

CONSOLIDATED HEARINGS BOARD

IN THE MATTER OF Sections 2 and 3 and 6 (3) of the Consolidated Hearings Act, 1981, S.O. 1981, c.20;

— and —

IN THE MATTER OF Section 12(2) of the Environmental Assessment Act, R.S.O. 1980, c.140;

— and —

IN THE MATTER OF Sections 30, 35 and 38 of the Environmental Protection Act, R.S.O. 1980, c.141, as amended;

— and —

IN THE MATTER OF Sections 24 and 61 (2) of the Ontario Water Resources Act, R.S.O. 1980, c.361, as amended;

— and —

IN THE MATTER OF Section 28 (3) of, and Regulation 164 under, the Conservation Authorities Act, R.S.O. 1980, c.85, as amended;

— and —

IN THE MATTER OF Section 40(12) of the Planning Act, S.O. 1983, c.1, as amended; in connection with site plan control of the sanitary landfill site;

— and —

IN THE MATTER OF Section 22(1) of the Planning Act, 1983 in connection with a referral to this Board by the Honourable Bernard Grandmaitre, Minister of Municipal Affairs, on a request by the Regional Municipality of Halton to amend the Official Plan for the Town of Milton to redesignate a parcel of land comprising Part Lots 3 and 4, Concession 2 N.S. in the Town of Milton from "Agriculture" and "Conservation and Hazard Lands" to permit the construction, operation and maintenance of a landfill site, Minister's File No. 24-OP-0208-A01;

— and —

IN THE MATTER OF Section 34(11) of the Planning Act, 1983 in connection with an appeal to this Board by the Regional Municipality of Halton for an order directing an amendment to By-law 61-85 of the Town of Milton to rezone the lands situated at Lot 3 and part of Lot 4, Concession 2 N.S., in the Town of Milton from "Agriculture" to permit a regional sanitary landfill site and ancillary uses;

— and —

IN THE MATTER OF Section 15(1) of the Planning Act, R.S.O. 1980 ch.379 in connection with a referral by the Honourable Claude F. Bennett, Minister of Housing on a request by Tremaine Britannia Citizen's Group for consideration of part of the Official Plan for the Halton Planning Area with respect to Sections 1 to 5 inclusive, 7, 9 and 10 of Part III D3 Solid Waste Management, Minister's File No. OPC-0026;

— and —

IN THE MATTER OF Section 64 of the Ontario Municipal Board Act, R.S.O. 1980, c.347 as amended in connection with an application by the Regional Municipality of Halton for an order approving:

a) the acquisition of land for the construction, operation and maintenance of a sanitary landfill site to contain 7.96 million cubic metres of waste in the Regional Municipality of Halton and to do so by one of two alternative methods as follows:

- (i) landfilling at the site referred to in Halton's Environmental Assessment as Site F in the City of Burlington;
- (ii) landfilling at the site commonly referred to in Halton's Environmental Assessment as Site D in the Town of Milton

at an estimated cost of \$12,775,000.00, and the borrowing of money by way of temporary advances not exceeding in the aggregate such estimated cost pending the sale of debentures, and

(b) the issuance of necessary debentures to a maximum of \$12,775,000.00 for a term not to exceed fifteen years;

— and —

IN THE MATTER OF Section 193(5) and Paragraph 84 of Section 210 of the Municipal Act, R.S.O. 1980, c.302, as amended;

— and —

IN THE MATTER OF Sections 6, 7 and 8 of the Expropriations Act, R.S.O. 1980, c.148;

— and —

IN THE MATTER OF an undertaking of the Regional Municipality of Halton to provide facilities for the purpose of receiving, dumping and disposing of waste as required by section 137 of the REGIONAL MUNICIPALITY OF HALTON ACT, R.S.O. 1980, c.436, as amended, by acquiring the land for, constructing, operating and maintaining a landfill to contain 7.96 million cubic metres of waste in the Regional Municipality of Halton.

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NETHERCUT & COMPANY LTD.

185 RICHMOND ST. W.,

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Toronto, Ontario

I N D E X

WITNESS:

STANLEY FEENSTRA (Resumed)

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Cross-examination by Mr. Estrin 9711

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BEFORE: Dr. D.J. Kingham - Acting Chairman

H.H. Lancaster, Q.C. - Member



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Toronto, Ontario

Hearing conducted at The Oakville
Granary Commercial Centre, 105 Robinson
Street, Oakville, Ontario, on
Thursday, October 15, 1987

VOLUME 43

APPEARANCES:

T.R. Lederer and H.D. Hodgson	for the Regional Municipality of Halton (Proponent)
J.R. Tidball	for the Ministry of the Environment
T. Vigod J.F. Castrilli	for the West Burlington Citizens Group
D. Estrin, F.E. Leitch and H. Dahme	for the Corporation of the Town of Milton
S.R. Garrod and A. Nurvo	for the Milton Area Citizens Coalition and several affected Milton area landowners
R.B. Tuer, Q.C. E.A. Cronk and F. Perrier	for National Sewer Pipe Limited
L.F. Longo	for Azova Investments Limited
M.J. McQuaid, Q.C. and C.J. Tzekas	for the City of Burlington
C. Mansfield	for the Ministry of Natural Resources
P. Renaud	for Cumis Limited



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APPEARANCES (Cont'd):

1	C. Stevenson	for Framgard Holdings,
2	P. Hancock	Fosseri Investments
3		Limited, Seriphos
4		Investments Limited and
5		Topic Investments
6		
7	J.H. Olah	for the Halton Region
8		Conservation Authority
9		
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Per: C. F. Nethercut, C.V.R.



---Upon commencing at 9:30 a.m.

1 DR. KINGHAM: Thank you, please be
2 seated.

3
4 There are a number of things that we
5 would like to bring to your attention at the outset.

6
7 Firstly, we now have a copy of
8 an order by the establishing authority in accordance
9 with section 4(9) of the Consolidated Hearings Act of
10 1981 confirming that the Board now comprises of
11 Mr. Lancaster and myself and making an observation
12 about Mr. Lancaster resuming the Chairmanship on October
13 17 which is next Monday.

14
15 The second matter we have considered
16 overnight is the matter of the information that was
17 brought to bear at the end of yesterday, and we have
18 come to the conclusion that we have accepted
19 Mr. Feenstra as an expert, qualified to offer opinion
20 evidence in the field of hydrogeology and hydrogeo-
21 chemistry and we recall that there was a feeling in the
22 hearing earlier on that this is indeed a new and
23 evolving field.

24
25 Mr. Feenstra, or Mr. Hodgson made the



1 point that in forming his opinions Mr. Feenstra has
2 indeed used quite recent information and it remains
3 to be seen and it will probably be demonstrated,
4 and we remain to hear this, but whether this recent
5 information is being adopted as Mr. Feenstra's view
6 in establishing the nature of the information and so on.

7 The Board would not want to deny any
8 party the privilege and right to bring to bear the
9 best available evidence, and the Board recognizes that
10 if any party has information which could affect the
11 weight that this Board should accord to this evidence,
12 of course they will have the opportunity to bring
13 that information to the Board's attention.
14

15 That being the case, we are prepared to hear
16 further on this information which Mr. Feenstra began to
17 present to us at the close of yesterday's hearing.

18 MR. HODGSON: Thank you.

19 STANLEY FEENSTRA (Resumed):

20 EXAMINATION IN CHIEF BY MR. HODGSON (Cont'd):

21
22 MR. HODGSON: Could we mark this document
23 as the next exhibit?

24 DR. KINGHMAN: Could you identify it as
25 we don't have a copy?



MR. HODGSON: University of Waterloo

Tracer Study - Sarnia.

DR. KINGHAM: You will explain in more detail about it?

THE WITNESS: I certainly will.

DR. KINGHAM: It will become Exhibit H-245, I believe.

---EXHIBIT NO. H-245: University of Waterloo
Tracer Study-Sarnia

MR. HODGSON: Q. Mr. Feenstra, I think it would be appropriate for the Board if you could explain how you came to have information contained on H-245, what information came to you and from what source and in what way and for what reason, and how much of the information is in fact information supplied to you by others and how much is work you have done or calculations you have made as a result of information you have received. Could you explain the whole context of H-245?

A. I certainly could. Maybe before I begin an actual response to Mr. Hodgson's question, I can refresh everyone's memory about what we were starting to discuss at the close of yesterday, and that was that the issue of the selection of a value for the



1 transport porosity of the weathered upper till strata
2 at Site D. As I described on the basis of theoretical
3 calculations which relate hydraulic conductivity and
4 fracture frequency to the actual fracture porosity,
5 those calculations would lead you to an estimate of
6 transport porosity that was very low, in the order of
7 .001 to .0001 or something in that range.

8 I mentioned yesterday how that was a very
9 low transport porosity, and transport porosity such as
10 that and consequently the very high travel velocities
11 which would result from the use of porosities that low
12 are quite inconsistent with what we observed at many
13 waste disposal facilities in Southwestern Ontario
14 which are located on weathered till deposits.

15
16 We are trying -- at the time we prepared
17 or I prepared my report last year, Exhibit H-86,
18 it was our feeling that the effect of matrix diffusion
19 would be reasonably significant with respect to
20 contaminant migration through fractured weathered till
21 units and that the assumption of a transport porosity
22 of .001 which was used in the model calculations as
23 I will describe in a few minutes, were rather
24 conservative and we fully expected the effect of
25



matrix diffusion to be fairly significant.

