stratified flow systems in the aquifer… stratification of the bed-rock formation observed in the field…. A significant contrast between K_h and K_v, [i.e. significant difference between the ability of water to flow horizontally {K_h} and the ability of water to flow vertically {K_v}]…. In the centre and eastern centre of the watershed, recharge becomes horizontal flow when entering the aquifer, and primarily migrates in layer 1 (thickness = 22 m) with a small component ["only 16 %"] moving into the deeper layers due to the significant contrast between K_h and K_v [i.e. **a confining layer prevents most of the recharge from moving into the deeper aquifer layers**]…. **layer 1** [22 m thick] probably **accounts for both the local and intermediate flow systems**… and **layers 2–15 correspond to basin-scale** [regional] **flow systems**…. ***Below* layer 1**, [thickness = 22 m] **groundwater divides do not consistently match the locations of surface water divides**." (text pg. 7)

"[Approximately] **~ 80 % of the total recharge** [precipitation]… **moves laterally** [horizontally] **in layer 1** [22 m thick]… **only 16 %** of the recharge diverges [manages to flow**] into layer 2 or deeper** layers… and… 80 % of the base flow originates from shallow groundwater…. the average residence time in layer 1 was estimated as 3.8 years and residence times *exponentially increase* [increase very dramatically *****] with increasing depth." (text pg. 7).

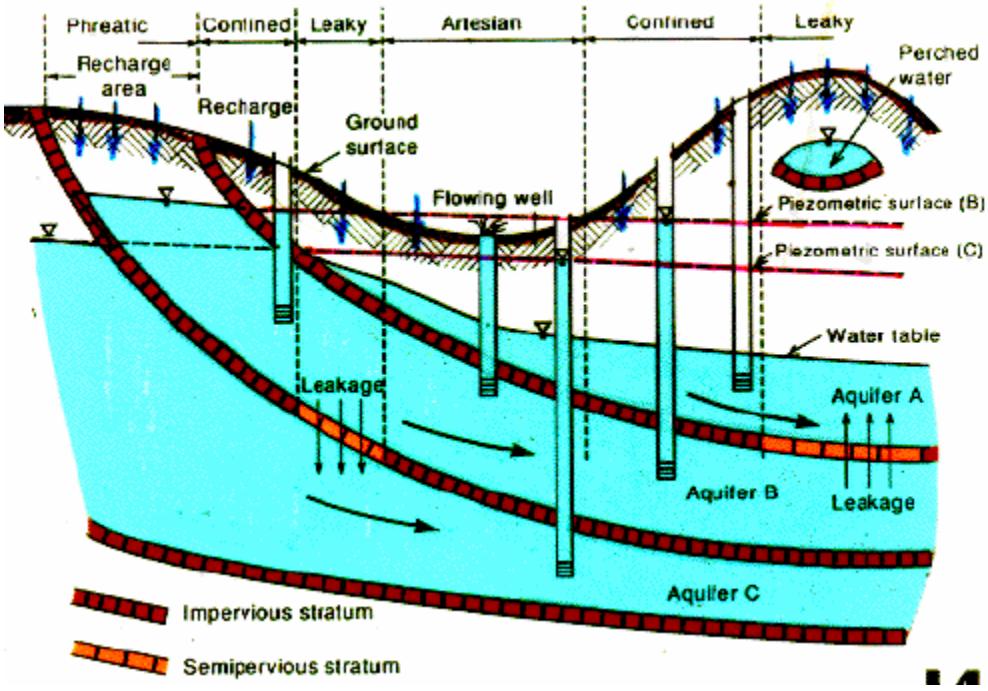
Modeling effects of nitrate from non-point sources on groundwater quality in an agricultural watershed in Prince Edward Island, Canada; **Jiang** & **Somers** (2009); Hydrogeology Journal 17, no. 3: 707–724.
http://www.gov.pe.ca/photos/original/cle_WA20.pdf (18 pgs.)

*** See box on page 30 re: the dramatic, exponential *decrease* in *conductivity* as depth increases. The rate at which water can flow through the sub-surface is directly related to *residence time*, which is the amount of time water spends in the sub-surface.**

'Topic A: The Hydrological Cycle and the Distribution of Moisture in the Subsurface, Lecture 2: Aquifers':

At the top edge of the following figure, note the *changing* 'aquifer type' names as aquifer layers A, B, & C transition from being one type of aquifer to being another type of aquifer.

'unconfined' ↓ ↓ 'semi-confined'



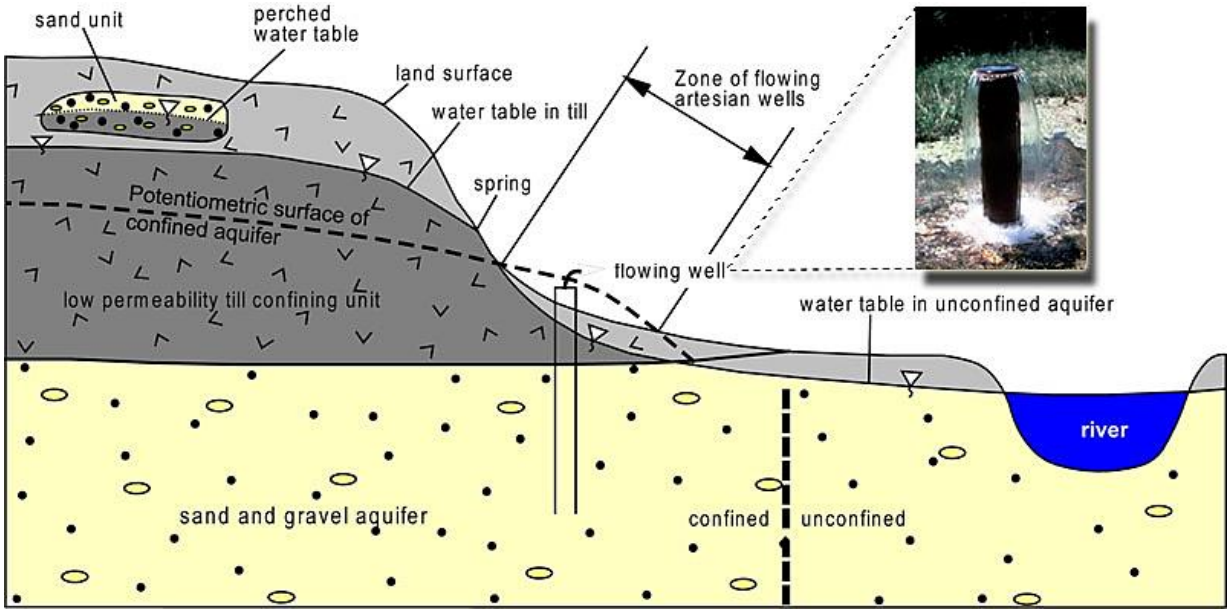
[Note that the symbol ▽ marks where the water-table is]

"Recall that the scale of this figure is [like most hydro-geological figures] highly distorted: the vertical dimension may be tens or hundreds of meters, while its horizontal dimensions may extend to thousands of meters, or many kilometers."

"The figure shows a vertical cross-section with several aquifers and observation wells. Also indicated are the phreatic surface [top surface; water-table] of aquifer A and the piezometric [pressure] surfaces of aquifers B and C. [**see pg. 27 definition of piezometric**] The upper phreatic [unconfined] aquifer (A) is [underlain] by two confined ones (B and C are leaky [some portions 'confine' less, are less impermeable], with directions and rates of leakage determined by the elevations of the piezometric [pressure] surface of each of these aquifers. The boundaries between the various confined and unconfined portions may vary with time, as a result of fluctuations in the piezometric surfaces [water pressure relationships] and the water table."

Computer-Mediated Distance Learning Course on Advanced Ground Water Hydrology, **Topic A: The Hydrological Cycle and the Distribution of Moisture in the Subsurface, Lecture 2: Aquifers**, Jacob Bear, Professor Emeritus, Faculty of Civil Engineering, Technion-Israel Institute of Technology, Haifa, Israel; (bold & underlining added; labels added to graphic), https://www.new.interpore.org/reference_material/agwh-course/agwh_aq.html

'Water-Table Elevation':



[Confined aquifer ← →Unconfined aquifer]

"Figure 3. Cross section showing the relationship between the water table, …potentiometric surface, and zone of saturation (shaded) in <u>confined</u> [aquifer] **and <u>unconfined</u>** [aquifer] **parts of a sand and gravel aquifer and the overlying till confining unit…"**

[This 'aquifer system' has three kinds of wells: confined, artesian, and unconfined.]

Water-Table Elevation, Fleming & Rupp (2020); Indiana Geological & Water Survey, Indiana University, (bold & underlining added), https://igws.indiana.edu/AllenCounty/waterTableElevation

"**Confined versus unconfined** - There are **two 'end members' in the spectrum** [continuum] of types of aquifers; confined and unconfined (with semi-confined being in between). Unconfined aquifers are sometimes also called water table or phreatic aquifers, because their upper boundary is the water table or phreatic surface…. Typically (but not always) the shallowest aquifer at a given location is unconfined, meaning it does not have a confining layer (an aquitard or aquiclude) between it and the surface…. Confined aquifers are aquifers that are overlain by a confining layer, often made up of clay. The confining layer might offer some protection from surface contamination."

Aquifer, Wikipedia (2020), https://en.wikipedia.org/wiki/Aquifer#:~:text=An%20aquifer%20is%20an%20underground,of%20aquifers%20is%20called%20hydrogeology.

"**Confined and unconfined aquifers are the opposite end members of a continuum** from pressurised aquifers (confined) to ones that are in equilibrium with the atmosphere (unconfined)…. Semi-confined (leaky) and semi-unconfined (delayed yield) aquifers are found in between." (text pg. 8)

Ecological and Environmental Impacts of Large-scale Groundwater Development in the Table Mountain Group (TMG) Aquifer System, Discussion Document for Scoping Phase; Brown et al. (February 2003), Water Research Commission (WRC) project K5/1327, South Africa, (40 pgs.), http://fred.csir.co.za/project/tmg/documents/pre-scoping_doc_final.pdf

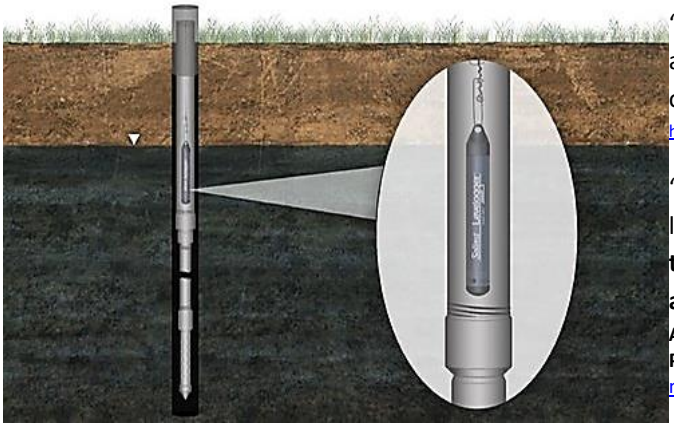
P.E.I. may have only *one aquifer system*
but it has *many aquifers* and several *types* of aquifers.

'A Call for Uniform Groundwater Classification':
"The first step to promoting a consistent and practical approach to groundwater protection and restoration is to develop and implement a comprehensive and uniform classification system…. '**If we can't agree on what groundwater is** [or, about what an aquifer is]**, how can we agree on how to protect it?**'…. "

"Comprehensive groundwater protection must be founded on common, quantifiable terms that address the groundwater resource as a whole. This would not be the first time that such a uniform classification system has been proposed and successfully developed for a complex system with unique variations across states. One can simply point to the Unified Soil Classification System as an example of a functional classification system that is embraced by scientists across the country."

A Call for Uniform Groundwater Classification; Michael E. Covert, P.G. (Professional Geologist) (Jan 14, 2010); Environmental Protection online; https://eponline.com/pages/contact-us.aspx

Piezometers are basically just pressure gauges



"A **piezometer** is… used to measure liquid pressure in a system by measuring the height to which a column of the liquid rises."
https://www.indiamart.com/proddetail/piezometer-20488342648.html

"**Piezometric surface**: A surface that represents the level to which water will rise in a well. The **water table is a piezometric surface for an unconfined aquifer**." (pg. 229)
Assessment Report - Glossary Niagara Peninsula Source Protection Area, (28 pgs.) http://www.sourceprotection-niagara.ca/wp-content/uploads/2014/06/Chapter-13.pdf

"**Piezometers** or pore pressure meters are the pressure transducers that…
measure the sub-surface piezometric level within groundwater level, soil, or rock."
Encardio-rite geotechnical instrumentation, https://www.encardio.com/blog/piezometers-types-functions-how-it-works/

Next page, box (3): '*watershed boundaries*' are *precisely* specified (i.e. ***not*** just an e.g. '*example*').

https://grammar.yourdictionary.com/grammar/style-and-usage/**how-to-use-i-e-and-e-g.**html (format modified)

Clearly, we have more than one aquifer and more than one type of aquifer. But, the same paragraph where the author/s dis-informed us about aquifers, goes on to dis-inform us further:

(1)	"It is *important to note that* while the province is underlain by a single aquifer,
(2)	*groundwater movement can be separated into many individual* ***groundwater flow systems***
(3)	***defined by*** topography (***i.e. watershed boundaries***)."

(1) *"*It is important to note that" the first part of the above sentence not true.

(2) The second part is true, but largely irrelevant. It will be deflated **in the paragraphs below**.

(3) The third part is *partially true*, but virtually irrelevant: **see next page**.

In their next paragraph, the Abracadabra author/s go on to say:

> *"The PEI aquifer also has a significant vertical extent [it's supposedly deep]. Van de Poll (1983) describes the geological formation…. more than 850 m [deep] however not all this thickness represents accessible groundwater. The permeability of the aquifer declines with depth, and… [therefore] well yields would be expected to be very low. Secondly… deeper slow moving* ***groundwater*** *[****flow****] becomes more and more saline [salty]…"*

If we try '*to make sense of the nonsense*' blurted in those two paragraphs, the "groundwater movement [that] *can be separated into many individual* ***groundwater flow*** *systems*" …

- would have to be **inside** the author/s supposed "single geological formation… sandstone aquifer *covering the province*" [italics added];
- The groundwater movement couldn't be *outside* the supposed *single* 850 metre deep aquifer, because below it there is *virtually* no ground-water 'flow';
- The deeper you go, the less water you get, and the saltier the water is.

The only "*individual groundwater flow systems*" from which water *can* be pumped, *are* aquifers. Therefore, *if* the author/s are inferring that ground-water flow systems can be pumped, then those 'ground-water flow systems' capable-of-being-pumped must be *inside* aquifers. They are aquifers.

It must be a challenge for the author/s to cram so much disinformation and confusion into a single sentence. They seem to excel at obfuscation offering some degree of *almost* 'credible deniability' resulting from: intertwining half-truths with irrelevant facts; back-pedalling; ambiguity blended with decisive but untrue statements; misleading and / or invented citations (references); and, misrepresentation in general. *A Brief Review of the Physical Characteristics of PEI's 'Redbed Aquifer'* (Abracadabra) does not reflect competence or transparency; is appallingly arrogant; and, is disingenuous.

What's *the opposite* of 'disingenuous'? **On-the-level, frank, sincere, truthful, trustworthy**

What is the opposite word for disingenuous?; Thesaurus.plus, (text modified); https://thesaurus.plus/antonyms/disingenuous

The Only Ground-water Flow Capable of Being Pumped, Flows Through Aquifers

The following *Abracadabra* quote is only partially true**:**

"… groundwater movement can be separated into many individual groundwater flow systems, ***defined by*** **topography** (*i.e.* ***watershed boundaries*** [*watershed surface water divides*])."

(Aquifer Size, para. 1; bold, italics & underlining added)

"…surface-water watersheds and ground-water watersheds [boundaries] ***may*** **not coincide."**

(**U.S. Geological Survey Circular 1139**; text pg. vii, para. 1; bold, italics & underlining added)

"… **groundwater divides do not** consistently **match** the locations of **surface water divides**."

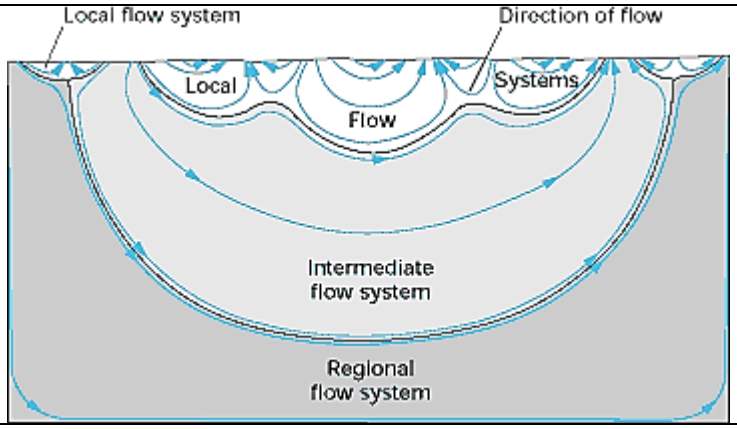
Modeling effects of nitrate from non-point sources on groundwater quality in an agricultural watershed in Prince Edward Island, Canada; **Jiang** & **Somers** (2009); Hydrogeology Journal 17, no. 3: 707–724; (text pg. 7), http://www.gov.pe.ca/photos/original/cle_WA20.pdf (18 pgs.)

Local ground-water flow systems	*may* be defined/delineated by…	***local*** **watershed** boundary topography.
Intermediate and regional ground-water flow systems	*may be defined/delineated by…*	***intermediate and/or regional*** **watershed** boundary topography.

"A **watershed** is simply defined as an area of land that drains surface water and groundwater into a river or stream [*i.e*. **local watershed boundaries**]. Prince Edward Island has more than 250 watersheds…"

(***A Guide to Watershed Planning on Prince Edward*** **Island**, text pg. 4)

https://www.princeedwardisland.ca/sites/default/files/publications/**a_guide_to_watershed_planning_on_prince_edward_island**.pdf



Ground-water Flow can be:

- Local**:** coincide/overlap with *local* watershed topography
- Intermediate**:** flow '*intermediately*' beneath two or more watersheds
- Regional**:** flow beneath an entire *region*

"Figure A-4. [↑] Ground-water flow systems can be local, intermediate, and regional in scale. Much ground-water discharge into surface-water bodies is from local flow systems…" (text pg. 7)

Most 'local ground-water flow' is *within* aquifers delineated by local watershed boundary topography.

Ground Water and Surface Water A Single Resource - U.S. Geological Survey Circular 1139; Winter et al. (1998); https://pubs.usgs.gov/circ/circ1139/pdf/circ1139.pdf (87 pgs.; includes Fig. A-4) https://pubs.usgs.gov/circ/circ1139/htdocs/boxa.htm (image copy source)

The attached 'Overview' document demonstrates that Van de Poll (1983) is an interesting book about geology that says the geological formation is 850 m deep… but says absolutely nothing about water, ground-water, or aquifers. Groundwater flow through aquifers **can** be pumped, but ground-water flow systems that are not aquifer systems are **not** capable of being pumped.

Water becomes increasingly salty with increasing depth… but, that is probably *almost* irrelevant since very little water can be pumped from those depths anyway:

With increasing depth, there is a drastic reduction in the ability of water to flow:

"…analyses were conducted to examine the variation of hydraulic conductivity with depth for each borehole…. [found] consistency of hydraulic conductivity trends… across the basin…. an **average reduction in hydraulic conductivity** [permeability; the ability of water to flow] **of an order of magnitude for each 60 m depth**." (text pg. 46, para. 2; bold added; often cited quote)

Hydrogeology of the Winter River Basin - Prince Edward Island, Francis (1989), P.E.I. Dept. of the Environment, Water Resources Branch, http://www.gov.pe.ca/photos/original/cle_WinterR.pdf (200 pgs.)

In other words, **water's ability to flow** through the ground **decreases** drastically **to**:

one tenth	hydraulic conductivity at	60 metres	depth	1/10th
one hundredth	hydraulic conductivity at	120 metres	depth	1/100th
one thousandth	hydraulic conductivity at	180 metres	depth	1/1,000th
one ten-thousandth	hydraulic conductivity at	240 metres	depth	1/10,000th

Again, the ability of water to flow does not decrease ***by*** the above fractional amounts… it decreases **to** those fractional amounts. For instance, at a depth of 120 m a well would produce one hundredth the amount of water it would have produced at a depth of 60 m.

"**At depth of 220–240 m** the bedrock is assumed [A]**impervious**." (pg. 5)

Modeling effects of nitrate from non-point sources on groundwater quality in an agricultural watershed in Prince Edward Island, Canada, **Jiang** & **Somers** (2008), Hydrogeology Journal DOI 10.1007/s10040-008-0390-2, http://www.gov.pe.ca/photos/original/cle_WA20.pdf (18 pgs.)

[A] "**impervious**…. not allowing liquid to go through…. impenetrable… impermeable…" https://dictionary.**cambridge.org/dictionary**/english/impervious

"… hydraulic conductivity of the aquifer generally decreases with depth (Paradis et al. 2006), which agrees with previous findings by Francis (1989). From the viewpoint of water supply, the permeability of the bedrock **decreases to near [1]negligible levels at depths of 200 m**." (pg. 42)

Consequences of climatic changes on contamination of drinking water by nitrate on Prince Edward Island; Savard & **Somers** (Editors) et al. (2007); Report submitted to Natural Resources Canada Climate Change Action Fund: Impacts and Adaptation, Contribution Agreement A881/A843; web-accessed Feb. 8, 2019; http://www.gov.pe.ca/photos/original/cle_WA3.pdf (142 pgs.)

[1] "**negligible** - insignificant, not worth bothering about", https://en.**oxforddictionaries**.com/thesaurus/negligible

It is well beyond misleading for Abracadabra's author/s to *very strongly imply* that *the supposed single aquifer* is *in the order of* **850 m** deep, when former and current staff *of their own Department* report that the geological formation is impervious by a depth of around **200 metres;** and, that water would tend to be salty by a depth of 200 metres.
The geological formation's depth is *irrelevant*.

The following quote (in *italics*) bears repeating to highlight how it is either *an arrogantly blatant example of disinformation*; or, *a reflection of a disturbing lack of competency*:

"The PEI aquifer also has a significant vertical extent [the aquifer is supposedly very deep; **but**, it is not the aquifer that is 850 m deep, it is the geological formation that is]. *Van de Poll (1983)* [who says absolutely nothing about water or aquifers] *describes the geological formation* [which is]*…. more than 850 m* [deep] *however not all this thickness represents accessible groundwater* [much less than a fifth of that 'thickness' represents accessible groundwater]. *The permeability of the aquifer declines with depth* [it's considered to be impervious by 200 m]*, and…* [therefore] *well yields would be expected to be very low* [negligible, insignificant, virtually zero]. *Secondly… deeper* [excruciatingly] *slow moving groundwater* [flow; which already tends to be salty by around 200 m] *becomes more and more saline* [salty]*…"*

Did the Abracadabra author/s actually *intend* to imply that there was accessible *fresh*-water right down to a depth of 800 metres or more? :

"One of the things that's *particularly difficult for people to understand* is just **how much water we have in groundwater**. In PEI, away from the shoreline, **the *fresh* water-groundwater resource** which is in the pores in between the rock, and actually in the pores inside the rock as well, extends down hundreds of metres. **Maybe 800 metres** is a reasonable distance to think about how far down it [the fresh water-groundwater resource] goes."

It's *not particularly difficult to see* that Mr. Raymond believed it reasonable to say that our resource of fresh (i.e. drinkable) ground-water extends down 800 metres; and, that the Abracadabra author/s intended to imply a similar thing (although slightly moderated).
(see the debunking of the '800 m of fresh-water', in the 'Overview' attachment).

Deep-well Irrigation, Bruce **Raymond** (2014), Manager of Watershed and Subdivision Planning, Dept. of Environment, Labour and Justice; Standing Committee on Agriculture, Environment, Energy and Forestry, 13 February 2014, Pope Room, Coles Building, Charlottetown; Hansard transcript, http://www.assembly.pe.ca/sittings/2013fall/transcripts/11_2014-13-02-transcript.pdf (35 pgs.)

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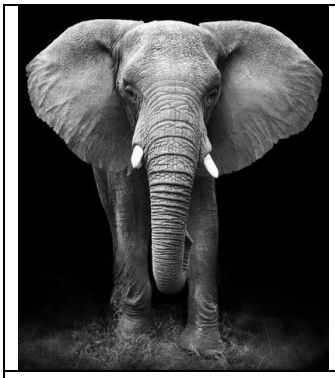
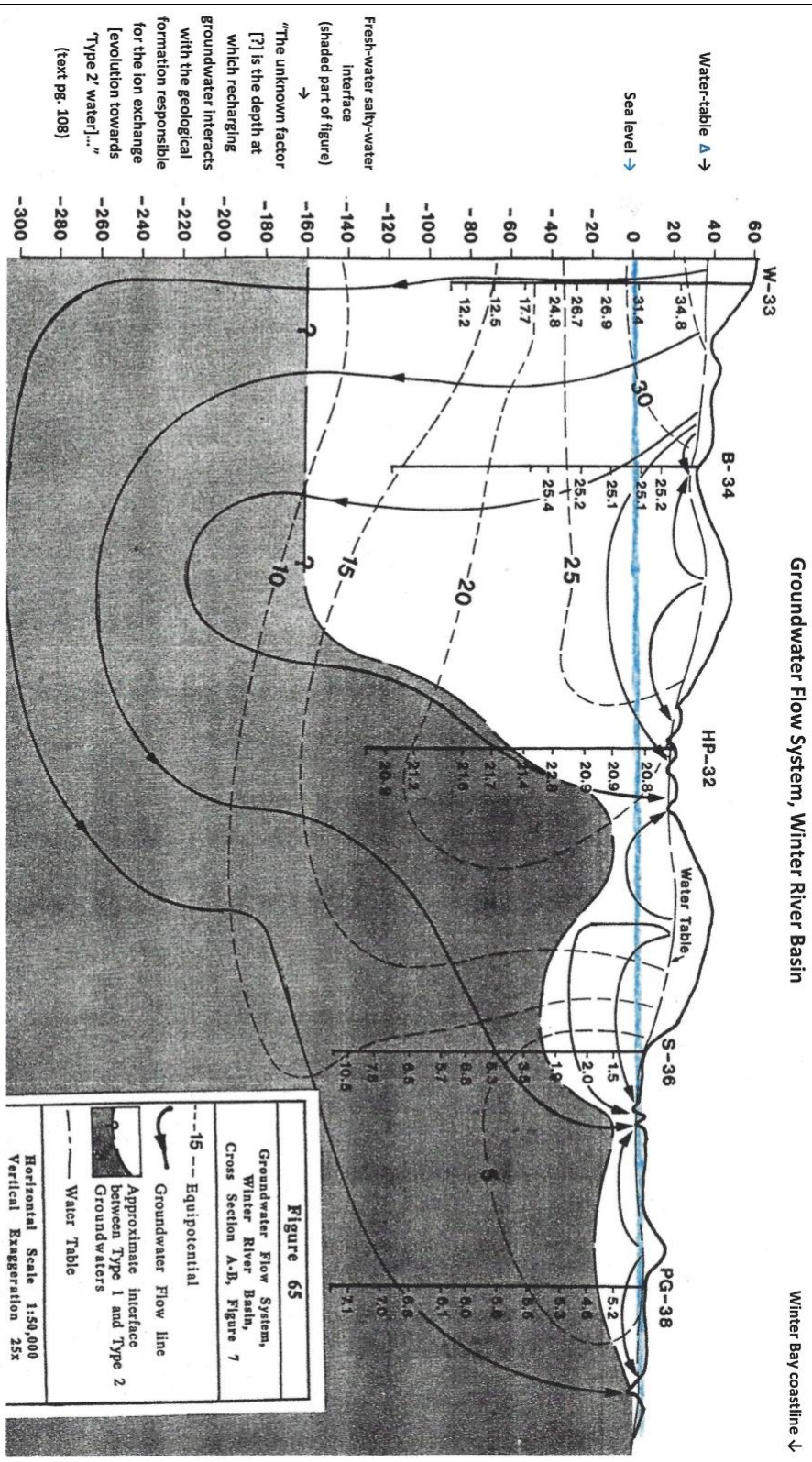


Ignore Me

The author/s should have absolutely nothing to do with managing Island water.

Unless the author/s have just simply 'gone rogue',
their opinions might appear to some casual distant observers to be conceivably reasonably suggestive perhaps of something akin to vaguely maybe tentatively and hypothetically but not necessarily
'the elephant in the room'
a Departmental disinformation strategy.

Ground-water Flow System, Winter River Basin



"'Type 2' is a Na-HCO_3 groundwater, with high sodium [salt] concentrations (up to 190 mg/L).... and is attributed to the effects of cation exchange in strata with significant amounts of clay minerals with exchangeable sodium.... This Na-HCO_3 [saline/salty] groundwater exists only at depths of more than 50 or 60 m [closer to the coast].... at a depth greater than 150 m, groundwater encounters geologic materials having sodium-rich clay minerals, and the cation exchange process takes place."

Hydrogeology of the Winter River Basin - Prince Edward Island, Francis (1989), P.E.I. Dept. of the Environment, Water Resources Branch, http://www.gov.pe.ca/photos/original/cle_WinterR.pdf (200 pgs.)

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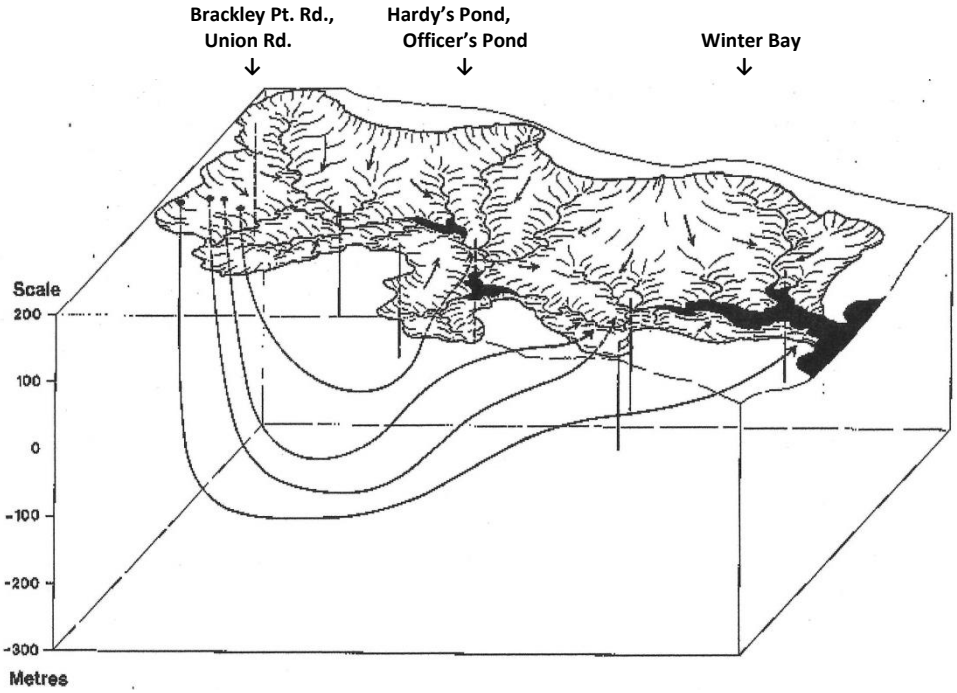
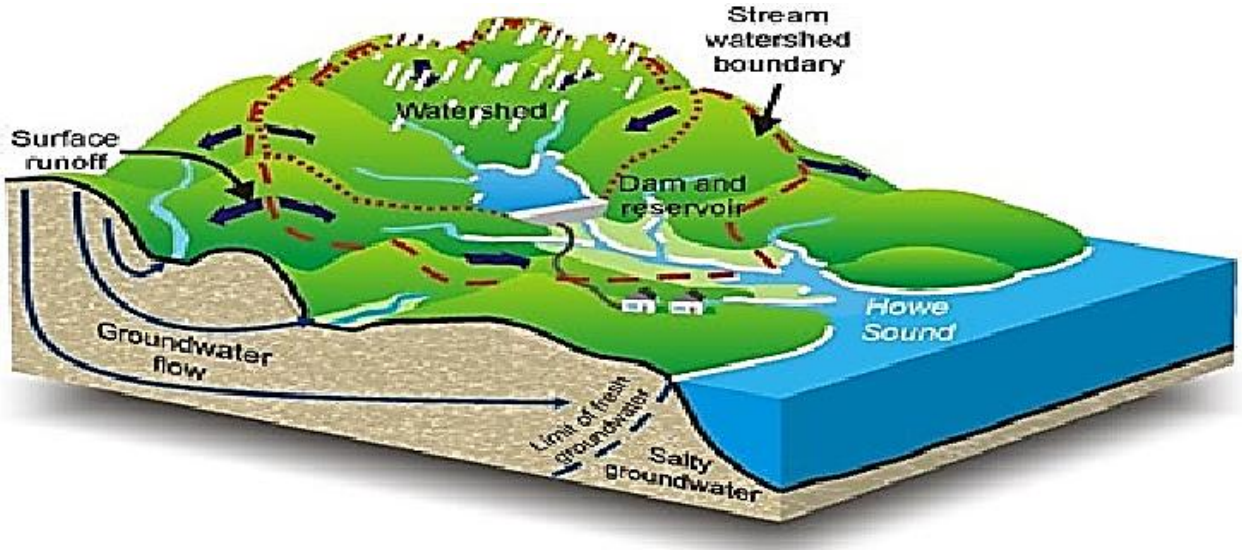
Typical Ground-water Flow System



"Figure 33. Three dimensional schematic of groundwater flow, Winter River basin."
Arrows showing flow directions on the surface, as well as arrows showing sub-surface flow.

PEI Water Extraction Policy, Department of Environment, Labour and Justice, 2014, pg. 4, (location labels added), https://www.princeedwardisland.ca/sites/default/files/publications/pei_water_extration_policy_presentation_with_background_information.pdf (33 pgs.)

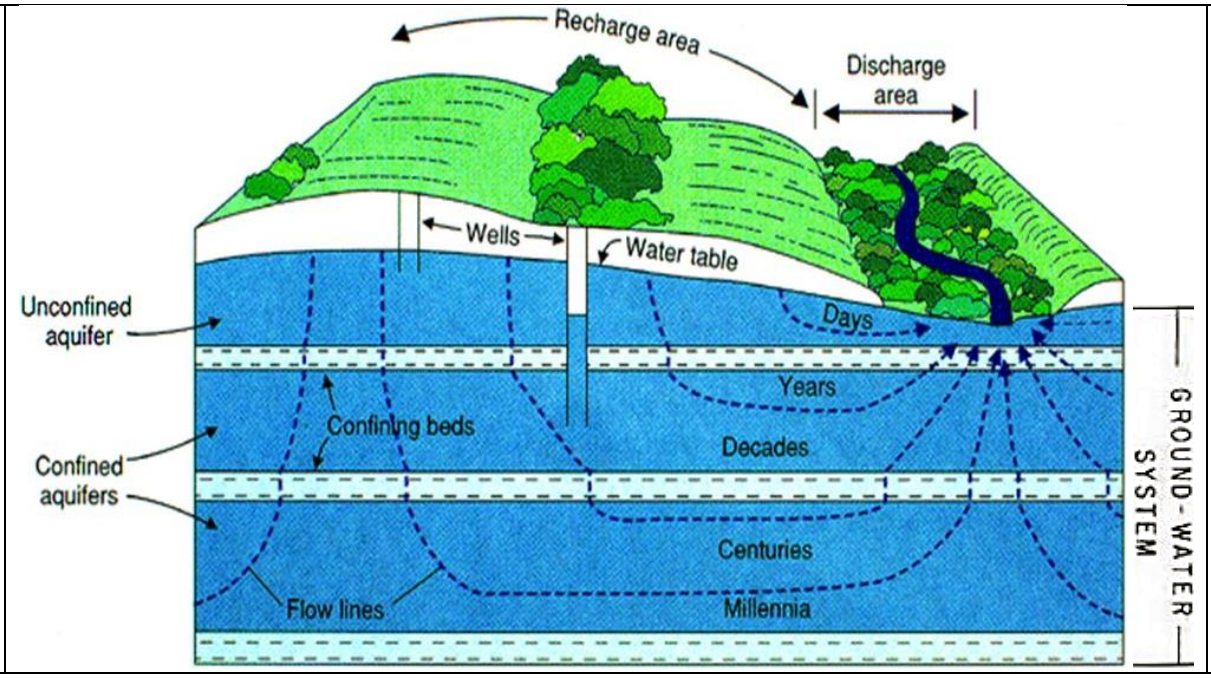
[Intentional gap to prevent different text boxes from merging]



Sec 1 NA - River system & drainage, Watershed & Drainage basin [and, groundwater flow], chua.geog (2008), (slide 17). https://www.slideshare.net/chua.geog/sec-1-na-river-system-drainage

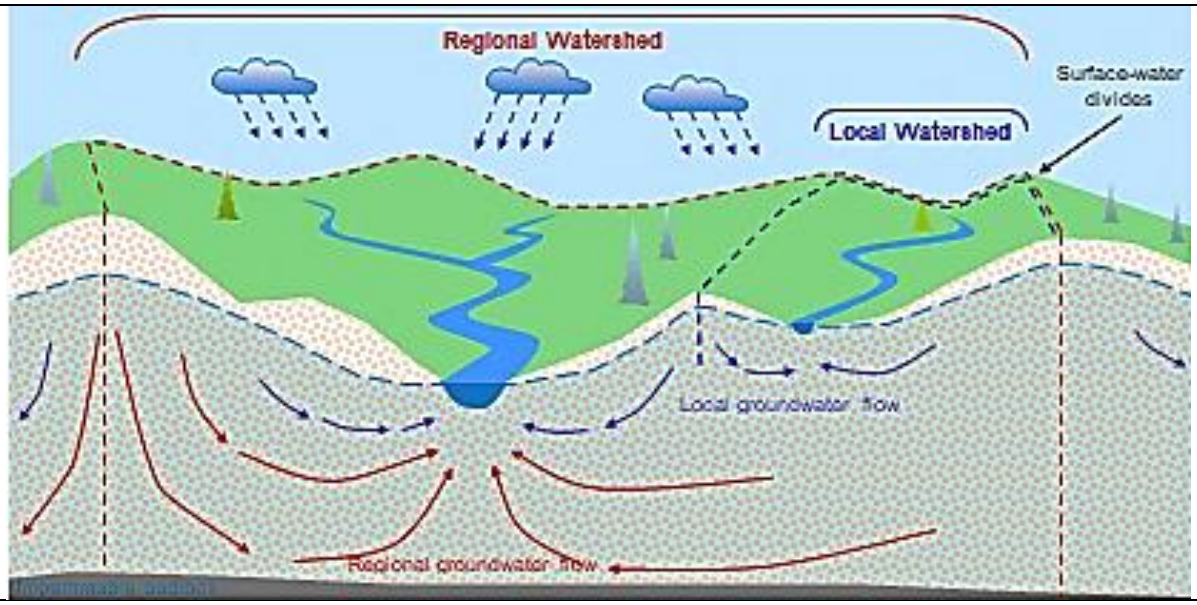
[Intentional gap to prevent different text boxes from merging]

Ground-water flow system / aquifer system: parts of the system are excruciatingly slow.