1 So, with that having been said, I
2 would like to describe briefly some recent work done
3 at the University of Waterloo which I would intend to
4 present as further support to the initial assumption
5 that was made last year that a transport porosity of
6 .001 is quite a conservative assumption.
7

8 Now, this study was just conducted in
9 this past summer by the University of Waterloo in the
10 Sarnia area, and I came to know of this study from
11 my conversations with Professor Cherry with whom I have
12 worked on quite a number of projects. This study was conducted
13 or directed by Dr. Cherry and conducted by several
14 of his graduate students, Andre D'Astaus, Wilf Ruland
15 and Rob Bruce, and they did a variety of studies in the
16 Sarnia area attempting to install a variety of different
17 types of water level monitoring devices, piezometers in-
18 stalled in boreholes drilled by different methods and
19 one of the components of their study was an examination
20 of the hydraulic properties of the weathered clay till.
21

22 They investigated these properties
23 by the excavation of two trenches through the weathered clay
24 zone, these trenches being approximately four metres
25



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1 in depth, four metres in length and separated by approxi-
2 mately four metres and these trenches are approximately
3 two metres in width also.

4 These trenches were excavated with a back-
5 hoe and, as you can imagine, the sides of the trenches
6 were quite extensively smeared by the digging action of
7 the backhoe. So to actually observe the fractures and
8 fissures in the weathered till, the trenches were supported
9 from a safety point of view so they would not collapse,
10 and the graduate students would go down to the bottom
11 of the trench and carefully scrape off the sidewalls
12 of the trench with a trowel to expose the fissures and
13 fractures that were quite evident on an unsmeared
14 trench wall surface.
15

16 The fractures were mapped, the fracture
17 frequency was noted, the fracture separation was
18 determined, and a variety of collection devices were
19 put on the sides of the trench where they identified
20 fairly significant fractures. Many of these fractures
21 were observed to actually drip water while the
22 excavation was open.
23

24 Now, at this site the water table is
25 approximately a metre below ground surface which is



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fairly typical of the clay till areas in Southwestern Ontario.

So, at approximately, I believe 16 points on the sidewalls of these trenches, collection devices were installed and the collection devices basically being like a cookie tin, the bottom of a cookie tin. They were pressed into the side of the trench to intersect the fracture and the outside of the tin was grouted with bentonite, a bentonite paste, and then an access tube lead from the collector up out of the trench and was installed in a small depression downstream of the receiver trench, so that the elevation of the bags was below the water table and the bags did not have to be pumped, the tubes led to a bag which filled because groundwater flowed into the collectors.

When the fractures were logged and mapped and the collectors were installed, the trenches were backfilled with sand to try and maintain the stress conditions around the trenches. Before the trench was backfilled up to ground surface a plastic and bentonite barrier was put in in the upper metre with the intention of preventing any flow from the very near surface zone above the water table and with the expectation

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that there are open fractures in that area and that is not really the area we are interested in, because we are interested in the contaminant migration below the water table in the saturated zone.

To prevent any flow from this trench to that trench a barrier was put in the upper metre. The trenches were filled with sand and then they were filled with water and the receiver trench being filled with clean water to a level of approximately the pre-existing groundwater table and the input trench had water containing a bromide tracer and a fluocene dye tracer was added, and the water level in the input trench was raised to approximately the ground surface so there was approximately a metre head differential between the receiver trench and the input trench inducing quite a hydraulic gradient from the input trench over to the receiver trench.

On the basis of the actual water flow rates that were measured in the different collectors on this side or on the receiver trench, it was determined by the authors -- maybe I can say at this point that at the present time this experiment, together with all the other experimentation that has gone on at the Sarnia site in the past summer, was written up



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in a paper which has been completed in draft form at the present time, and it is the intention of Dr. Cherry and his students to finalize, probably within the next month, for submission to the Canadian Geotechnical Journal.

In this paper at the present time, and I was asked by Dr. Cherry to review this paper approximately two weeks ago, and in the paper the authors have calculated a hydraulic conductivity based on an average hydraulic conductivity based on water flows into the collectors and receiver trench and this hydraulic conductivity reflects the bulk hydraulic conductivity of the till lying between the two trenches, that being in the range of 6×10^{-6} and when you calculate the hydraulic conductivity from an individual collector, the range is from approximately 1×10^{-6} to 6×10^{-4} and the average being in a range of around 10^{-5} which is nicely in the range that hydrogeologists in Ontario have been assuming for weathered clay till in Ontario which was actually rather nice.

Now, another calculation that was provided in the draft report which will also appear in the final report is a calculation of the transport porosity based on the same relationships I described



yesterday afternoon with the graph, Exhibit H-244, I believe, which relates the hydraulic conductivity which was measured, the fractures basin that was measured in the trenches and, on that basis, the calculated transport porosity was .0005, which is exactly in the range that one would expect and in the range that we used in our model calculations at Site D.