1 2

A Groundwater System: how the water flows. A watershed (ground surface downward to the water-table) with three 'stacked' aquifers beneath it.



3

1 **GSC1620 Chapter 11 Resources Overview and Water as a Resource**, Jasmin Webb (2016), Slide 32, https://slideplayer.com/slide/6645616/

2 **Groundwater 101: Where Does Groundwater Come From? Where Does It Go?** Clean Up the River Environment (CURE) (2019), Montevideo, Minnesota, https://www.cureriver.org/2014/07/22/groundwater-101-where-does-groundwater-come-from-where-does-it-go/

3 **Sauk County Community Drinking Water Program**, H. Isabelle (2016), Center for Watershed Science and Education, University of Wisconsin, (Slide 5), https://slideplayer.com/slide/download/

[Intentional gap to prevent different text boxes from merging]

The geological formations where ground-water flows through the ground with short enough 'travel times' ('residence times'; 'recharge times'); and, in large enough volumes to be worthwhile pumping; are called **aquifers**. Aquifers are the geological 'pipes' or 'conduits' through which the-percentage-of-groundwater-capable-of-being-pumped flows and from which that water can be pumped.

The author/s uttered "while the province is underlain by a single aquifer, groundwater movement can be separated into many individual groundwater flow systems…" But, the **only** "groundwater flow systems" *from which water can be pumped are* **aquifers**! The author/s are engaging in obfuscation 'doublespeak' that is either irrelevant enough or false enough to be disinformation. The ability of water to flow through the ground decreases very rapidly as depth increases. Therefore, although hydro-geologists may accurately and correctly speak of **ground-water 'flow' *outside of an aquifer***, the rate of that type **of ground-water flow may be so *excruciatingly slow* that the average person might not even consider it to be flowing at all**.

Consider the next three pages (excerpts from the 'Overview' attachment pages 8 to 15), where the *shallow* LF (low flow) **ground-water flow system** (below 36 m but above 100 m), takes **up to 10,000 years 'travel time' to 'flow' less than three (3) kilometres.** That is a 'residence time' of 10,000 years below the surface of the ground {*Multi-scale nitrate transport in a sandstone aquifer system under intensive agriculture*, Paradis, Ballard, Lefebvre, Savard (2017)}. Or, consider *Consequences of climatic changes on contamination of drinking water by nitrate on Prince Edward Island*, Savard & **Somers** (Editors) et al. (2007), where the residence time in the *shallow* low-flow system is from 5,000 to 7,000 years. Clearly, **the author/s use of the expression 'ground-water *flow* system', is extremely misleading.**

Ignoring what's happening *beneath* the surface…		
is like re-arranging the deck chairs on the Titanic…		while admiring the iceberg.
The 'tip of the iceberg' gives you a darned good idea where the rest of it lies. Abracadabra is just the tip of the iceberg.		
https://www.leftfutures.org/2014/03/the-banking-reform-act-is-rearranging-the-deck-chairs-on-the-neoliberal-titanic/ (text by **Bourdon**)		

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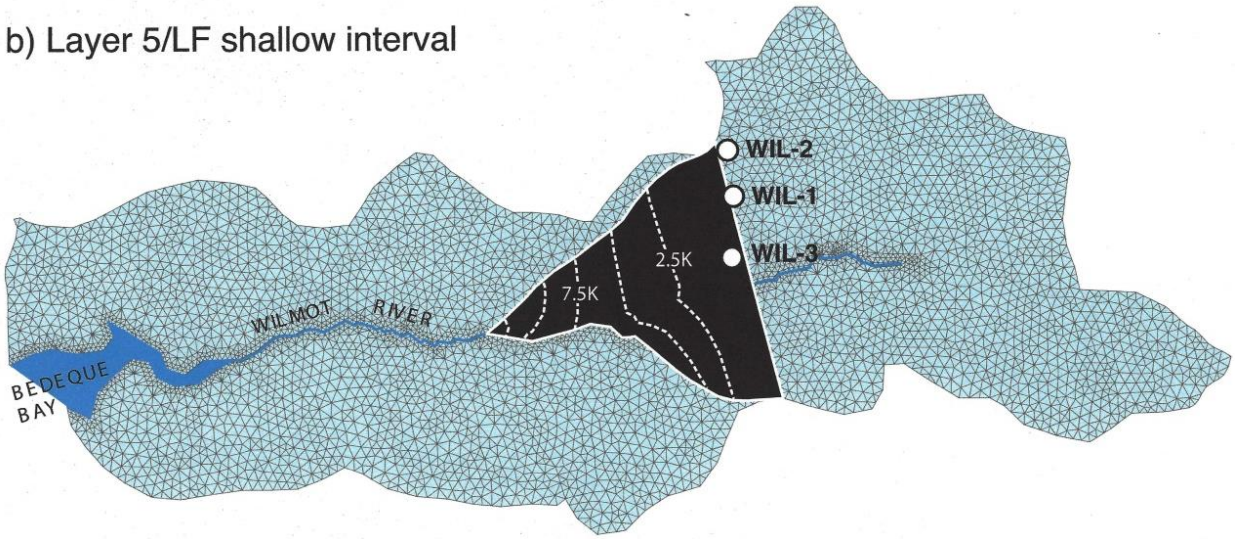
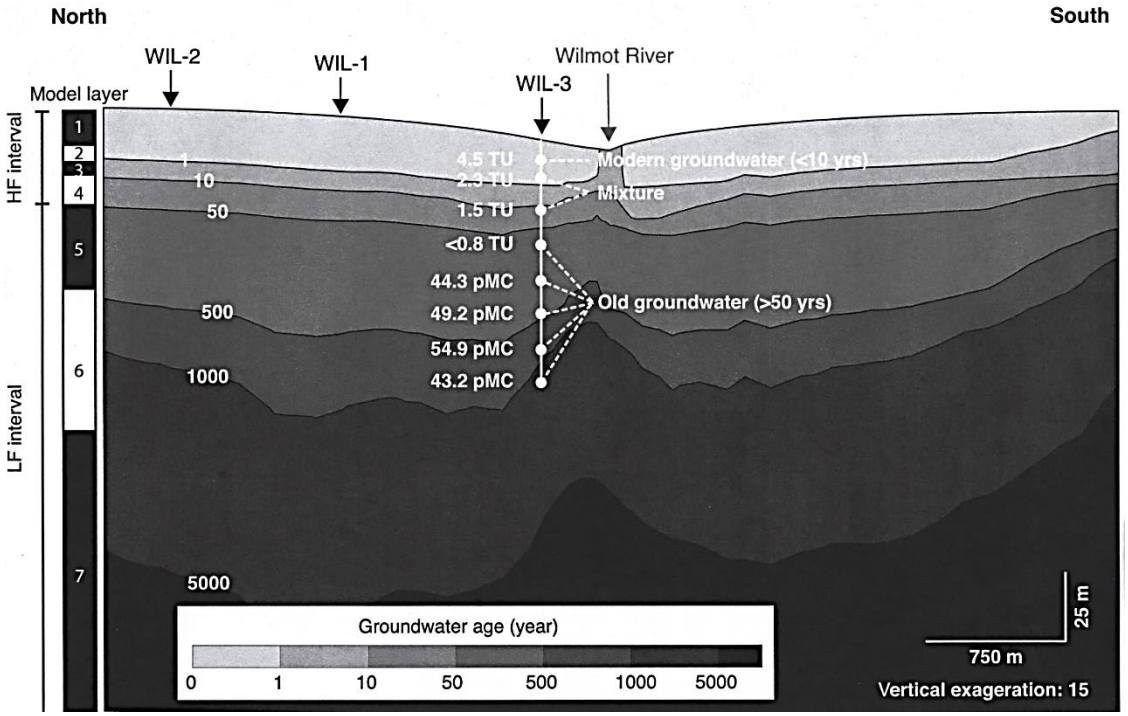


"**Fig. 7** Particles tracking for… **b** the low flow (LF) shallow interval (layer 5)…. Particles were released from a transect crossing **WIL-1 to WIL-3** [**less than 3 km**]. The figure shows the envelope of particle tracks…" (pg. 16; fig. format modified)



"Fig. 4 - Simulated groundwater ages… in the Wilmot River watershed…." (pg. 13)

"The LF shallow interval (model layer 5; **Fig. 7b**) is also connected to the Wilmot River… and takes **a travel time of up to 10,000 years** [at rate of roughly **0.3 metres per year**] to reach the river…." (pg. 13; 3,000 m ÷ 10,000 yrs.)

Multi-scale nitrate transport in a sandstone aquifer system under intensive agriculture, Paradis, Ballard, Lefebvre, Savard (2017); Hydrogeology Journal · September 2017, (pg. 13), https://www.researchgate.net/publication/320036922_Multi-scale_nitrate_transport_in_a_sandstone_aquifer_system_under_intensive_agriculture (22 pgs.)

”5000 to 7000 years” residence time:

Consequences of climatic changes on contamination of drinking water by nitrate on Prince Edward Island; Savard & **Somers** (Editors) et al. (2007); Report submitted to Natural Resources Canada Climate Change Action Fund: Impacts and Adaptation, Contribution Agreement A881/A843; web-accessed Feb. 8, 2019; http://www.gov.pe.ca/photos/original/cle_WA3.pdf (142 pgs.)

“Consequences of climatic changes on contamination of drinking water by nitrate on Prince Edward Island”

Report Prepared by

Martine M. Savard, George Somers, Daniel Paradis, Eric van Bochove, Harold Vigneault, René Lefebvre, Georges Thériault, Reinder De Jong, Yefang Jiang, Budong Qiang, Jean-Marc Ballard, Rim Cherif, Noura Ziadi, John MacLeod, Odile Pantako, Jingyi Y. Yang

Edited by Martine M. Savard & George Somers

EARTH SCIENCE SECTOR
GEOLOGICAL SURVEY OF CANADA

and

Agriculture and Agri-Food Canada | Agriculture et Agroalimentaire Canada

Prince Edward Island CANADA — Environment, Energy and Forestry

Presented March 20, 2007
to

NATURAL RESOURCES CANADA
CLIMATE CHANGE ACTION FUND: IMPACTS & ADAPTATION
Contribution Agreement A881/A843

Natural Resources Canada | Ressources naturelles Canada
Geological Survey of Canada | Commission géologique du Canada

The hydraulic conductivity profiles for monitoring wells WIL-2 and WIL-3 shown on Figure 5.2b indicate that the sandstone aquifer comprises a high flow (HF) and a low flow (LF) system. The HF system extends from the water table to a depth of 18 to 36m, the LF system being under the HF. Groundwater flow within the HF system is mostly horizontal whereas flow inside the LF system is characterized by an important vertical downward gradient near the GW divide that becomes flat toward the middle of the section and upward near the Wilmot River. Hydraulic conductivities in the HF system are always relatively high and average $1.3x10^{-4}$ m/s, whereas in the LF system the average conductivity is an order of magnitude lower at $3.5x10^{-5}$ m/s, and it is also more variable with a range between $8.4x10^{-7}$ and $1.7x10^{-4}$ m/s.

Tritium analyses on GW samples indicate an age younger than 50 years in the HF system. In the shallow LF system, Carbon-14 analyses on GW samples suggest an age between 5 000 to 7 000 years. ←

Based on the conceptual GW flow model (Fig. 5.2) and GW age dating, it is inferred that GW flow predominantly occurs in the HF system. The HF system is relatively shallow and in good contact with the Wilmot River as will be shown in the next section. Nitrate transported to the aquifer by infiltration of precipitation will first reach the shallow HF system. Nitrate is likely to be transported mostly in the HF system, together with the dominant GW flow. It is thus thought that nitrate found in the Wilmot River is coming predominantly from the HF system. However, it is also likely that a proportion of the nitrate transported in the HF system has also reached the underlying LF system. Considering the reduced GW flow and the mostly large GW ages encountered in the LF system, the nitrate that may be present in the LF system may not have yet reached the Wilmot River. The numerical modelling of GW flow and nitrate transport in the Wilmot Watershed will allow a verification of these hypotheses.

5.2.3 Groundwater and Wilmot River Interaction

Rivers and streams may represent a source of GW or act as a drain depending on their water level relative to the water table in the underlying aquifer. Observation of GW levels and river stages suggests that the Wilmot River gains water from the aquifer, thus acts as a drain most of the year.

Base flow represents water supplied to the river by the aquifer. The streamflow analysis with filters described by Furey and Gupta (2001) was applied to the Wilmot River, showing that base flow accounts for 63% of the mean annual streamflow (38% of the mean annual precipitation). This analysis also shows that base flow may be the only source of water to the river during summer, except immediately after precipitation events. Moreover, seasonal sampling of nitrate performed over a period of two years (2002-2004) in domestic wells (n=107) and in the Wilmot River (n=17) shows similar average nitrate concentrations as well as water and nitrate isotope properties (Savard *et al.*, 2004; this report, chapter 3). These observations indicate a highly effective connection between the aquifer and the river.

5.3 Numerical Modelling of Groundwater Flow and Nitrate Transport

The main objective of the model is to asses the impact of various scenarios of agricultural practices on the future nitrate level in the Wilmot aquifer. The three-dimensional finite element numerical simulator FEFLOW (Diersch, 2004) was used to reproduce the GW flow system and to simulate nitrate transport in the aquifer.

Evidently, **salt-water underlies the Island**: ***long 'residence time' water chemically evolves towards the composition of ocean water*; and, *ocean salt-water intrusion wedges inland* to merge with it. The Ghyben-Herzberg fresh-water lens is 'buoyed up' by ('floats on') the denser salt-water beneath it.** (see pg. 51 'buoyed up' definition)

"Many groundwaters of the world show **chemical evolution during flow**, as described by Chebotarev (1955); from shallow zones of active flushing (HCO_3^- water) through intermediate zones (HCO_3^- + SO_4^{2-} rich water) into zones where water flow is very sluggish [slow] and the water is old (Cl^- rich water) [the '*residence time*' is 'old']…. The different **anion-evolution sequences** are determined either by the sediment/rock types in which the groundwaters occur, or by the supply of old sea-water/sea salts…"

Chemistry and Flow Patterns in some Groundwaters of Southeastern Norway, Jens-Olaf Englund (1983); Institutt for geologi, Norges Landbrukshøgskole; Norges geol. Unders. 380, 221-234, https://www.ngu.no/FileArchive/NGUPublikasjoner/NGUnr_380_Bulletin_70_Englund_221_234.pdf (14 pgs.)

"Generally speaking, the longer the residence time, the higher the concentration of dissolved ions in groundwater. **Groundwater tends to *evolve* chemically toward** the composition of **sea water** during the course of flow."

Quaternary climate history, Kayane (1995), United Nations University, http://archive.unu.edu/unupress/unupbooks/uu02fe/uu02fe0d.htm

"**Major-Ion Evolution Sequence** - As groundwater moves along its flow paths… increases of total dissolved solids and most of the major ions normally occur…. In a classic paper based on more than 10,000 chemical analyses of well samples from Australia, **Chebotarev** (1955) concluded that **groundwater tends to evolve** chemically **toward** the composition of **seawater**." (text pg. 241)

Chemical Evolution of Natural Groundwater, chapter 7, Groundwater; Alan Freeze[1] & John Cherry[2] (1979); Pearson Publishing, Freeze.& Cherry allow Hydrologists Without Borders to post this textbook free of charge on their website; [1]Dept. of Geological Sciences University of British Columbia; [2]Dept. of Earth Sciences University of Waterloo, Ontario; (underlining & bold added); http://hydrogeologistswithoutborders.org/wordpress/wp-content/uploads/7-Chemical-Evolution-of-Natural-Groundwater.pdf (624 pgs.)

"For a large sedimentary basin, the anion-evolution [**Chebotarev**] **sequence**… can be described by three main zones, which correlate in a general way with depth…."

1.	"The upper zone - characterized by active groundwater flushing through the relatively well-leached rocks. Water in this zone has HCO3 as the dominant anion and is low in total dissolved solids."
2.	"The intermediate zone - with less active groundwater circulating and higher total dissolved solids. Sulfate is normally the dominant anion in this zone."
3.	"The lower zone - with very sluggish groundwater flow. Highly soluble minerals are commonly present in this zone because very little groundwater flushing has occurred. High chloride (salt) concentrations and high total dissolved solids are characteristic of this zone."

"For large aquifer systems, Chebotarev (1955) suggests that salinity should generally increase: with depth; with distance from the recharge area; with proximity to the sea (where applicable); and with duration of contact with aquifer minerals, which can also be referred to as **residence time** as measured from time of recharge." (text pg. 6-8)

"Groundwater salinity can be classified based on **TDS** [**t**otal **d**issolved **s**olids]concentrations:

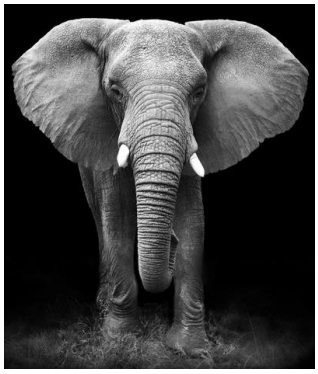
- fresh (0-1,000 mg/L),
- brackish (1,000-10,000 mg/L),
- saline (10,000-30,000 mg/L), and
- brine (>100,000 mg/L) (Freeze and Cherry, 1979)."

"Alternatively, salinity can be classified into:

- fresh (0-1,000 mg/L),
- slightly saline (1,000-3,000 mg/L),
- saline (3,000-10,000 mg/L),
- very saline (10,000-35,000 mg/L) and
- briny (>35,000 mg/L)…" (text pg. 5-1)

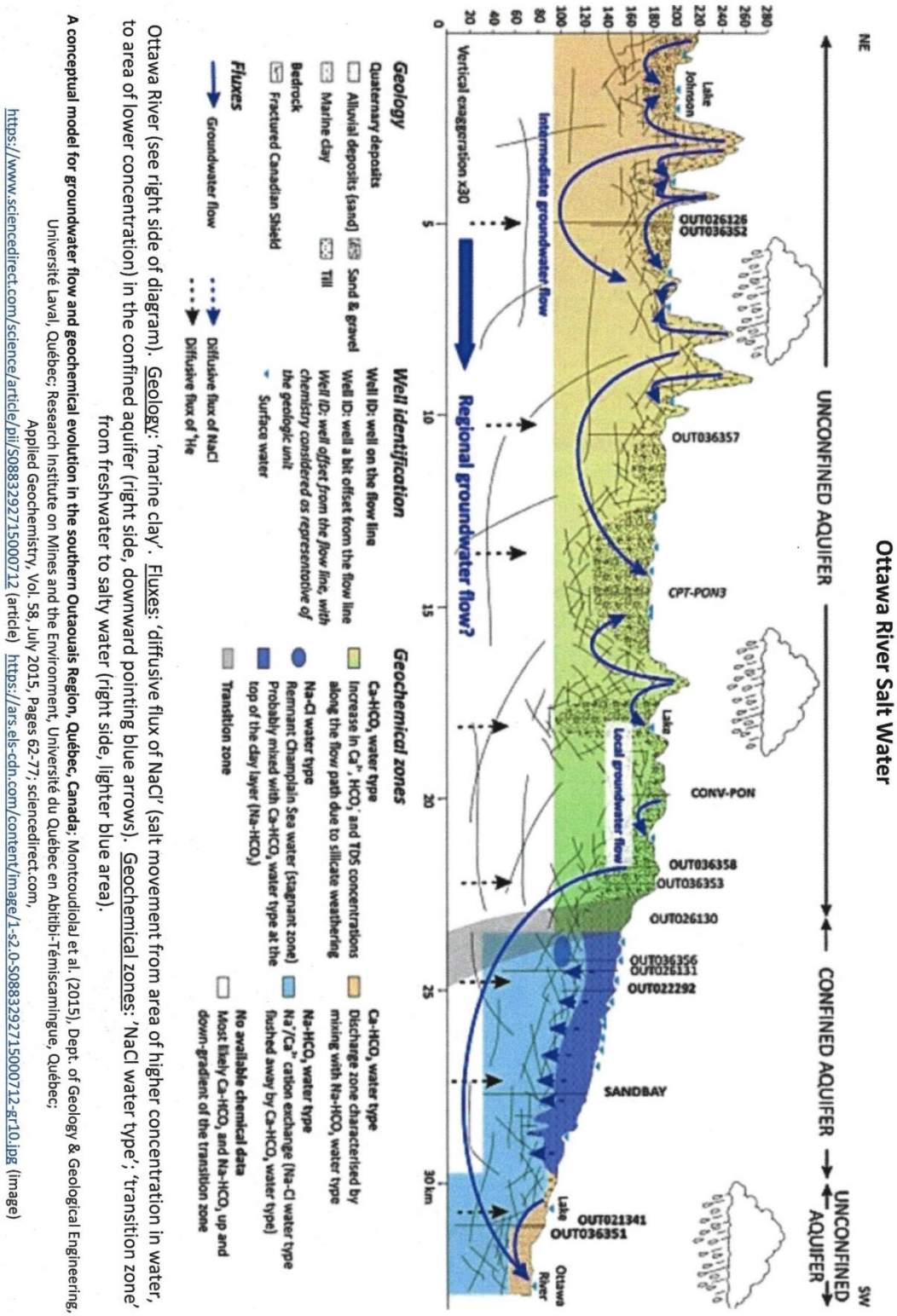
"In general, low-TDS groundwater is relatively young, occurs in the shallower subsurface, and tends to be actively recharged. In contrast, a large part of all saline [salty] groundwater occurs in more or less stagnant conditions at greater depths and may have been [residence times] there for many thousands of years." (text pg. 5-1)

Final Hydrogeochemical Evaluation of the Texas Gulf Coast Aquifer System and Implications for Developing Groundwater Availability Models; Young, Pinkard, Bassett, & Chowdhury (2014); prepared for: Texas Water Development Board, Austin, Texas, (italics, bold, bullets, & box added), http://www.twdb.texas.gov/publications/reports/contracted_reports/doc/1148301233.pdf (375 pgs.)



Ignore Me

On the next two pages, note that *salty* ground-water flow systems underlie the Ottawa area and the Winnipeg area. Those are just two examples of a common phenomenon of islands and also very, very far inland on continents… so it's not unusual that salty water would also underlie the Island.



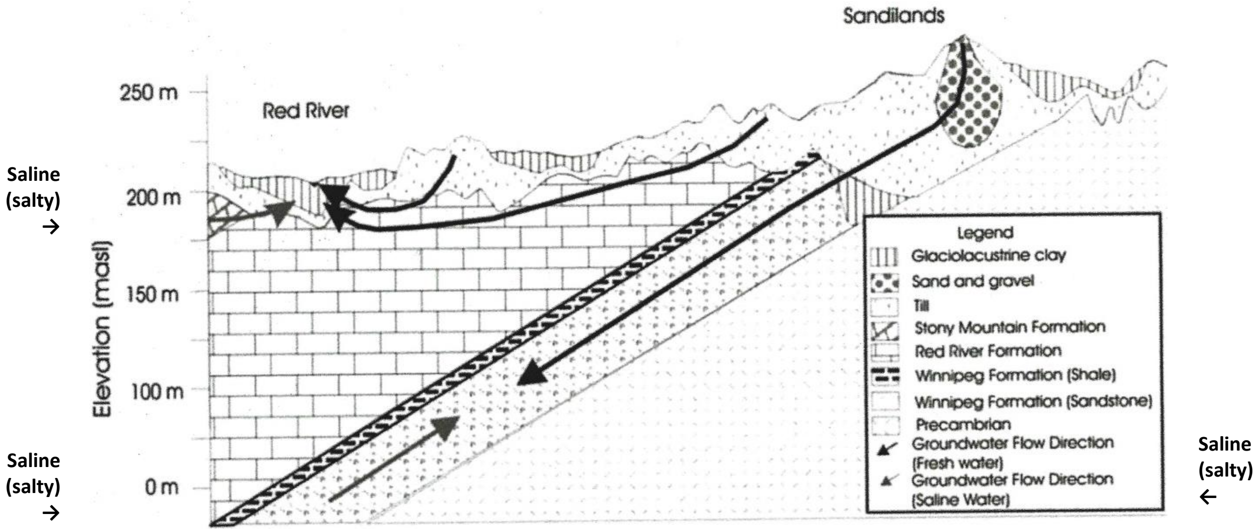
Ottawa River (see right side of diagram). Geology: 'marine clay'. Fluxes: 'diffusive flux of NaCl' (salt movement from area of higher concentration in water, to area of lower concentration) in the confined aquifer (right side, downward pointing blue arrows). Geochemical zones: 'NaCl water type'; 'transition zone' from freshwater to salty water (right side, lighter blue area).

A conceptual model for groundwater flow and geochemical evolution in the southern Outaouais Region, Québec, Canada; Montcoudiolaj et al. (2015), Dept. of Geology & Geological Engineering, Université Laval, Québec; Research Institute on Mines and the Environment, Université du Québec en Abitibi-Témiscamingue, Québec; Applied Geochemistry, Vol. 58, July 2015, Pages 62-77; sciencedirect.com,
https://www.sciencedirect.com/science/article/pii/S0883292715000712 (article) https://ars.els-cdn.com/content/image/1-s2.0-S0883292715000712-gr10.jpg (image)

Article: https://www.sciencedirect.com/science/article/abs/pii/S0883292715000712 **Image without added comments:** https://ars.els-cdn.com/content/image/1-s2.0-S0883292715000712-gr10.jpg

Salt-water underlies the Ottawa area… so it's not unusual that it also underlies the Island.

Salt-water underlies the Winnipeg area… so it's not unusual that it also underlies the Island.



"Figure 6… groundwater recharge dynamics in… Southeastern Manitoba…" Friesen Drillers Ltd. (2015)

"… the Winnipeg Formation shale separates the <u>saline/brackish</u> [salty] **glaciogenic** [glacial] groundwater of the formation with the overlying freshwater of the carbonate aquifer. It is highly likely that some fluid movement occurs through the Winnipeg Formation shale, although it is expected that with the similar heads, and the **Ghyben-Herzberg** relationship [**Ghyben-Herzberg Approximation**], there is little fluid transfer between the two formations. In reviewing the theory of saline/fresh water boundaries in *porous media aquifers*, we note the Ghyben-Herzberg relation, which states that in the event of a 1.0 foot drop in the static water level of an unconfined coastal aquifer, the saline water interface will rise approximately 40 feet..." (text pg. 10)

[**It is a 1:40 ratio**: in the event of a long-term average **1** *metre* drop in the **fresh-water table**, the <u>underlying</u> **salt-water table** {where fresh-water meets salt-water} will rise approximately **40** *metres* - i.e. 40 metres of formerly-fresh-water becomes salt-contaminated.]

> "1.2 Terminology and classification of glacigenic sediments….
> **Glacigenic** sediment (also glacigene, **glaciogenic**):'**of glacial origin**'; …
> with a greater or lesser component derived from glacier ice." (text pg. 8)
>
> **Glacial Environments**, Hambrey (1994), CRC Press , Liverpool John Moore University, https://books.google.ca/books?id=Dx8TxSHwTPQC&pg=PA8&lpg=PA8&dq=glaciogenic+dictionary+OR+glossary+OR+%22geological+terms%22+OR+terminology&source=bl&ots=fVrMPMByhV&sig=ACfU3U0lH7PHk76GUiSgUSZoUOCu3Vb4KA&hl=en&sa=X&ved=2ahUKEwi6jPqc_MLhAhUKnFkKHUQUDPUQ6AEwBHoECAkQAQ#v=onepage&q=glaciogenic%20dictionary%20OR%20glossary%20OR%20%22geological%20terms%22%20OR%20terminology&f=false (302 pgs.)

Municipal Groundwater Well Field Investigation, NW ¼ 3 -7 - 6 EPM, Proposed Park Road Municipal Supply Well Field – Environment Act Proposal, City of Steinback – Manitoba, Friesen Drillers Ltd. (2015), Manitoba, https://www.manitoba.ca/sd//eal/registries/5403.1steinbach/eap.pdf (213 pgs.; fig modified)

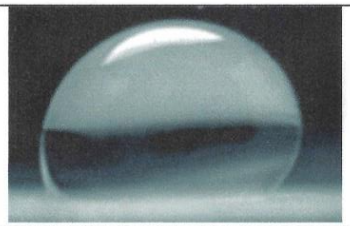
<u>**Next page**</u> (table by Bourdon)**: (1) *Ghyben-Herzberg Fresh-water Lens* & *Ghyben-Herzberg Approximation (of the Lens Thickness)*. (2) *Water-table elevation*.**

<u>Below</u>: citation links for next page's table. (to permit larger-sized table)

A https://pubs.rsc.org/en/content/articlelanding/2017/ra/c7ra09345d#!divAbstract **B** https://www.cambridge.org/core/books/coastal-hydrogeology/analytical-solutions-for-a-steady-freshwatersaltwater-interface/7919681C7F962C94F22F0B1C1839A6A9 **C** https://www.sfu.ca/personal/dallen/SFU%20Final%20Report%20the%20Hydrogeology%20of%20Salt%20Spring%20Island.pdf **D** https://pubs.usgs.gov/circ/1312/c1312.pdf

(1) Ghyben-Herzberg Fresh-water Lens & Ghyben-Herzberg *Approximation* (of the Lens Thickness). (2) Water-table Elevation

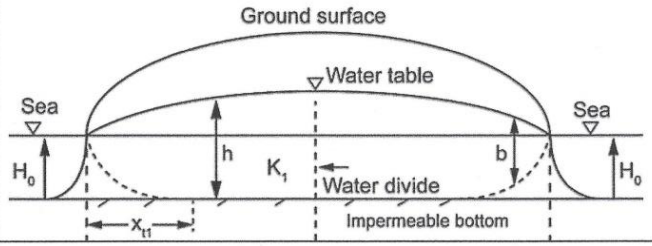
A



←

Picture *a single lens-shaped droplet of water* (like the one to the left), flattened on the bottom by an impermeable ['confining'] surface. Water displaced within the droplet due to it being flattened, slightly distorts the shape of the droplet. Note that the shape of the lens (where the arrow at left is pointing) is similar to the curved dotted-lines in the drawing below it, where the more dense (heavier) intruding ocean water 'wedges' under the lighter fresh-water lens.

B



C

"In island aquifers [within the sand, soil, gravel, or rock], the freshwater floats on [is 'buoyed up' by] the saltwater as a lens-shaped layer..." (text pg. 5)

D

"The porosity and permeability of an aquifer affects the shape of the freshwater lens and how water flows through the aquifer." (text pg. 5)

←

There are a great many examples of **Ghyben-Herzberg fresh-water lens** all over the world, including the aquifers of Prince Edward Island.

D

"As freshwater recharges an island aquifer, saltwater is displaced, and the freshwater forms a 'lens' that floats [is 'buoyed up'] on underlying, denser saltwater [within the sand, soil, gravel, or rock].... ***Frictional resistance to water flow*** **within the aquifer elevates the 'water table' relative to sea level.** In general, the water table is the [piezometric] surface where water pressure is equal to atmospheric pressure, but more simply, the water table is the top of the underground body of water [an unconfined aquifer]. The *elevation... of the water table generally increases with distance [away] from the coast*. Near the coast, water levels may undergo daily changes driven by ocean tides. Water levels in a freshwater-lens system are also influenced by seasonal and annual variations in sea level." (text pg. 4)

"The principle commonly used **to estimate the thickness of freshwater in a freshwater-lens system** is called the **Ghyben-Herzberg principle** [or, ***Approximation***]." (text pg. 6) [i.e. there are **two distinctly different G-H concepts**: (**i**) the G-H fresh-water lens, and (**ii**) the G-H *Approximation* or Principle]

A **Dynamics of a water droplet on a hydrophobic inclined surface: influence of droplet size and surface inclination angle on droplet rolling**; Yilbas et al. (2017); Royal Society of Chemistry, Issue 77, 2017, https://pubs.rsc.org/en/content/articlelanding/2017/ra/c7ra09345d#!divAbstract

B **Analytical Solutions for a Steady Freshwater–Saltwater Interface**; Jiao & Post (2019); University of Hong Kong; Cambridge University Press; pgs. 47-72, https://www.cambridge.org/core/books/coastal-hydrogeology/analytical-solutions-for-a-steady-freshwatersaltwater-interface/7919681C7F962C94F22F0B1C1839A6A9

C **The Hydrogeology of Salt Spring Island** - A summary of research conducted by Simon Fraser University as part of a project 'Risk Assessment Framework for Coastal Bedrock Aquifers'; Larocque, Allen, & Kirste (2015); Dept. of Earth Sciences Simon Fraser University, (62 pgs.), https://www.sfu.ca/personal/dallen/SFU%20Final%20Report%20the%20Hydrogeology%20of%20Salt%20Spring%20Island.pdf

D **Ground Water on Tropical Pacific Islands - Understanding a Vital Resource**; Circular 1312 U.S. Dept. of the Interior; U.S. Geological Survey; Gordon Tribble (2008), https://pubs.usgs.gov/circ/1312/c1312.pdf (45 pgs.)

(2) Inland **water-table elevation** is higher since the further inland the water is (or, the higher the 'lay of the land'), the further / longer the water tortuously and tediously has to thread down-gradient ('down-hill') underground to the coast. *'Frictional resistance to water flow'* is like congested commuter traffic that slows outflow. *Literally*, water 'backs up' / 'mounds up' causing higher inland water-tables and lower coastal water-tables (as outgoing traffic flow 'thins out').

(A) There are <u>two</u> water-tables. (B) water-table '<u>mound</u>' (C) Ghyben-Herzberg

'Effect of Lining of Distributaries/Minors in Saline Groundwater Areas on Scarcity of Good Quality Water for Drinking and Supplemental Irrigation':

(A)

[There are <u>two</u> water-tables:

- the ***fresh-water table*** is the top surface of *fresh*-water in the ground.
- the ***saline/salt-water table*** is the top surface of <u>*salty*</u> water in the ground; it is the interface between the fresh-water lens and salt-water (i.e. <u>below</u> the *fresh*-water).

Applying the 'water-table' *concept* <u>to *salt*-water</u> is an unusual but very useful idea.

'Saline' water *may* mean 'ocean water', but not necessarily.

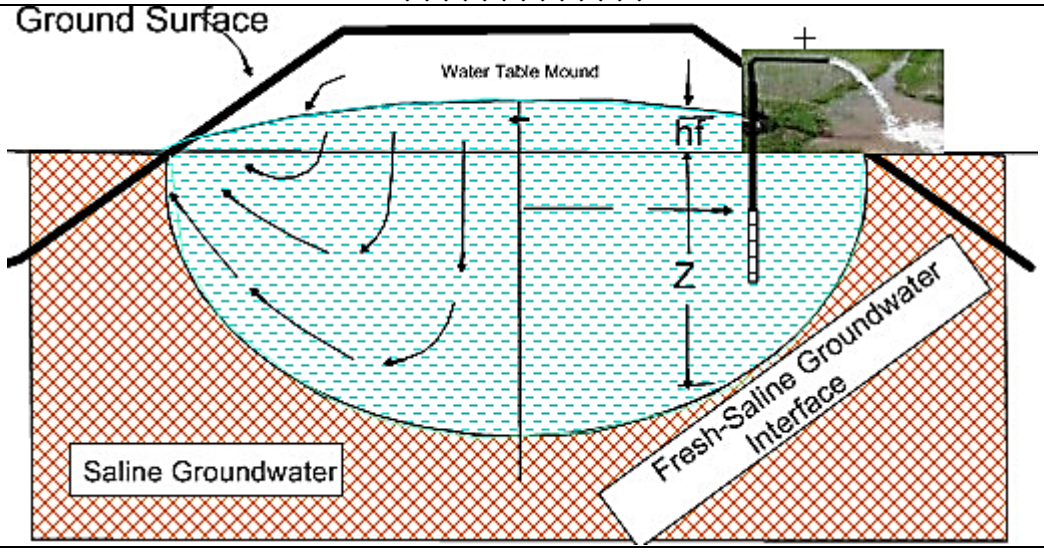
It may simply be formerly-fresh-water that has become 'salty' due to, for instance:

- extremely long 'residence times' (e.g. spending centuries underground).
- agricultural practices (as is the case in this article).]

↓ Recharge ↓

↓↓↓↓↓↓↓↓↓↓↓↓↓

(B) →



"Fig 2. Depth to fresh-water salty-groundwater interface in relation to height of fresh-water table mound."