However, one calculation that was not presented in the draft report which I did myself on the basis of the tracer experiments, and which I will certainly encourage the authors to add to their report in my comments, is the actual calculation of the apparent porosity in the fractures intervening -- in the fractures in the till between these two trenches. That can be calculated on the basis of the time of travel of the tracer to go from the input trench to the receiver trench.

We know the hydraulic conductivity and we know the hydraulic gradient that was applied across the trench and we know the actual travel velocity of the tracer. It took approximately three weeks for the tracer to first arrive in the receiver trench after the tracer was added to the input trench and the



groundwater level increased to ground surface. If

1 you do that calculation you will find the apparent
2 porosity or the apparent transport porosity based
3 on the travel time of the tracer is considerably
4 higher than what you calculate based on just the
5 hydraulic conductivity and fracture spacing
6 calculations , that apparent porosity being .02
7

8
9 or approximately 2 per cent compared to .0005. Now,
10 as far as I am aware ...

11 Q. Can I stop you for a second?

12 You said "apparent porosity" but in Table 3-1 and in
13 Mr. Sobanski's work on Table 10 of H-39, the phrase
14 is not apparent porosity but effective porosity and
15 can you tell us what the relationship is between those
16 two?
17

18 A. I probably should have called
19 it apparent effective porosity. The effective porosity you
20 calculate using this method and we calculated to make
21 estimates of the effective porosity for our modelling
22 calculations is based strictly on the hydraulics. It is
23 not based on the actual velocity of a contaminant,
24 it is based on the velocity of the groundwater. So,
25



this is an apparent porosity.

1 Q. Which porosity are you referring
2 to, the .02?

3 A. The .02, the higher value. It is
4 an apparent porosity that incorporates the effect of
5 matrix diffusion or other attenuation. There actually
6 shouldn't be any attenuation mechanisms here for a bromide
7 tracer. As far as I am aware, this is the only
8 experiment of its kind that allows us to get an
9 indication of what difference there may be between the
10 porosity we calculate based on hydraulics, the hydraulic
11 conductivity in fracture spacing, and the actual travel
12 rate of a tracer.
13

14 So, I would not intend to adopt a value
15 such as .02 for work done at Site F because ...
16

17 Q. Site D?

18 A. Site D, sorry, mainly because of
19 the timing involved and also these tests were not
20 actually conducted at Site D and it may be reasoned that
21 there may be some differences. There is also a concern
22 that this apparent porosity was calculated over a fairly
23 short distance and maybe if you did a test over 40
24 metres or a much larger distance which you might be
25



interested in at Site D, this value may be different.

1 MR. ESTRIN: "This value?"

2 THE WITNESS: The apparent porosity may
3 be different; but based on this experiment and certainly
4 our expectation of the effect of matrix diffusion, I
5 think this experiment does illustrate that it is a
6 reasonable assumption to expect an effect due to matrix
7 diffusion and it reinforces the view that using a low
8 calculated effective porosity, as was done at Site D,
9 is quite a conservative assumption.
10

11 MR. HODGSON: Q. Then, based on this
12 work, what do you now say is the appropriate effective
13 porosity to use in the upper weathered till at Site D?
14

15 A. I wouldn't actually at this stage
16 support the use of the value that was used, .001, and
17 with the recognition and with the additional support
18 from this information that that is quite a conservative
19 assumption, and not knowing what the actual transport
20 porosity is, but recognizing that it is likely somewhat
21 higher than that and consequently groundwater contaminant
22 velocities would be somewhat lower than actually incor-
23 porated into the Site D model.
24

25 Q. So with an effective porosity of .001 and



1 a linear groundwater velocity is 13 metres per year
2 and the effective porosity, if it were higher, the
3 groundwater travel would be what?

4 A. Less than 13 metres per year.

5 Q. Can I ask you to go back to your
6 Figure 3-3, Site D, lateral migration of contaminants through
7 the weathered upper till, and explain what that calculation
8 means?

9 A. This shows the results of our
10 contaminant migration simulation using the Ogata-Banks
11 equation which, as Mr. Hodgson mentioned, is Figure 3-3
12 in H-86, and also it appears in Exhibit H-39, page 97.

13 This illustrates the relative contaminant
14 concentration, and this is for a non-adsorbed contaminant
15 such as chloride, on migration through the weathered
16 upper till with a groundwater velocity determined
17 from a hydraulic gradient of, I believe .004, a hydraulic
18 conductivity of 10^{-5} centimetres per second at a
19 distance of 100 metres, which is the site boundary
20 100 metres from the edge of the landfill.

21 This curve illustrates the concentrations
22 at the site boundary with time and, as suggested in the
23 report, if one calculated, as I discussed yesterday, if
24 one calculated the actual travel velocity on the basis
25



of Darcy's Law and assuming plug flow, one would get a velocity and one would look at a C over C_0 of .5 and go down to the time scale and get a travel time, something in the order of 7-1/2 to 8 years and that represents the rate of advance of a contaminant if one considered this plug flow.

The Ogata-Bank equation allows you to illustrate the effect of dispersion and due to dispersion, the mixing process at the front of the contaminant migration, you actually get a first arrival of contaminants if you look at a C over C_0 of .1, something in the order of five years, and that is in fact somewhat faster than you would have predicted just looking at the Darcy's Law relationship.

Q. There was one other change which was made over the course of the evidence given by Mr. Beechinor; the hydraulic gradient of the weathered upper till was changed from .004 to .0052. Do you recall that?

A. I do.

Q. How does that affect this calculation?

A. Changing the hydraulic gradient from .004 to .008...



Q. .0052.

1 A. That increases the groundwater
2 velocity by a similar factor, which would be probably
3 about 25 per cent, just over 25 per cent, and an increase
4 in groundwater velocity would tend to take this S-shaped
5 curve on Figure 3-3 and because the groundwater velocity
6 has increased the travel times obviously will be shorter
7 and this whole curve is going to shift over somewhat
8 by probably 25 or 30 per cent to result in a faster
9 travel time.
10

11 Now, if you will recall the degree of
12 dispersion is also related to the groundwater velocity,
13 and this curve will probably flatten out somewhat as
14 a result of a slightly increased amount of dispersion.
15 So the actual first arrivals of a contaminant at the
16 site boundary would -- my guess would be somewhere around
17 three years, three to five years.
18

19 Q. Now, this calculation on Figure
20 3-3; how would you characterize it. Is it a conserva-
21 tive calculation or a prediction, what is it?
22

23 A. It is quite a conservative
24 estimate or a conservative calculation based on the
25 value assumed for the effective porosity as we were



1 just describing earlier this morning. This groundwater
2 velocity is calculated on the basis of an effective
3 porosity of .001 and we fully expect matrix diffusion
4 to have a significant effect on contaminant migration
5 through the weathered upper till, and what that would
6 do is give you a lower or a higher value for the
7 apparent or effective porosity for that particular
8 contaminant and, consequently, a lower groundwater velocity,
9 and that would tend to result in slowing down the rate
10 of contaminant migration and would have the effect of
11 shipping this curve backwards.

12 Q. Backward meaning to the right?

13 A. Further along in time and to result
14 in longer travel times.

15 Q. How would you characterize the
16 longer travel time? Is it significantly longer or
17 somewhat longer?

18 A. It could be significantly longer.
19 It could be an order of magnitude, a factor of 10, but
20 we are not really able to quantify the degree of
21 attenuation due to matrix diffusion.

22 Q. Now, you have described lateral
23 migration through the upper weathered till, and what
24
25



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other migrations from the landfill, assuming the
leachate collection system is not operational, what
other migrations did you look at and calculate?

A. We also looked at downward migration from the landfill through the underlying unweathered upper till, the upper part of the lower till, this sequence (indicating), laterally through the granular units off-site from the landfill toward the site boundaries and continuing on down through the lower till and then again laterally through the shale bedrock.

Q. Would you take us through each one of those calculations?

A. Yes. The first procedure we followed in actually examining contaminant migration along these pathways, these pathways being downward out of the landfill, was to look at each component or each unit individually. I think I will continue to call each of these components, because I believe in the report each of the contaminant transport simulation models are called component models.

So, we can first look at -- we looked at the component models individually first just to get some idea of what the various travel times were in the



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different units, the effect of adsorption on weakly adsorped and moderately adsorped contaminants in the different units, Because the organic carbon contents are different in the different geological units, the degree of attenuation due to adsorption will also be different and so we wanted to look at each of the components individually to get some idea of how the different processes were acting in the different units.

This is the first component we looked at, the unweathered till, upper till immediately underlying the landfill. As I recall in this case, the input for the model included a groundwater velocity based on a hydraulic conductivity of 8×10^{-8} centimetres per second, a hydraulic gradient of .85, which reflects the hydraulic gradient that would exist in the case where there is a large-scale failure of the leachate collection system, and a mound of approximately of 6 metres in height developed within the landfill.

Other inputs into the model are the thickness of the unweathered till beneath the landfill, the dispersivity and the diffusion coefficient. The one thing I didn't point out which I should probably mention right now is the values used for



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dispersivity, if I just flip back to one previous over-head, if I can just recall what the dispersivity is; you will recall looking at how the degree of dispersion is formulated, the coefficient of hydrodynamic dispersion is the sum of two different components and one is a dispersivity value times the groundwater velocity and the other is the diffusion component. Now, this dispersivity value is a value which is very significant mathematically with respect to calculating contaminant transport, but to some degree dispersivity is only a mathematical representation of the dispersion and spreading we see in the real world. If you look at laboratory column experiment and look at the degree of dispersion or spreading on a small scale, one can calculate the value of the dispersivity and typically one gets a small number, be it for a sand or silt or clay material tested in a laboratory.