(C) "**Ghyben-Herzberg**…. equation predicts the depth to fresh-saline groundwater Interface [fresh-water salty-groundwater interface, where the two meet] being directly related to the height [elevation above mean sea-level] of **fresh water table mound *hf*** [in fig. 2] over and above the existing ***<u>saline</u>*** [salt] ***<u>groundwater table</u>*** [*the water-table of the salty water*] in the area. If the height of fresh water mound [the ***fresh water table***] is increased one foot, the depth to interface between fresh-saline groundwater will correspondingly increase up to 40 feet. [The rule-of-thumb is that there are 40 'units-of-measure' of fresh water below sea-level, for every single 'unit-of-measure' of fresh water above sea-level]."

Effect of Lining of Distributaries/Minors in Saline Groundwater Areas on Scarcity of Good Quality Water for Drinking and Supplemental Irrigation; Akram (2017); Center of Excellence in Water Resources Engineering, University of Engineering and Technology, Pakistan; (no pg. numbers; italics, bold, & 'recharge' label added), https://www.linkedin.com/pulse/effect-lining-distributariesminors-saline-groundwater-muhammad-akram-1/

"[Freshwater] Lenses can be thought of as **mounds** of groundwater bordered by marine water at the edge, bedrock on the bottom…. Groundwater in the aquifer is always moving, *keeping a balance* of *recharge and discharge*. **Groundwater moves** from areas of higher elevation to lower elevation at a fairly slow rate of **one foot** [**0.3 m**] **per day**. Flow from the middle of the **lens** [the middle of the island] to the shore - a distance of **10,000 feet** [**1.9 miles**; **3.1 km**] - **takes** 10,000 days, or **nearly 30 years**. This is an extremely long time for the aquifer to flush itself. So contaminants that are introduced to the **lens** degrade water quality and can ruin our drinking water for generations."

[Cape Cod] **Monomoy Lens Aquifer: How does the Lens work?** Harwich Water Dept., Harwich, Maine, https://www.google.ca/search?as_q=groundwater+hydrology++&as_epq=Barnstable+County&as_oq=&as_eq=&as_nlo=&as_nhi=&lr=&cr=&as_qdr=all&as_sitesearch=&as_occt=any&safe=images&as_filetype=&as_rights=

"On Cape Cod, bays and streams divide the ground-water system into six areas or cells, each of which has a **water-table mound** [freshwater lens]…. **Ground water flows** in the direction of the greatest hydraulic gradient, which is from the center of the *mounds* to the ocean…. On Martha's Vineyard, the ground water flows mainly in one cell, which has a *water-table mound* that reaches an altitude of 18 to 19 ft. above sea level near the center of the island…. On Nantucket, the water table forms several low *mounds*, the largest of which reaches an altitude of 12 to 14 ft. above sea level…." (pg. 53)

Water Resources of Massachusetts; Simcox (1992), U.S. Geological Survey, Water-Resources Investigations Report 90-4144, https://pubs.usgs.gov/wri/wri904144/pdfs/wrir904144.pdf (105 pgs.)

Why are the Abracadabra author/s trying '*to control the narrative*' (political 'spin doctor' talk) by shifting the focus away from the most logical term 'aquifer'/ 'aquifers', towards the very general and *far* less useful term 'ground-water flow'? Why do they assert that there is only one aquifer (and, *absurdly* exaggerate its depth); when the Island obviously has many aquifers of several types? What is their motivation?

Why attempt *to shift our attention* away from our *relatively* shallow aquifer system (from which we pump ground-water flow); towards *deeper* 'ground-water flow systems' that tend to be salty and from which we *can't* pump water?

"Water flows in *the uppermost* part of **the aquifer**, which is strongly fractured and **constitutes a fast path layer for groundwater flow**." [**which is what makes it an aquifer**]

Prince Edward Island regional bedrock aquifer;
Groundwater Information Network (2014); italics, bold, & underlining added),
https://gin.gw-info.net/service/api_ngwds:gin2/en/data/standard.hydrogeologicunit.html?id=215

2.0 OCCURRENCE OF SALINE GROUNDWATER IN PRINCE EDWARD ISLAND

2.1 General

The province of Prince Edward Island may be considered to be an oceanic island with respect to its near-shore groundwater flow regime. In the classic homogeneous, isotropic aquifer model, at hydrostatic (non-pumping, no flow) conditions, fresh groundwater tends to float on top of the denser saline sea water, resulting in a lens of fresh groundwater below which predominantly saline water occurs. This condition is described by the Ghyben-Hertzberg relationship. The boundary between the saline water and fresh groundwater is called the "salt water interface" which extends into the aquifer at an angle of about 45 degrees as shown on Figure 2-1 [a]. Based on the density relationships between the fresh and salt water, the depth to the salt water interface should be approximately 40 times the elevation of the water table above sea level. In other words, a one metre decline in the water table could result in a forty metre rise in the salt water interface.

This Ghyben-Hertzberg relationship is rarely met in the real world, due to a variety of factors. These include: strong seaward hydraulic gradients which can push the interface seaward (Figure 2-1 [b]); the dispersive properties of the aquifer which tends to produce a wide zone of diffusion rather than a sharp salt water interface (Figure 2-1 [c]), such as lithology (thickness of zone increases with decreasing grain size) and hydrodynamic mixing in the aquifer by tidal oscillations; and aquifer heterogeneity such as layered aquifers, fractured aquifers and confined aquifers which can result in a variable degree of salt water intrusion with depth in a well (Figure 2-1 [d]).

<u>However</u>… for Island water managers to dismiss a forty-to-one *<u>magnitude</u>* potential threat to our water supply by *quibbling* that the Ghyben-Herzberg *<u>Approximation</u>* *<u>rule-of-thumb</u>* may be imprecise, would demonstrate a profound lack of insight and foresight. Whitford & Associates *don't* dismiss it, they *use it* for the useful *approximation* and *rule-of-thumb* it is.

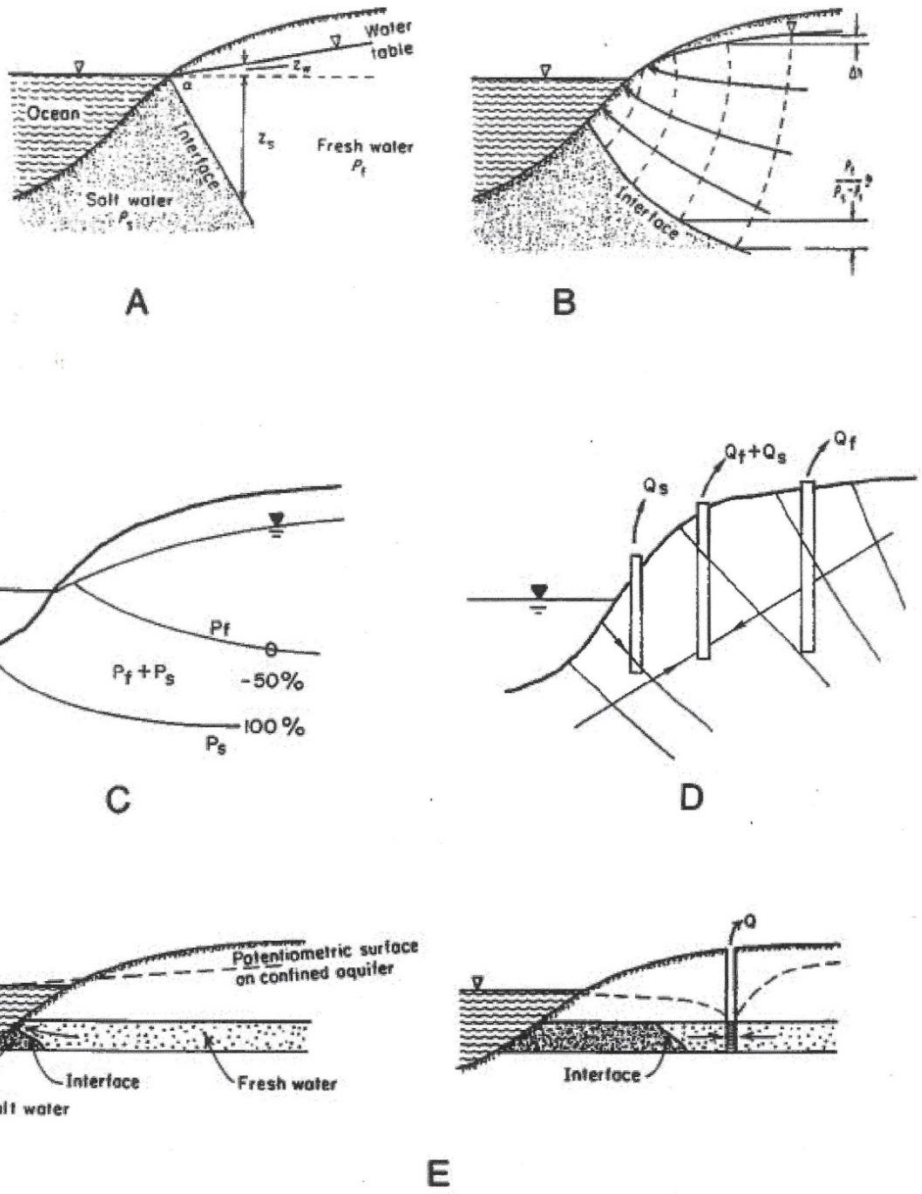


FIGURE 2-1
Saltwater - freshwater interface in an unconfined coastal aquifer. A)Under hydrostatic conditions (Ghyben Hertzberg relationship) B) Under conditions of steady - state seaward flow (after Hubbert,1940). C) Zone of diffusion. D) Saltwater intrusion in a fractured aquifer. E) Saltwater-freshwater interface under steady state and pumping conditions.

Salt Water Well Study - Prince Edward Island, Project No. 5424, Jacques Whitford & Assoc. Ltd. (March 1990).

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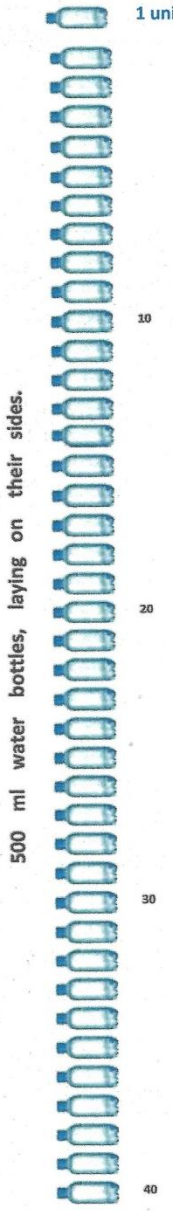
Ghyben-Herzberg Fresh-Water Lens & Salt-Water Intrusion: *A little bit contaminates a whole lot.*



1 unit-of-measure of fresh-water above mean (average) sea level.

40 units-of-measure of fresh-water below mean sea-level.

When the multi-year average water-table elevation measured (*by definition*) relative to (compared to) mean sea-level, drops by one unit, then forty (40) units of formerly-fresh-water (at the bottom end of the aquifer system) slowly & inevitably becomes contaminated by salty water.

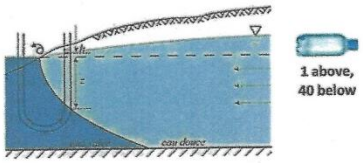
One bottle (out of forty) of ocean water is more than enough to contaminate 39 bottles of fresh-water *forever*.

0.2 x 40 = 0.80
(4/5^{ths})

Four-fifths of a 500 ml bottle of ocean-water would do it.

A volume of fresh-water only has to be 2% ocean-water (i.e. 2 parts ocean-water mixed with 98 parts fresh-water) to become *permanently* contaminated.

A one unit multi-year average drop in the water-table does not have to turn the entire underlying forty units of fresh-water into ocean-water for it to be forever contaminated… it just has to diffuse (mix) until 2% of it is ocean-water.



Hydrological graphics drawn to scale would tend to be too large to fit onto a page.

500ml * 18,000ml (18l)

Another way of visualizing the contamination caused when a volume of water is 2% ocean-water, is that a water-cooler-sized bottle of fresh-water would become *forever* undrinkable if less than three quarters of one small bottle's worth of ocean-water was added to it.

The potential cost of down-playing or not understanding the impact of fresh-water pumping (*no matter how far inland it may be*) on salt-water intrusion is… absolutely massive.

As mean sea-level rises the water-table drops by the same amount; and, forty (40) times that amount of formerly-fresh-water becomes salt-water contaminated.

Water-bottle Image: Boccione d'Acqua di Fonte, https://www.coffeebreakservice.it/images/immagini/complementari/boccioni.jpg

Text & graphic concept: Bourdon

"Fig. 50: Ghyben-Herzberg position of the ocean saltwater… and island freshwater… interface and depth"
'Study of the hydrodynamic relationship between deep groundwater of the Sfax and the southern aquifers (Menzel Habib et Gabès North): Origins and mechanisms of sub-surface water mineralization' - **ETUDE DES RELATIONS HYDRODYNAMIQUES ENTRE LA NAPPE PROFONDE DE SFAX ET LES SYSTEMES AQUIFERES MERIDIONAUX (Menzel Habib et Gabès Nord): ORIGINE(S) ET MECANISMES DE MINERALISATION DES EAUX SOUTERRAINES**, Ben-Cheikh (2013); Doctoral thesis in Environmental Management Engineering; University of Sfax, National Engineering School,

Water-bottle Image: Boccione d'Acqua di Fonte, https://www.coffeebreakservice.it/images/immagini/complementari/boccioni.jpg

"Fig. 50: Ghyben-Herzberg position of the ocean saltwater… and island freshwater… interface and depth" http://docplayer.fr/58486068-These-presentee-a-l-ecole-nationale-d-ingenieurs-de-sfax-en-vue-de-l-obtention-de-doctorat.html

"**What's in your handout is correct.**" (personal communication, Jan 21, 2021), **Dr. Adrian Werner,** Prof. of Hydrogeology, Flinders University, Adelaide, South Australia; Assoc. Editor of the *Journal of Hydrology* & Assoc. Editor of *Advances in Water Resources*.

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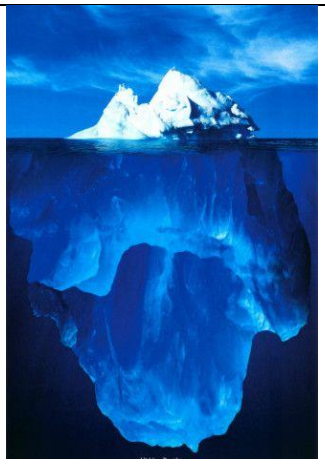
Three Videos in *Under Four Minutes*: the Ghyben-Herzberg *Density* Relationship

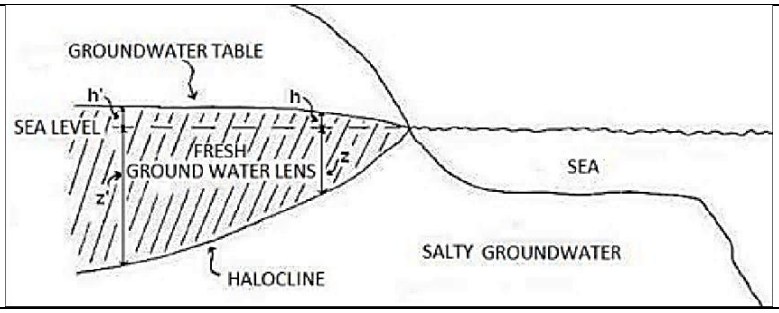
(1) 33 seconds	**Fresh water + Salt water = Estuary**, 33 second, simple YouTube video very clearly demonstrates fresh-water floating on salt-water. Note what happens when the sliding partition (between the fresh-water and salt-water) is removed: https://www.youtube.com/watch?v=gocDE2ue04U
(2) 30 seconds	***Halocline - Cenote Mexico Scuba Diving**, 30 second video of a scuba diver passing through the boundary (halocline) between salt-water and the fresh-water that floats on it. https://www.youtube.com/watch?v=6Jmpq4BvXU8
(3) 2:54 minutes	For a very clear 'live' demonstration of the formation of a freshwater lens: **Sand Tank Experiments, for a better understanding of density driven flow**, FLIN (**F**reshwater **L**ens **IN**vestigation), 2:54 minute English language time-lapse video of an actual freshwater lens forming on saltwater in a transparent water tank, https://sandtank.wordpress.com/2014/09/05/educational-video-clip/



Icebergs & Fresh-water Lens: the ratio of what's *above* sea-level to what's *below* sea-level is **not** one-to-one.

Ghyben-Herzberg fresh-water "… island **lenses** are like ***fluid* icebergs**…."
Unlike icebergs, only **1/40th** of a fresh-water lens is **'buoyed up' above sea level.**
The percentage of a fresh-water lens that is above sea-level is small enough that (unlike the figure below) it would be hard to see if the lens was drawn to scale.

Plato, Archimedes, Ghyben-Herzberg, and Mylroie, Proceedings of the 12th Symposium on the Geology of the Bahamas and Other Carbonate Regions, Gerace Research Center, San Salvador, Bahamas, Vacher (2006), (text pg. 13; bold, italics, & underlining added), http://www.geraceresearchcentre.com/pdfs/12thGeology/Keynote_Vacher_12thGeology.pdf



***** The term '**halocline**' is synonymous with the term 'interface'.

Sea Caves, Flank Margin Caves and Tufa Caves Observed on Antalya Coastal Cliffs, Dipova & Okudan (2016); Dept. of Civil Engineering & Faculty of Aquatic Sciences & Fisheries, Akdeniz University, Turkey, Sea Caves, Flank Margin Caves and Tufa Caves Observed on Antalya Coastal Cliffs (34 pgs.)

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"The Ghyben-Herzberg relationship is useful **primarily as a rule of thumb**… ' (text pg. 4)

Sea Water Intrusion Model of Amchitka Island, Alaska, Wheatcraft (1995), Publication No. 45127, Hydrology/Hydrogeology Dept., Environmental and Resource Sciences, University of Nevada; (bold added), http://www.iaea.org/inis/collection/NCLCollectionStore/_Public/28/036/28036375.pdf (54 pgs.)

For mathematical information about Ghyben-Herzberg and other hydrological math, see:

(1) Computer-Mediated Distance learning Course on ADVANCED GROUND WATER HYDROLOGY, **SEAWATER INTRUSION INTO COASTAL AQUIFERS; LECTURE 1: Introduction**, Jacob Bear, Professor Emeritus, Faculty of Civil Engineering, Technion-Israel Institute of Technology, Haifa, Israel, https://www.interpore.org/ref-mat_pub/agwh-course/agwh_int.html

(2) **Simple saltwater intrusion equations, 'Innovative web-based decision support system for water sustainability under a changing climate' (INOWAS)**, Dept. of Hydro-sciences, Faculty of Environmental Sciences, Technical University, Dresden, Germany, (2017), https://wiki.inowas.hydro.tu-dresden.de/t09-simple-saltwater-intrusion-equations/

(3) **Plato, Archimedes, Ghyben-Herzberg, and Mylroie**, Proceedings of the 12th Symposium on the Geology of the Bahamas and Other Carbonate Regions, Gerace Research Center, San Salvador, Bahamas, Vacher (2006), http://www.geraceresearchcentre.com/pdfs/12thGeology/Keynote_Vacher_12thGeology.pdf

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"The BGH [**B**adon **G**hyben-**H**erzberg] formula is a crude approximation and has significant limitations….. Notwithstanding these limitations, the BGH formula is **useful as a first approximation** if correctly applied, using corrections when necessary, and avoiding extreme situations in which vertical flow components cannot be neglected." (text pg. 91; bold added)

Hydrology and water resources of small islands: a practical guide, International Hydrological Programme, IHP-111, Project 4.6, Studies and reports in hydrology, UNESCO; Falkland et al. (1991), http://unesdoc.unesco.org/images/0009/000904/090426eo.pdf (453 pgs.)