If you go into the field into a small scale field experiment, one gets in the same geologic materials, one gets a larger number for the dispersivity. Similarly, if you look at large scale groundwater contamination plumes, and some of the plumes that have been evaluated are thousands of feet long or more, you

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would get even a larger value for the dispersivity.

1 Although mathematically the dispersivity should be
2 a property of the medium you are modelling, in reality
3 it depends on the scale of the groundwater contaminant
4 transport problem you are assessing.

5
6 For that reason, given the different
7 values -- okay, for that reason, the way we approach
8 estimating a value for the dispersivity was based
9 on the actual travel distance and also on the type of
10 material it was moving through. Because it is generally
11 believed that dispersion is due to heterogeneities
12 on a microscopic scale and a macroscopic scale, geological
13 materials like tills that are -- they are heterogeneous
14 from the point of view of being a mixture of grain
15 sizes, but in terms of having layers or beds or areas
16 of different hydraulic properties, one would expect
17 that the degree of those hydraulic heterogeneities
18 would be reasonably small.

19
20 So, for the till materials and for
21 contaminant migration through the till materials we
22 estimated the dispersivity based on a value of 5 per cent
23 of the actual travel distance. There are not many
24 estimates of dispersivity for fine-grained materials
25



1 like clay tills reported in the literature, most of
2 those being laboratory experiments showing dispersivities
3 considerably smaller than were actually used in this
4 situation.

5 For the sandy units at Site D, we assumed
6 the dispersivity was approximately 10 per cent of the
7 travel distance and this is reasonably consistent with
8 studies that have been done, particularly at the
9 Armed Forces Base Borden landfill in the studies
10 conducted by the University of Waterloo and a variety of
11 others, and for fractured media such as the fractured
12 shale at Site F one would expect the heterogeneities
13 to be on a much larger scale because contaminants --
14 groundwater flow and contaminant transport is primarily
15 due to fractures and it is not really controlled
16 by the geology in a strict manner.

17 We assume that the degree of dispersion
18 or the degree of spreading in a fractured media would
19 be considerably higher than in a porous media, and so for
20 the fractured media we assumed a value for dispersivity to be
21 30 per cent of the travel distance, but it has to be
22 recognized that dispersity is simply an estimate. It
23 is something that is extremely difficult to measure and
24
25



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1 to measure -- you can measure it in a laboratory and
2 you can measure it on a small scale in the field, but, as
3 you can imagine, to measure it on a scale which is
4 appropriate to a waste disposal problem would take a
5 tracer test of a very large size and one you would have
6 to monitor for many, many years to get meaningful
7 results on the same scale.

8 So, we don't really have many options
9 but to estimate it in some way based on other studies.

10 Now, with that, we can go back to the
11 unweathered upper till at Site D.

12 DR. KINGHAM: Before you get into that
13 in any detail, could you remind us all of the significance
14 of the word "uncoupled" at the beginning of that
15 model?
16

17 THE WITNESS: Okay. Uncoupled. Uncoupled
18 with respect to this model means that contaminant
19 migration was only evaluated with respect to the upper
20 till itself. It was assumed that the contaminant
21 concentrations in the landfill were constant, constant
22 in time, and this unit was just considered individually.
23

24 Now, we will go through each one of
25 these units and consider them individually and likewise



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when we look at contaminant migration for the uncoupled model for the lower part of the lower till, we have ignored this for the moment and are just assuming that the contaminant input to the lower upper till was constant.

Now, that allows us to look at what the actual contaminant travel times are and to separate the effect of attenuation by adsorption from other effects which will come into play later when we actually couple these component models together. When we couple the component models together, the input we would use to the model for the lower part of the lower till will be the actual output from the overlying upper till model and then they will be linked or coupled together in the final analysis.

So, moving on to the unweathered upper till, this model simulation was performed using a groundwater velocity calculated from a hydraulic conductivity of 8×10^{-8} and a hydraulic gradient of .85 and an effective porosity of .25.

Now, in this case ...

DR. KINGHAM: I beg your pardon, could you repeat the numbers, you said the hydraulic gradient?



THE WITNESS: .85.

DR. KINGHAM: Will we find that in your exhibit?

THE WITNESS: Yes, Table 3-1, and with no leachate collection and the unweathered upper till and the hydraulic gradient is 'point'...

MR. HODGSON: It is probably easier to follow this on page 88 of H-39 and then you won't have to flip back and forth between exhibits.

DR. KINGHAM: I have found where he is now.

THE WITNESS: As I mentioned earlier, the hydraulic gradient of .85 reflects a mounding of approximately 6 metres within the landfill as a result of a large-scale failure of the leachate collection system. The thickness of the upper till was modelled as 4 metres, based on a typical thickness for the upper till underlying the landfill, a dispersivity of .2, which reflects 5 per cent of the actual travel distance, and the coefficient of molecular diffusion which basically in all these models is -- the effect of dispersion due to diffusion is relatively small because the groundwater velocities are reasonably high.

So, if we look at the curve, the



1 arrival curves for various non-adsorbed, weakly adsorbed
2 and moderately adsorbed contaminants migrating through
3 the unweathered upper till, we see there is not much difference
4 between a non-adsorbed contaminant such as chloride
5 and a weakly adsorbed contaminant such as diethyl-
6 ether or 1, 2 dichloroethane, and first arrivals for
7 a non-adsorbed or weakly adsorbed contaminant as shown
8 by the C over C_0 of .1 occurs something in the order
9 of 25 years.

10 Because the organic carbons...

11 MR. HODGSON: Q. What is the concentra-
12 tion of contaminant arriving at 25 years?
13

14 A. That is a relative concentration
15 of 10 per cent of the input from the landfill.

16 Q. The input here for chlorides
17 was how much?

18 A. Later on when we couple the
19 models together we will actually assign input values
20 for either chloride or a weakly adsorbed or moderately
21 adsorbed contaminant, and for chloride we assumed the
22 value of 1500 milligrams per litre representing
23 approximately the chloride concentration in the present
24 Burlington landfill leachate.
25



As you can see, because the organic carbon content of the unweathered upper till is reasonably high, there is a significant difference in the rate of migration between a weakly adsorbed organic contaminant and a moderately adsorbed organic contaminant due to adsorption on the till solid organic carbon, with first arrivals for a moderately adsorbed contaminant being something in the order of 225 years.

So, the moderately adsorbed contaminants are defined by an R value of 8.6 and basically moving at a rate 8.6 times lower than the rate of chloride migration.

Q. Then you are going to go down to the lower till?

A. That is correct. So, we did similar uncoupled models looking at each component separately for each of the other -- each of the other components in the various pathways beneath Site D. These are the results of the simulation of contaminant migration through the lower part of the lower till. Rather than going through all this separately, but quickly to indicate that travel times for a non-adsorbed contaminant or weakly adsorbed contaminant



are again fairly similar and are something in the order of approximately 25 years to first arrival through the three metre thickness of lower till, and again there is a considerable difference between the contaminant migration rate of a moderately adsorbed contaminant such as trichloroethylene or xylene and compared to chloride and a more weakly adsorbed contaminant with first arrivals being something in the order of 200 years

Q. Can you now talk about migration through the granular units?

A. Yes, we will now go to that. This overhead, which is from Figure 3-6 in Exhibit H-86 or Figure 11 in Exhibit H-39, shows the results of the contaminant migration simulation for the granular units at Site D. For the purposes of the contaminant transport modelling it was assumed that the upper granular unit was extensive throughout the site, through the site beneath the Site D landfill, and the granular units had the hydraulic conductivity of the upper granular unit, and that value is 8×10^{-3} centimetres per second, and that hydraulic conductivity being approximately 30 times higher than the measured hydraulic conductivity in the lower granular unit.



1 This assumes a groundwater velocity of
2 the most permeable unit of the two granular units that
3 existed in various areas of Site D. As you will see,
4 there is extremely little difference between the rate
5 of migration between a non-adsorbed contaminant like
6 chloride and a weakly adsorbed organic contaminant
7 because there is very little organic carbon in the actual
8 sand units. So in this case a weakly adsorbed
9 contaminant, chloride, travels at virtually the same rate
10 and in terms of contaminant migration in sand aquifers
11 at other landfill sites, this is completely consistent
12 with what is observed at landfills such as North Bay
13 and Woolwich, studied by the University of Waterloo.

15 Even a moderately adsorbed contaminant
16 which moves at a much slower rate through the clay
17 units overlying the granular units travels at a rate
18 quite similar to the non-adsorbed compounds because the
19 organic carbon content is reasonably low.

21 Q. Now, you have modelled migration
22 through the granular units on the basis that it was the
23 upper granular unit and you used the lower K value for
24 that unit, is that correct?

25 A. The higher K value, 8×10^{-3} .



Q. Do you recall on Exhibit M-162

1 Mr. Estrin suggested to Mr. Sobanski that in fact the
2 appropriate hydraulic conductivity for the upper granular
3 unit should be 1.2×10^{-2} ?