"Projected sea-level rise due to climate change is several mm/yr. over the next century. This has serious consequences for people living in coastal areas through the effects of flooding, coastal erosion and saltwater intrusion."

"Ghyben-Herzberg principle (based on hydrostatic equilibrium): **sea-level rise of 2.5 mm** [results in] thinning of the fresh water wedge by [approximately] 10 **cm** [i.e. **forty** times 2.5 mm]." (pg. 3; bold added) [*Whatever* the sea-level rise is (relative to the water-table), forty times that amount of formerly-fresh-water becomes contaminated.]

Comprehensive Monitoring of Salt Water Intrusion and Submarine Groundwater Discharge in Coastal Ecosystems, Teng-fong Wong, Dept. of Geosciences Stony Brook University, Stony Brook, N.Y, U.S.A.; (bold added), http://www.un.org/esa/sustdev/csd/csd16/LC/presentations/wong.pdf (16 pgs.)

"The Ghyben-Herzberg relation is applicable also to **confined and semi-confined aquifers**…. If there is more than one aquifer, each aquifer outcropping to the sea has its own interface separated by impervious or semi-pervious layers." (pg. 282; bold added)

Ground Water Assessment: Development and Management, Karanth (1987), https://books.google.ca/books?id=SD3IvN90glkC&pg=PA282&lpg=PA282&dq=%22ghyben-herzberg+relation+is+applicable+also+to+confined+and+semi-confined+aquifers%22&source=bl&ots=IDRii7rpTT&sig=h1zBPy3T7jH-Ugb43LwnKYmQ-3c&hl=en&sa=X&ved=0ahUKEwiW-Ovr4snbAhWMrFkKHZryD6MQ6AEIKTAA#v=onepage&q=%22ghyben-herzberg%20relation%20is%20applicable%20also%20to%20confined%20and%20semi-confined%20aquifers%22&f=false

The ratio h = l/40H is **valid under both unconfined and [semi-confined or] confined aquifer conditions**." (text pg. 77; italics, bold & underlining added),

Sea-Water Intrusion: Bolsa-Sunset Area Orange County, Bulletin 63-2 (1968), Resources Agency Dept. of Water Resources, State of California, (218 pgs.), http://www.water.ca.gov/waterdatalibrary/docs/historic/Bulletins/Bulletin_63/Bulletin_63-2__1968.pdf

"The sharp-interface simplification, based basically on the Ghyben-Herzberg relation, requires fewer parameters [factors to consider] and, in certain situations… **provides reasonably good approximations**." (pg. 1)

Stochastic Optimization for an Analytical Model of Saltwater Intrusion in Coastal Aquifers; Stratis et al (2016); School of Production Engineering and Management, Technical University of Crete, Greece; Applied Mathematics & Computers Laboratory, Technical University of Crete, Greece, (bold added), http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0162783

"The classic Ghyben-Herzberg estimate of the depth of the freshwater-saltwater interface together with the Dupuit approximation is **a useful tool** for developing analytical solutions to many seawater intrusion problems."

A correction factor to account for mixing in Ghyben-Herzberg and critical pumping rate approximations of seawater intrusion in coastal aquifers, Pool and Carrera, Water Resources Research, Volume 47, Issue 5, May 2011, (bold added) http://onlinelibrary.wiley.com/doi/10.1029/2010WR010256/epdf

"Under static [stable; still] conditions, the Ghyben-Herzberg relation… predicts a freshwater-saltwater interface that is a distance below mean sea level proportional (40 times larger…) to the head level above mean sea level at any location upland of a saltwater body…. **This relationship is only approximate** for an actual system with moving groundwater and a dispersed interface, **but it remains true** …. seasonal changes in recharge will generate seasonal changes in the interface that are potentially magnified [multiplied] by 40…"

Seasonal Dynamics in Coastal Aquifers: Investigation of Submarine Groundwater Discharge through Field Measurements and Numerical Models, Michael (2005), University of Notre Dame, Massachusetts Institute of Technologgy, http://studylib.net/download/10888661 (186 pgs.; (pg. 85; bold added)

"Using Ghyben-Herzberg as **a rule of thumb**…. Essaid (1986) stresses the point that the Ghyben-Herzberg rule is based on the assumption that the salt water flow zone can instantaneously adjust to changes in the fresh water zone [however]….. *The duration of* ***the period over which the system does not behave*** *[immediately]* ***as predicted… can be as much as 10 to 20 yrs***.'

Linear and Quasilinear Parabolic Problems: Volume I: Abstract Linear Theory, Amann (1995), (text pg. 194; bold added), https://books.google.ca/books?id=VRYnocx4ACoC&pg=RA1-PA194&lpg=RA1-PA194&dq=%22Using+Ghyben-Herzberg+as+a+rule+of+thumb%22&source=bl&ots=vz8tD5zY7k&sig=05yHS_WMSw_wk3M8n1a-vIjS500&hl=en&sa=X&ved=0ahUKEwjj0MizzdzYAhXD7YMKHUQNAAIQ6AEIKTAA#v=onepage&q=%22Using%20Ghyben-Herzberg%20as%20a%20rule%20of%20thumb%22&f=false

The fresh-water lens is 'buoyed up' by, 'floats on' the *more dense* salt-water beneath it

Ghyben-Herzberg fresh-water lenses are 'buoyed up' ***within*** *the soil and rock of the Island* wherever the geology permits; and, 'grounded' where the geology is impermeable.

"**buoy** up…. to uplift… keep afloat, to act as buoyancy…"

https://images.freeimages.com/images/large-previews/cdb/bouy-2-1450336.jpg

The *back* of the canoe is '**buoyed up**' / 'floats'… although the front end of the canoe is grounded.

"Free Beached Canoe, Bate Island, Ottawa River", **Alistair Williamson**, https://www.wordnik.com/words/buoy%20up

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"**Where Does Aquifer Water Come From?**" (**A**) quoted text. (**B**) summary of text.		
(**A**)	"Deeper aquifers are recharged as part of the **regional groundwater flow regime**; groundwater may travel a great distance and take many years to reach the aquifer. Shallow aquifers are recharged directly by infiltrating surface water. Residence time of groundwater in shallow aquifers tends to be short and **local flow regimes** fluctuate in response to surface conditions, compared with the slow and methodical flow trends in deeper aquifers. Groundwater in shallow aquifers retains many of the characteristics of the infiltrating surface water."	
(**B**)	**<u>Deeper aquifers</u>**: • **Recharged as part of the regional groundwater flow regime**. • Groundwater may travel a great distance and take many years [**long** 'travel times' / '**residence times'**] to reach the aquifer. • **Slow and methodical flow regimes** in deeper aquifers.	**<u>Shallow aquifers</u>**: • **Recharged directly by local infiltrating surface water**. • **Residence time** of groundwater in shallow aquifers tends to be **short**. • **<u>Local</u> flow regimes fluctuate in response to surface conditions**.
State of the Watershed; Mighty Peace Watershed Alliance (MPWA), is the Watershed Planning and Advisory Council for the Peace/Slave River Water Basin (2015), http://mightypeacesow.org/cardinal.html		

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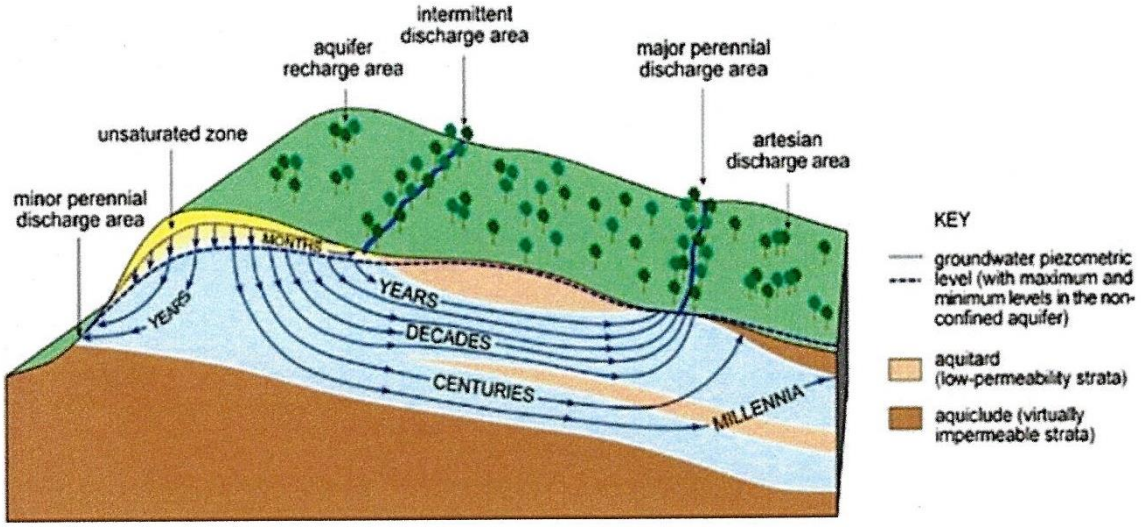
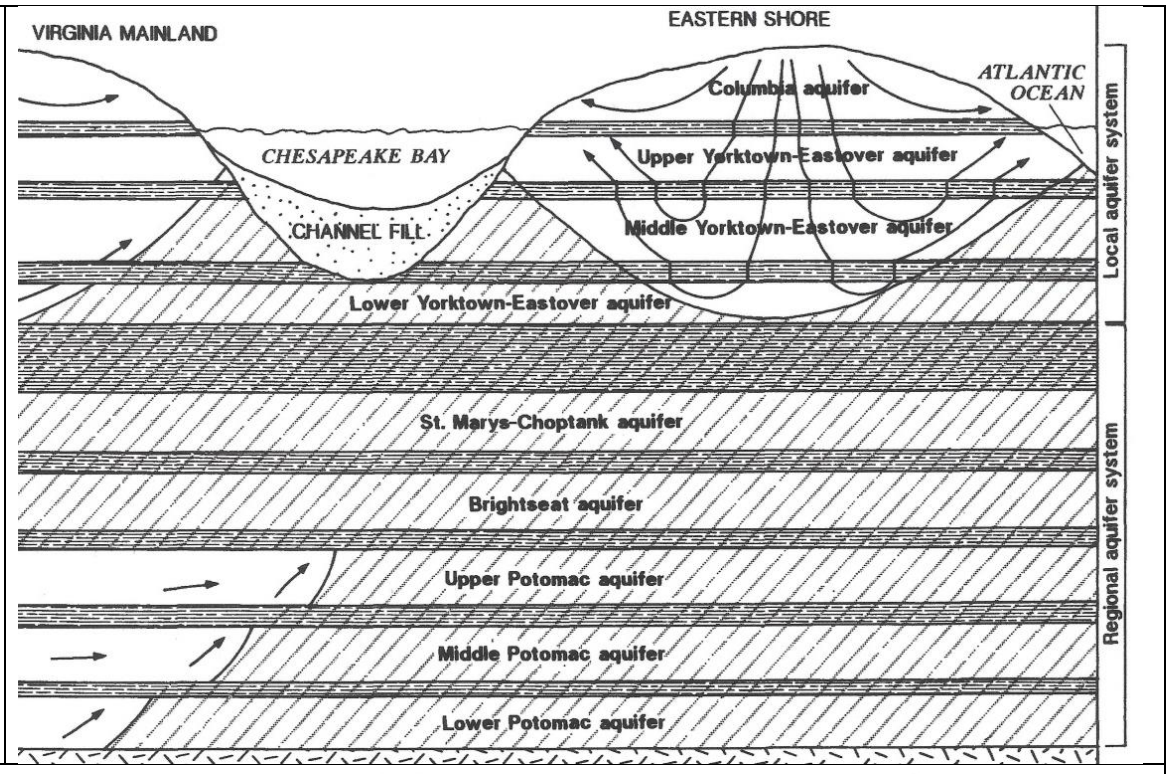


"Figure 3.2: Typical <u>groundwater flow regime</u> and <u>residence times</u>…"

Integration of Groundwater Management into Transboundary Basin Organizations in Africa - a Training Manual; AGW-Net, BGR, IWMI, CapNet, ANBO, & IGRAC (2015); Module 3 - **Aquifer Systems Characterization for Groundwater Management**, (bold & underlining added),
Module 3: Aquifer systems characterization for groundwater management (deutsche-rohstoffagentur.de) (22 pgs.)

Local ground-water flow system.

Regional ground-water flow system.



[Note the local aquifer system Ghyben-Herzberg freshwater lenses buoyed up by the underlying saltwater]

Hydrogeology and Analysis of the Ground-Water-Flow System of the Eastern Shore, Virginia; Donna Richardson (1994); in cooperation with Accomack County, Northampton County, and the Virginia Water Control Board; U.S. Geological Survey Water-Supply Paper 2401;(fig. format & legend modified, left side labels added, bold added); https://pubs.usgs.gov/wsp/2401/report.pdf (117 pgs.)

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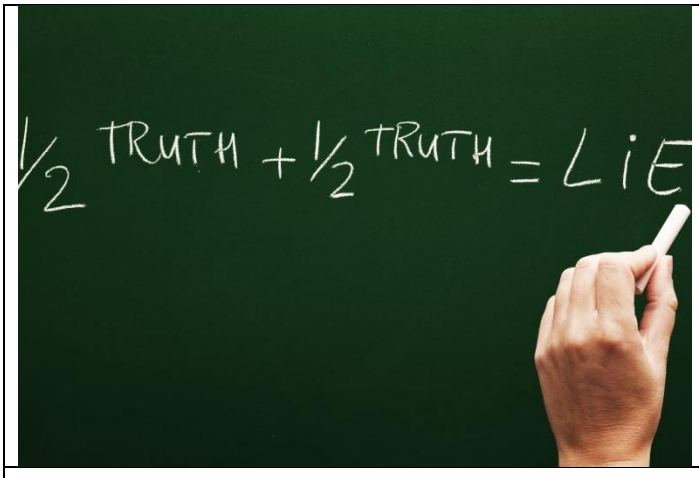

"… doublespeak is dishonest and dangerous"

(Word Watching, 2004). (Cristian Baitg/Getty Images)

What Is Doublespeak? Glossary of Grammatical and Rhetorical Terms, https://www.thoughtco.com/doublespeak-language-term-1690475

2 Types of Propaganda and 1 Type of Double Speak,

JBURTO45 (Oct. 22, 2014)

https://jburto45.wordpress.com/2014/10/22/2-types-of-propaganda-and-1-type-of-double-speak/

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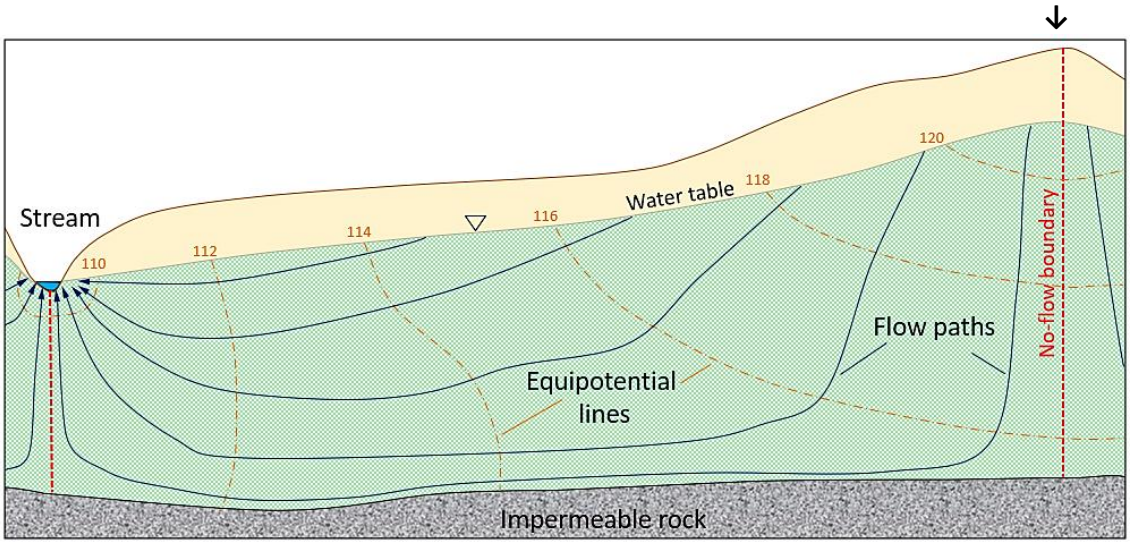
Shallow groundwater flow path contained *within* an aquifer *within* a watershed:

The vertical dotted red line "no-flow boundary" is the 'surface water divide' (marks the watershed boundary)



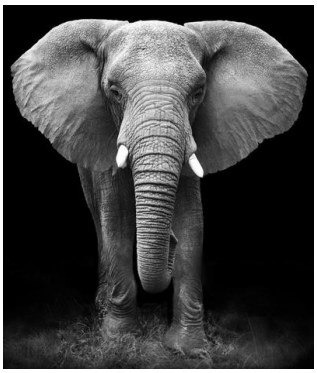
"Figure 14.2.5 - Predicted **equipotential lines** (orange) and **groundwater flow paths** (blue) in an **unconfined aquifer**. The orange numbers are the elevations [height above mean (average) sea level] of the water table at the locations shown, and therefore they **represent the** [**water**] **pressure along the equipotential lines**."

"The water table is denoted with a *small upside-down triangle*."

[The "impermeable rock" (at figure bottom) is a 'confining' layer.]

Physical Geology - 2nd Edition, Chapter 14 - Groundwater; 4.2 Groundwater Flow; Steven Earle (no date); licensed under a Creative Commons Attribution 4.0 International License; BC-campus Open Education; funded by British Columbia Ministry of Advanced Education & Skills Training, & the Hewlett Foundation; (pages are not numbered; coloured text, labels, arrow, italics, & bold added), https://opentextbc.ca/physicalgeology2ed/chapt er/14-2-groundwater-flow/

(Intentional space to prevent tables from merging)



Ignore Me

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June 7, 2018
CONSULTATION DRAFT
WATER ACT
WELL CONSTRUCTION REGULATIONS
[underlining, bold, & italics added]

https://www.princeedwardisland.ca/sites/default/files/publications/consultation_draft_-_well_construction_regulations.pdf

Pursuant to subsections 76(1), (2) and (3) of the Water Act R.S.P.E.I. 1988, Cap. W-1.1, Council made the following regulations:

1. In these regulations

…. (e) "**aquifer**" means a saturated, permeable geologic unit capable of transmitting useful quantities of water to wells and springs;

…. (dd) "pumping test" means a test that is conducted to determine the **characteristics** of a well or an **aquifer** by pumping the well at a known discharge rate and measuring the amount of drawdown of the water level in the well; ….

…. (gg) "return well" means a well that is a component of an open-loop system, intended to accept discharge water and return it to the **aquifer** from which it is withdrawn;

…. (mm) "supply well" means a well that is a component of an openloop system, intended to extract water from an **aquifer** for delivery to a heat exchanger; ….

WELL COMPLETION

10. (1) A person who constructs a well shall, immediately after construction,

(a) remove all earthen material and drill cuttings from the well;

(b) determine whether sufficient yield is available for the intended use of the well by first recording the static water level, conducting a **pumping test** for a minimum of 30 minutes, and recording on the well construction report at the conclusion of the test, the static water level, the pumping rate and the pumping water level;

(c) record on the well construction report a **recommended pump capacity and pump *depth***, based on the drawdown **characteristics** of the well; ….

PUMP INSTALLATION

11. (1) A person who installs pumping equipment in a well **shall install it in a manner consistent with** the recommendations set out in the well construction report with respect to the **characteristics** of the well and the pumping rate for the well.

[Intentional gap to prevent different text boxes from merging]

July 3, 2019
CONSULTATION DRAFT
EC2019-
WATER ACT
WATER <u>WITHDRAWAL</u> REGULATIONS
[underlining, bold, & italics added]

https://www.princeedwardisland.ca/sites/default/files/publications/proposed_water_withdrawal_regulations.pdf

Pursuant to section 76 of Water Act R.S.P.E.I. 1988, Cap. W-1.1, Council made the following regulations:
Interpretation
1. (1) In these regulations
(g) "return well" means a well that, as part of an open-loop system, accepts discharge water and returns it to the **aquifer** from which it was withdrawn;

In the draft of the 'water withdrawal regulations' there is:

- **only one** (**1**) inadvertent **mention of the word 'aquifer'**;
- **no** mention of the draft 'well construction regulations', or of its:
  - <u>mandatory</u> **pumping test** "conducted to determine the **characteristics** of a well or an **aquifer**" (i.e. to determine the *degree* to which it may be confined); or, of the…
  - recommended (although it should <u>definitely</u> be mandatory) **pump capacity** and **pump *depth***, *<u>based on the drawdown **characteristics** of **each particular well**</u>*.
- <u>Nothing</u> in the draft 'water withdrawal regulations' to suggest that any attention needs to be paid to the 'pumping test results', 'pump capacity', or 'pump *depth* '.
  After all, they are not even mentioned.

To be substantively and meaningfully 'science-based',
in the final versions of <u>both</u> sets of regulations
the 'pumping test', 'pump capacity', and 'pump *depth* '
requirements must be <u>mandatory</u> and *<u>directly cited</u>* by regulations.

Watershed groups must be funded by a department
<u>other than</u> the author/s Department,
since watershed groups have expressed <u>significant</u> reluctance
to critique the hand that funds them.

Because of that conflict of interest, watershed groups must <u>not</u> be somehow considered to be 'the guardians of Island water'… they are <u>not</u>… they are guardians of the watershed.

In the June 7, 2018 Consultation Draft Water Act Well *Construction* Regulations, the word 'aquifer' is defined and is then mentioned three times. It is mandatory to conduct a 'pumping test' to determine the pump depth and pumping rate for the well, based on the drawdown characteristics of the well. In essence, it is mandatory to characterize the qualities of each well at a particular depth within each particular well - the well has different characteristics at different depths.

Hydrogeology assigns names to the characteristics and characterization of aquifers:

- "The study of water flow in aquifers and **the characterization of aquifers is called hydrogeology**." (text pg. 1)
- "Groundwater aquifers may be **characterized** basically as either **confined** or **unconfined**. Others [other names] may include; **semiconfined, artesian, perched aquifer, phreatic and leaky aquifers** etc." (text pg. 24)

A Status Review of the Hydrological Characterization of the Basement Complex Aquifers in Taraba State, N.E. Nigeria, Okeke & Omoko (2017); Dept. of Geology, Federal University of Technology, Owerri, Nigeria; IJRDO-Journal of Applied Science, Volume-3 | Issue-5 | May,2017 | Paper-1; (26 pgs.),

https://www.google.ca/url?sa=i&url=https%3A%2F%2Fmail.ijrdo.org%2Findex.php%2Fas%2Farticle%2Fdownload%2F1276%2F1204%2F&psig=AOvVaw0UK7aD0rKLTgAkm4VVtBVX&ust=1608207554273000&source=images&cd=vfe&ved=0CA0QjhxqFwoTCJCctpy-0u0CFQAAAAAdAAAAABAU

In the July 3, 2019 Consultation Draft EC2019- Water Act Water Withdrawal Regulations the word '**aquifer**' is not defined and it is only inadvertently mentioned once. The characterization of wells is ***neither*** referred to in terms of the pumping tests ***nor*** in terms of names of the types of aquifers - which have distinctive behaviours and which (in addition) behave differently depending on the depth at which pumps are placed.

'Pumping test' characterization **of each well at each particular pump depth** is important enough to be considered in the draft well *construction* regulations. If water *pumping* is to be managed in a science-based way, then 'pumping test' results must also be **explicitly integrated** into the water withdrawal regulations - with 'pumping test' results being **directly applied to the interpretation and application of each clause of the regulations**. **'Pumping test' results must directly determine which pumping regulations apply; and, *how* each applicable pumping regulation is applied and enforced.**

Requiring '*pumping* tests'
for *well construction,*

but ignoring
'pumping test' *results*
for *well pumping,*

would be absurd.

Similarly, if the Withdrawal Regulations intend to have anything at all to do with the 'water-table', the term 'water-table' must be defined and must be **explicitly integrated** into the water withdrawal regulations. **The term 'groundwater' alone is totally inadequate.** For instance:

- When 'groundwater' totally saturates the ground below a certain level, that level is called the 'water table'; and, water above the 'water table' is also called 'groundwater'. 'Water-table' is the logical word to describe the level to which groundwater saturates the ground.
- If the Regulations continue to focus on 'groundwater' and to ignore 'aquifer', then there will be no appropriate word in the Regulations to describe that part of a geological formation that holds retrievable water: 'aquifer'.
- Groundwater below the water-table *and* **within an aquifer** is generally 'pump-able' (capable-of-being- pumped).
- Groundwater anywhere else underground is generally not capable of being pumped (not 'pump-able).

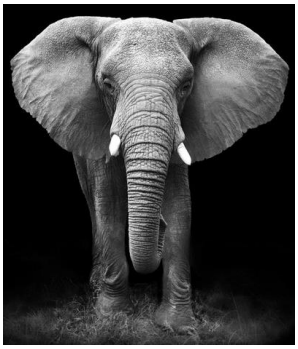
Prince Edward Island freshwater lens:

"… there's a relationship between the height of land and the depth below land that we expect freshwater to be present and that's about a one to 40. For every metre of elevation above ground, you get 40 metres of depth of groundwater…. [That is the Ghyben-Herzberg Approximation.] You can see [from a display shown to the Standing Committee] that the [Ghyben-Herzberg] freshwater lens, that dashed line underneath P.E.I., goes up and down because the Island is so sliced up…."

"You might not want to believe this relationship, one to 40…. This is a Canadian geological survey borehole looking for oil and gas drilled in 1910 and these are the notes that they made about the borehole."

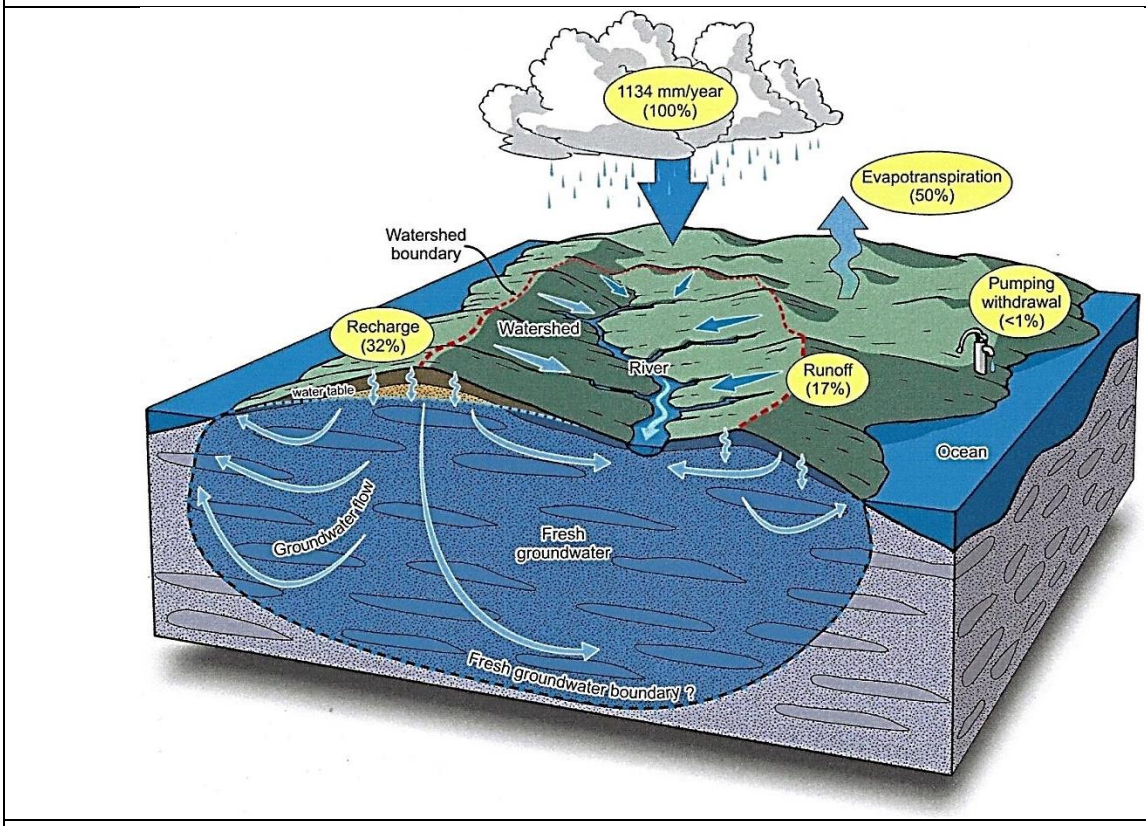
[Ghyben-Herzberg Approximation and G-H lens clarification added to quote pursuant to personal communication with Dr. Ryan, 02 March 2018]

Deep-Water Irrigation Wells, Dr. Cathryn Ryan (2014), Geoscience Dept., University of Calgary, funded by the Canadian Water Network; P. E. I. Legislative Assembly; Standing Committee on Agriculture, Environment, Energy and Forestry; Pope Room, Coles Building, Charlottetown, Published by Order of the Legislature, 25 June 2014, http://www.assembly.pe.ca/sittings/2014spring/transcripts/11_2014-25-06-transcript.pdf



Ignore Me

Looking *remarkably* like a P.E.I. '<u>Ghyben-Herzberg fresh-water lens</u>', but <u>not</u> labeled as that:



"Figure 8.2. Schematic representation of <u>the water balance</u> in PEI…"

<u>Diagram bottom</u>: the 'fresh groundwater boundary' is the sub-surface boundary point where the water-table elevation of the 'Ghyben-Herzberg fresh-water lens', exerts (hopefully) enough pressure/weight to counter-balance the ocean-water intrusion pressure, and to 'keep it at bay'.

Consequences of climatic changes on contamination of drinking water by nitrate on Prince Edward Island; Savard & **Somers** (Editors) et al. (2007); Report submitted to Natural Resources Canada Climate Change Action Fund: Impacts and Adaptation, Contribution Agreement A881/A843; web-accessed Feb. 8, 2019; (text pg. 98; bold, & underlining added), http://www.**gov.pe**.ca/photos/original/cle_WA3.pdf (142 pgs.)

<u>Next page</u>	• another ***italicized*** *Abracadabra quote*; with <u>non</u>-italicized notes **[**in square brackets**]**; followed by a paraphrasing of that quote. • another **italicized** *Somers & Nishimura* 'Executive Summary' quote (text pgs. 4-5); with <u>non</u>-italicized notes **[**in square brackets**]**; followed by a paraphrasing of that quote.

https://www.pngjoy.com/pngm/217/4230869_goodbye-change-ahead-png-hd-png-download.png https://www.princeedwardisland.ca/sites/default/files/publications/water_extraction_permitting_policy_2013.pdf

Salt Water Intrusion (*italicized* parts of this Abracadabra text, will be paraphrased below it:

> **"**This issue was examined… under the auspices of the Atlantic Regional Adaptation Collaborative (RAC) Climate Change Program, (Somers and Nishimura, eds. 2012*)*. The results of this work indicated that *only slight changes in the extent of salt water intrusion can be expected as a result of projected sea level rise…. management* of groundwater withdrawals [*pumping*] in coastal areas… are *likely be the most important and effective considerations in preserving the integrity of coastal aquifers*." (text pg. 11)

To paraphrase *the italicized parts* of the above Abracadabra quote:

> *'*Somers & Nishimura (eds., 2012) indicated that only *slight changes* in the extent of salt water intrusion can be expected as a result of projected sea level rise. Regardless of climate change effects, management of groundwater pumping will likely be the most important and effective consideration in preserving the integrity of coastal aquifers.'

The above, *somewhat moderates* the following, ***particularly damaging* disinformation** of the Somers & Nishimura (eds., 2012) '**Executive Summary**' of **'***Managing Groundwater Resources - Assessing the impact of climate change on salt-water intrusion of coastal aquifers in Atlantic Canada'*. The edited *articles* of that 2012 paper are not the problem. The 'Executive Summary' is the problem, because people like the Abracadabra author/s may read *and quote only* the 'Executive Summary', perhaps assuming that it accurately reflects the article. **It doesn't:**

> "*The **most significant finding** from this work* is *the fact* that *sea level rise itself is likely to be of little significance* to the integrity of coastal aquifers in the Atlantic Region. Even rises of sea level in the order of 1 metre are projected to result in only slight changes (roughly comparable in magnitude to the change in sea level rise itself) to the boundary between fresh and saline groundwater in coastal aquifers."
>
> (Somers & Nishimura 'Executive Summary', pg. 4; italics, bold, & underlining added)

The "slight changes… in coastal aquifers" (**Somers** & **Nishimura** text pgs. 4-5) would *supposedly* be *directly* proportional, 'one-to-one'. The 'Executive Summary' **dismisses the forty-to-one Ghyben-Herzberg threat ratio**; and, ***completely* ignores the physics of the matter, *the density* ('weight') *difference* between a cubic metre of fresh-water and a cubic metre of salt-water:**

- a 1 meter sea-level rise *would supposedly **just*** mean high tide was 1 meter higher; and…
- "the boundary between fresh-water salt-water" *would supposedly* move by ***just*** 1 meter.

About Somers & Nishimura (2012):

- George **Somers**: Manager of Drinking Water & Wastewater Management; Climate Change & Environment.
- Peter **Nishimura**: Senior Climate Change Adaptation Policy Advisor, Environment, Energy & Climate Action.

https://www.cleanpng.com/png-**joker**-playing-card-stock-photography-royalty-free-174813/

Next page: another ***italicized*** Somers & Nishimura 'Executive Summary' quote (text pgs. 4-5); with non-italicized notes **[**in square brackets**]**; followed by a paraphrasing of that quote.

"*By comparison* [to sea level rise]*… the position of the salt-water fresh water interface is likely to be more sensitive to changes in groundwater recharge rates,* ***as the rate of discharge of fresh groundwater toward the coast*** [ground-water flow rate towards the coast] ***is a key factor determining the inland extent of intrusion of marine*** [ocean]***, saline*** [salty] ***groundwater.*** [Pressure/'head' induced by the height of the water-table above average sea level; and, the seaward movement of fresh-water; serve to counter-balance salt-water intrusion]. *The factors controlling groundwater recharge rates* [to maintain a high enough water-table] *are complex… making firm predictions on future recharge rates more difficult to formulate* [determine].*"*

"Nonetheless, these [recharge] *effects, while not insignificant, are greatly overshadowed by sensitivity to groundwater extraction* [pumping] *rates, especially in areas… represented by municipal water supplies* [well-fields]…. *the full extent of the effects of groundwater withdrawal* [pumping] *on increased salinities* [**salt-water intrusion**] … ***can be expected in some cases to take decades to manifest*** [before it affects **future generations**]… ***groundwater demand*** [how much water is pumped]… ***is the one factor considered here to be within human control****…"*

"…. ***the most critical component in*** *the* ***sustainable management of*****…** ***groundwater*** *… is clearly* ***the management of groundwater extraction*** [pumping] **rates**."

To paraphrase Somers' & Nishimura's misleading backwards round-about assertions:

- since the critical factors of precipitation, recharge rates, and sea level rise are beyond their control; and since…
- salt-water intrusion can take decades before it becomes obvious; and, since…
- pumping rates *are* a critical component they can control (to counter sea-level rise); and…
- ***if*** they can control pumping rates (to counter sea-level rise salt-water intrusion); and…
- ***if*** they can *manage* to continually *raise the water-table* *above* historical levels to keep pace with sea level rise; then…
- the seaward fresh-water outflow may counter-balance salt-water intrusion; and then…
- "sea level rise *itself* [salt-water intrusion] is likely to be of little significance" compared to….
- "**the most critical component**", **"the one factor**… **within**… **human control**" by which sea-level rise salt-water intrusion may be minimized: **managing pumping in a way that raises historical water-table elevation**. **That** is *the actual* "***most significant finding***".
- **Clearly stated**, it is **not true** "that *sea level rise itself is likely to be of little significance*".

Backwards round-about

The Emperor's New Clothes

Magician Wizard

Borneo Elephant

Joker

Next three pages: how are they doing at *raising the water-table above* historic levels?

https://wernerantweiler.ca/blog/2016-01-01-a.png Character, Education, Economics, Fairy Tales, Science, Social Studies; https://www.dreamstime.com/royalty-free-stock-photography-magician-wizard-cartoon-illustration-isolated-magic-book-image33030907 https://a-z-animals.com/animals/borneo-elephant/ https://www.cleanpng.com/png-joker-playing-card-stock-photography-royalty-free-174813/

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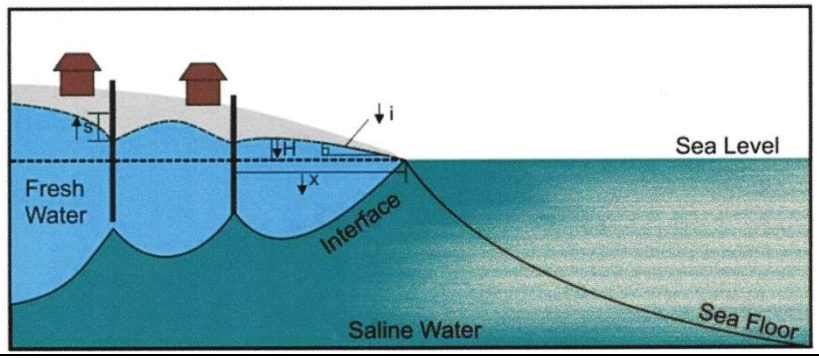
Managing Groundwater Resources… (**Somers** & **Nishimura**, eds., 2012)

"… **five variables considered to influence SWI** [**S**alt-**W**ater **I**ntrusion] **vulnerability…:**

1	2.2.2	**Distance to the Coastline**:	SWI risk is greatest near the coastline….
2	2.2.3	**Topographic Slope**:	Coastal aquifers with low hydraulic gradients [i.e. where the 'lay of the land' and the water-table are <u>not</u> high above sea level]….
3	2.2.4	[**Population**] **Density**:	Areas of intensive groundwater withdrawals [intensive pumping where more people live]….
4	2.2.5	**Large Groundwater Users**:	In addition to… domestic groundwater use, large non-domestic groundwater users [e.g. processing industries] ….
5	2.2.6	**Water Level Elevation**: [water-table elevation Relative to sea level]	An aquifer's susceptibility to seawater Intrusion is influenced by **pressure in the freshwater zone <u>relative to sea level</u>**, since adequate freshwater pressure **must be maintained to prevent SWI**…."

Managing Groundwater Resources - Assessing the impact of climate change on salt-water intrusion of coastal aquifers on in Atlantic Canada; (**Somers** & **Nishimura**, eds., 2012); text pg. 56, section 2.2.1, para. 1; text pgs. 57 & 59; fig. 3, pg. 57; bold & underlining added; table by Bourdon) http://www.**gov.pe**.ca/photos/original/cle_WA2.pdf



"…. vulnerability to SWI impacts can increase according to the **Ghyben-Herzberg relationship**…
(part (b) of fig. 3, text pg. 57, bold added)

"… the **Ghyben-Herzberg approximation**… **relates… to the <u>densities</u> [the 'weight' difference] of freshwater and saltwater** and the [map] distribution of hydraulic head..."
(text pg. 56; bold & underlining added)

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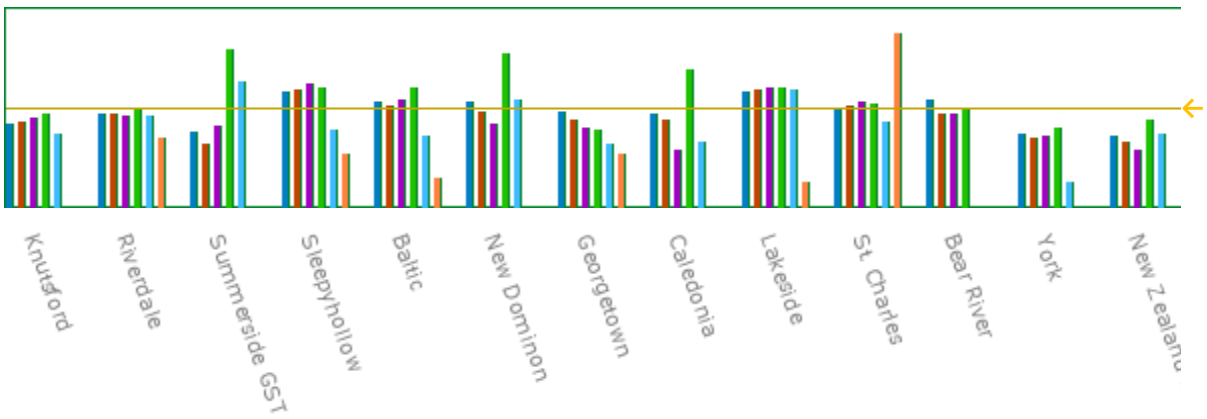
<u>A Brief Review of the Physical Characteristics of PEI's 'Redbed Aquifer'</u> <u>(Abracadabra page 11)</u>**:**

"From recent hydrological and groundwater *modeling*, <u>over **the *next* several decades**</u>, annual average <u>stream flow</u> and <u>groundwater levels</u> are <u>projected to increase slightly</u> [i.e. ***above historical levels***]…. **<u>The *last 40+ years* historical stream flow and groundwater level</u>** monitoring data in PEI, <u>show very similar trends and patterns</u> [i.e. supposedly ***<u>above historic levels</u>***] (**Qing Li**, personal communication, 2019)." (text pg. 11)

The water-table has been rising *above historic levels* for the past 40+ years?
The water-table will continue to rise *above historic levels* for the next 40 years?

Complete Observation Well List - Trend Graph



Legend for Graph

- **Representing Observation Wells Historic Average** → **[Above, note the Historic Average horizontal yellow line.]** ↑
- **Last 5 Years of Data Average**
- **Last 4 Years of Data Average**
- **Last 3 Years of Data Average**
- **Last 2 Years of Data Average**
- **Last Year of Data Average**
- **Last 2 Weeks of Data Average**

Ground Water Data, Government of P.E.I., (web-accessed 22 Jan. 2021), http://www.gov.pe.ca/envengfor/groundwater/app.php

Quoting **Qing Li** PowerPoint presentation[Y] cited below:

"In *last 40+ years* and the *next 40 years in* [*all over*] *PEI*: … Slightly increase in long-term trends of stream flow and groundwater level [[X] elevation of the water-table] in annual basis." (PowerPoint slide 23)

To paraphrase, *based on personal communication with Qing Li, Dec. 2018*:

'**On P.E.I., on an annual basis** (i.e. ***every year***) over the last 40+ years there has been a slight increase in stream flow and on groundwater levels ([X] elevation of the water-table); and, **over the next 40 years** there will also be a slight increase in stream flow and in the elevation of the water-table.'

"**Especially *in the last decade***,

- groundwater level in Island have trended slightly higher. [Slides 9, 40, & 41]
- stream flows have trended slightly higher." [Slide 39]

About the above graph 'historic average' horizontal yellow line:

- **Why are *most* of the graph bars (*including* most of the 'Last 5 Years of Data Average' graph bars) below the 'historic average' line?**
- **Why are they *below average,* when they are reportedly supposed to have been increasing annually over the past forty years and *especially over the last ten years*?**

Y	(1) **Historical and 2017 Streamflow**, and (2) **Climate Change Impacts on Stream Flow and Groundwater in PEI - From Bear River Watershed Case Study**; Qing Li (attachment to personal e-mail); provincial hydrologist, Dept. of Communities, Land & Environment; PowerPoint presentation; (43 slides/pgs.; bold, italics, & underlining added).
X	"**Groundwater level: Elevation**… **of the water table** or piezometric surface of an aquifer." (pg. 183) **Glossary**, **I**nternational **A**tomic **E**nergy **A**gency, (bold & underlining added), http://www-naweb.iaea.org/napc/ih/documents/global_cycle/vol%20IV/IV_Glossary.pdf

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'You don't miss the water-table until the well runs dry…
or, until the well is contaminated by salt-water intrusion'

(**Bourdon**)

The Qing Li, PowerPoint *assumptions* are the result of hydrological computer-modeling:

"A model is **only as good as the underlying data** that it is based upon."

How to Use the Antecedent Moisture Model, Robert Czachorski (Nov 13, 2020), H_2OMetrics, (bold added),
How to Use the Antecedent Moisture Model - H2Ometrics

"In computer science, '**garbage in, garbage out'** (**GIGO**) is the concept that flawed, or **nonsense** input **data produces nonsense** output or 'garbage'….
The principle also applies more generally to all analysis and logic, in that arguments are unsound *if their premises are flawed*."

Garbage in, garbage out, Wikipedia (18 December 2020), (bold added),
Garbage in, garbage out - Wikipedia **Medieval Monk https://t3.ftcdn.net/jpg/03/23/03/80/360_F_323038005_5d0jZUJRz9rU27MyaiJFRzK5DiGXZ53U.jpg Well aphorism: Bourdon**

The *revelation*…
of rising water-tables and flow levels in streams
over the *past* forty years…
and
The *prophecy*…
of rising water-tables and flow levels in streams
over the *next* forty years…
are not worthy of belief.

The notion

***alluded to* by *the* Somers & Nishimura (eds., 2012) 'Executive Summary';**

and, by *A Brief Review of the Physical Characteristics of PEI's 'Redbed Aquifer'*; that

"sea level rise *itself* is likely to be of little significance"

since the water-table has *supposedly* been rising *above historic levels*

over the past forty years; and,

since the water-table will *supposedly* continue to rise *above historic levels*

over the next forty years,

due to the remarkable insight, foresight, and preventative actions of Island water managers,

is ominously and tragically

absurd.

Intergenerational Equity:

Somers & **Nishimura** (Executive Summary, text pg. 5) say that it may be **decades from now** before the full extent of the effects of **salt-water intrusion** become obvious:

> *"… the full extent of the effects of groundwater withdrawal on increased salinities… can be expected… to take **decades to manifest** itself, thus **current groundwater quality may not be evidence of 'sustainable' groundwater extraction*** [pumping] ***rates with respect to salt-water intrusion**. Furthermore, groundwater demand, while potentially linked to climate change, is controlled by more immediate factors (e.g. population growth), and is the one factor considered here to be within human control.*"

"…***decades to manifest**…"* yet, the author/s of *A Brief Review of the Physical Characteristics of PEI's 'Redbed Aquifer'*/ Abracadabra dismiss **Intergenerational Equity** as being irrelevant:

> "*… the amount of water available for future generations will be determined by the water management practices at that* [***decades from now***] *time*." (pg. 10)

Essentially saying **'there's nothing we can do *now* about *the future*'**, the author/s of Abracadabra should instead consider the Somers & Nishimura observation:

> "*current groundwater quality **may not be** evidence of '**sustainable**' groundwater extraction rates **with respect to salt-water intrusion."*** (Executive Summary, text pg. 5)

Clearly, unless water-table elevations miraculously **actually** *do* **rise** each year to keep pace with sea-level rise (*literally* counter-balancing the heavier weight of salt-water intrusion), current ground-water extraction rates (**pumping rates**) "***may not be**… **sustainable***".

"Saltwater intrusion…. fresh water supplies become contaminated with saltwater, and the ***salt contamination is not reversible over any human time scale.***"

Oil, Water, and Climate: An Introduction, Cambridge University Press, Gautier (2008), Earth Space Research Group, University of California, (408 pgs.; quote pg. 235; bold, italics, & underlining added), https://books.google.ca/books?id=BUS20maWl8kC&pg=PA235&lpg=PA235&dq=freshwater+saltwater+reversible&source=bl&ots=M0JxIcn95V&sig=SMamadZ2D_YTJZxJLzXk7ZzPSoI&hl=en&sa=X&ved=0ahUKEwi-tcDY-MrYAhVpxoMKHR9uCKYQ6AEIPDAH#v=onepage&q=freshwater%20saltwater%20reversible&f=false

"It is very likely that not sea level rise, but human activities will cause a severe salinization [saltwater contamination] of most coastal aquifers…. A reason for this assumption can… be deduced from *the time lag* [a delay of decades] between causes [of intrusion] and effects [the end result of salt-water contamination]. Sea level rise takes place progressively …. in the order of decades [similar to intrusion]. On the other hand, the time characteristic of human activities, such as groundwater extraction projects, is in the order of years. **Before negative impacts**, such as upconing, **are recognised**, **it may be too late to take countermeasures**." (text pg. 442)

Improving fresh groundwater supply: problems and solutions, Ocean & Coastal Management 44 (2001) 429–449; Essink, Centre of Hydrology (ICHU), Institute of Earth Science, Utrecht University, Netherlands, (bold & underlining added) https://www.researchgate.net/publication/222565372_Improving_fresh_groundwater_supply_-_Problems_and_solutions (21 pgs.)

Intergenerational equity: There's *nothing* water managers can do *now*, about *the future*?

Democracy requires vigilant maintenance

From our American cousins, we have recently seen how damaging disinformation is; and, how fragile the *authentic* respect of what is *genuinely* '**science-based**' is.
We have also seen how democracy **can** too easily be trumped by economic interests.
It is an extraordinarily slippery slope and 'it certainly **can** happen here'.

"The punishment which the wise suffer,
who refuse to take part in the government,
is to live under the government of worse men."
Plato[$]

The price people pay for not taking part
in *participatory* democracy,
is *to risk* living under the government
of less competent people…
***and/or* of**
some
non-elected, incompetent, government
***management* rogues**

who *may be* the author/s

of an inordinate exercise of power

that makes a mockery of *genuine* consultation

and attempts to side-step democracy

•

Thank goodness… that couldn't happen on the Island… *could it*?

Bourdon

Backwards round-about

The Emperor's New Clothes

Magician Wizard

Borneo Elephant

Joker

Chubby Man Using a Push Broom

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https://www.cleanpng.com/png-joker-clipping-card-stock-photography-royalty-free-2798147/

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Democracy requires vigilance by electors, https://**stjohnsource**.com/2004/01/01/democracy-requires-vigilance-electors-1/
[$] **Wish I'd Said That**, https://wist.info/plato/3168/
/ "… **author:** To be the cause, source, or origin of; to instigate; to create." Columbia Journalism Review (2021), https://www.cjr.org/**language_corne**r/author-writer.php
/ "**Author**…. 2a**:** one that originates or creates something: source….(3)**:** one that supplies information…" https://www.**merriam-webster**.com/dictionary/source
/ "**Author**… the person who is responsible for something: 'Wray was the **author of his own misfortune**'." https://www.**macmillandictionary**.com/dictionary/british/author_1
/ "…'**Author *of his own demise*'**:** Coroner rules…" https://www.**wandsworthguardian**.co.uk/news/14519259.author-of-his-own-demise-coroner-rules-death-of-latvian-man-rudolf-slobins-in-battersea-was-drug-related/

Addendum: insert as pages 24-A and 24-B

'Ground-water Resources of Tignish Map-Area, Prince County, Prince Edward Island':

Note that the Abracadabra page two Introduction says that Island water needs are met "… by ***a single*** [i.e. **just one**] *bedrock* ***aquifer*** *underlying the Province*. It is hoped that the following review of the basic features and processes related to this aquifer *provides a sound scientific basis* for discussion about the Province's groundwater resources *and whether* ***concern is warranted***." In the very next paragraph, Abracadabra cites this Pollitt research and suggests that the extensive past history of groundwater research on P.E.I. "**permits *a robust understanding of groundwater resources***". But, *obviously* the Abracadabra author/s have failed to understand that **Pollitt speaks of there being many aquifers, not just one aquifer**.

"The most common wells and those that… yield the largest aggregate [the most over-all] supply of ground water are water-table wells [tapping into **unconfined aquifers**]…. [But] Many shallow water-table wells become dry during the late summer, winter, or periods of extreme drought…. due to the lowering of the water-table below the bottom of the well…. [Unlike unconfined aquifers] When a well penetrates [taps into] an aquifer confined by impervious beds [a confined aquifer], water flowing under pressure will rise in the well… If the… pressure is great enough to force the water to the surface, a flowing artesian well is formed." (text pg. 7)

"**Bedrock Formations and Their Water-bearing Properties**
The entire province of Prince Edward Island is underlain by… formations…. [that] consist of soft, dark red sandstone; soft, thin-bedded, red shale; hard pebble-conglomerate; and irregular beds of impure limestone containing pebble-conglomerate, and irregular beds of bright red shale… described locally as *limy conglomerates*." (text pg. 10; semi-colons & italics added)

"Although soft, red shales are not a satisfactory source of ground water in themselves, their location in bedrock suggests the possible presence of aquifers [plural] containing ground water under pressure [confined aquifers] as ground water located beneath such a shale bed will generally rise a considerable distance in the well…. The presence of impermeable shale beds [confining beds] near the surface may result in the creation of *perched water-tables* [see 'perched aquifers', diagram on pg. 25]…. shallow wells deriving [getting] their water from above the shale in such localities are not satisfactory and [these perched aquifers] will dry rapidly during drought." (text pg. 11)

"Beds of limestone and conglomerate are not extensive and are unimportant as sources of ground-water. Their relative impermeability ['confining' quality] causes them to behave like the shale beds in that ground-water occurring immediately below is under pressure [confined aquifer] and will rise in the well…" (text pg. 11)

"…. The chief sources of ground-water in the Tignish map-area are bedrock formations [plural], and of these, sandstone only is of any importance. Of the 1,809 wells [in 1952] and springs in the area, 49 per cent are known to have their aquifers [plural] in sandstone. Although the

Addendum: insert as pages 24-A and 24-B

character of the bedrock in 46 per cent of the wells is unknown, it is, without doubt, sandstone as no other type of bedrock was found to be a favorable source of ground water." (text pg. 11)

"….One of the five deep holes mentioned… was drilled on the west shore of the map-area, 1.5 miles [2.4 km] north of Miminegash. The various aquifers [**five (5) layered/stacked aquifers**]… are listed in the following commentary by E.D. Ingall….":

> '**Boring on Prince Edward Island**; Geol. Surv. [Geological Survey], Canada, Sum. Rept. [Summary Report] 1909, p. 30: Fresh water was encountered… at 230 feet [70 m]; a very heavy flow, which rose to within 30 feet [9 m] of the surface [**confined aquifer #1, fresh-water**]. At 460 feet [140 m] a very heavy flow of fresh water was again encountered…. This water finally rose to [ocean] tide level [**confined aquifer #2, fresh-water**]. At 620 feet [189 m] the water began to get brackish [salty]. At 871 feet [266 m] the water was cased off and a heavy flow of salt water was encountered at 960 feet [293 m], which rose to sea-level when the boring attained a depth of 1,020 feet [311 m; **confined aquifer #3, salt-water**]. The upper water was cased off at 1,279 feet [390 m], but another heavy flow of salt water was met with at 1,350 feet [412 m], which by the time 1,470 feet [448 m] of depth had been attained had risen to sea-level [**confined aquifer #4, salt-water**]. At 1,470 feet the upper water was again cased off, but a further supply of very salty water was met with at 1,480 feet [451 m], rising to within 100 feet [30 m] of the surface [**confined aquifer #5, salt-water**].' (text pg. 12)
>
> "….From the above commentary, the heavy flows of water encountered at various depths may be noted and also the height to which the water rose in each case [i.e. they were *all* confined aquifers]. **Eventually salt water found its way into the bore-hole and successive aquifers** [one after another] **all contained salt [water]**. [Although] It was mentioned that fresh water was encountered at 230 feet [70 m] this does not mean it was the first water to appear in the hole [e.g. unconfined aquifers above]…' (text pg. 12)

"Water supply of the Towns of Alberton and Tignish and Other Communities…" (text pg. 14; bold added; table created to summarize information)	
"**Alberton**….	All known aquifers [plural] are sandstone…"
Alberton South….	All but one of the known aquifers [plural] are sandstone…"
Tignish…. **Tignish Shore**…. **St. Louis**…. **Elmsdale**….	All known aquifers [plural] are sandstone…" (text pg. 15)
Miminegash	Has nineteen wells…. In **six** the aquifers [plural] are known to be sandstone and in four presumed also to be sandstone…."
Bloomfield….	All known aquifers are sandstone…" (text pg. 16)

Ground-water Resources of Tignish Map-Area, Prince County, Prince Edward Island; Pollitt (1952); Geological Survey of Canada, Water Supply Paper No. 312; (21 pgs.; bold & underlining added), https://geoscan.nrcan.gc.ca/starweb/geoscan/servlet.starweb?path=geoscan/downloade.web&search1=R=101783