4 A. Yes, I recall that.

5 Q. Would you assume for the moment
6 that 1.2×10^{-2} is a more appropriate K value for the
7 upper granular unit; could you indicate to the Board
8 how that would effect the calculation you have done
9 on Figure 3-6?
10

11 A. The effect of using a higher value
12 for the hydraulic conductivity in this case will serve
13 to increase the groundwater velocity by a similar factor.
14 So rounding things off and going from 8×10^{-3} to $1.2 \times$
15 10^{-2} is approximately a factor of 2, a little less than
16 a factor of 2, and that would serve to decrease travel
17 times and would shift this curve to the left indicating
18 shorter -- faster travel rates and shorter travel
19 times and again this curve would tend to flatten out
20 a little bit and would probably give you a first
21 arrival of something in the order of between two and
22 three years compared to five or six years as shown in
23 Figure 3-6.
24
25



The arrival of a moderately adsorbed
contaminant would also increase by a proportional
amount, to increase the hydraulic conductivity that
was considered.

DR. KINGHAM: Just so the record is
clear, you said going from 8×10^{-3} to 1.2×10^{-2} is
an increase...

THE WITNESS: ...of almost two times.

MR. HODGSON: Q. Perhaps that could
be calculated.

A. One and a half.

DR. KINGHAM: Would it be a percentage?
I think we shouldn't take a great deal of time and it
should be fairly straightforward.

THE WITNESS: Yes. I guess it is 1.5
times. I don't think that would change my estimate of
the first arrival at between two and three years as
it would still be somewhat of that order.

MR. HODGSON: Q. Thank you. Very
briefly would you take us through the other calculations
you did, downward migration of contaminants through the
lower till to the bedrock and lateral migration through
the bedrock, and indicate briefly the results you got



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and assuming the methodology was similar?

1 A. The methodology was identical to
2 what was used in the other component models, and this
3 shows the results in Figure 3-7 of Exhibit H-86, or
4 Figure 12 in H-39, page 103.

5 Now, for the thickness of till beneath
6 the upper granular units of 12 metres, this shows
7 the migration through the lower part of the lower till.
8 As you can see, the arrival times or the travel times
9 through this relatively thick unit are rather long
10 compared to the travel times through the overlying
11 upper till, upper part of the lower till and the
12 granular units, first arrivals from the granular
13 units to the shale bedrock through this lower till
14 being something in the order of 250 years for a non-
15 adsorbed contaminant and considerably longer for an
16 adsorbed contaminant, because again in the lower till,
17 the organic carbon content is relatively high compared
18 to the granular units.

19 Because of these very long travel times,
20 both for non-adsorbed contaminants and adsorbed
21 contaminants, we felt that certainly in comparison to
22 this primary pathway through the upper till, the lower
23
24
25



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part of the lower till and through the granular units, we felt that the pathway downward through the lower part of the lower till is relatively minor or insignificant in comparison to this pathway through the granular units.

Just to be complete in terms of looking at the different component models, we also quickly looked at lateral migration through the shale for contaminants that had made their way down through the lower part of the lower till, although this would be several hundred years in the future.

This is groundwater velocity based on a hydraulic conductivity of 10^{-5} and a very low fracture porosity of .001, because this is migration through the fractured shale bedrock and this is the arrival curve for contaminants at the site boundary at a distance of 100 metres, and the travel times are something in the order of 10 years to move through that shale bedrock formation.

Now, in this case, as was the case for the fractured weathered upper till, we would fully expect matrix diffusion to have an effect on contaminant migration in this situation, and then our estimates



of travel times of approximately 10 years were considered to be quite conservative estimates of the travel times.

Q. Now, would you take us to the coupled models and indicate the distinction between the coupled and uncoupled models and could you briefly describe the results of those calculations?

A. After we looked at each of the component models individually and determined the pathway downward from the granular units through the lower part of the lower till appeared to be relatively insignificant due to the very long travel times in this area, we tried to then take into account the fact that contaminants emanating from the landfill will move down through the unweathered upper till, and that will result in an attenuation processes acting and contaminants which then arrive -- the contaminants or chemical concentrations that the lower till sees aren't a constant input as modelled in the individual component models, but the coupling of these models allows us to take the output for the -- or the arrival curves-- from, for example, the weathered upper till and to input them into the lower till, i.e., the concentrations that



appear at the top of the lower part of the lower till aren't going to appear instantaneously as we modelled the individual uncoupled models, but they will build up as contaminants actually make their way through the unweathered upper till.

Now, it is possible using the Ogata-Banks equation to fairly simply take into account changing input concentrations to the component model and basically how that is done is it is based on the principle of superpositions. If you take your input concentrations and discretize them into a set of different input functions...

Q. Is discretize a verb based on discrete?

A. Mathematicians use it as a verb but it may not be in the dictionary. For example, we consider the input into the lower part of the lower till from the unweathered upper till, and in this case we are not assuming the input into this component is constant, but we are assuming it varies with time. If we know how that concentration function varies with time, we can actually take that time concentration graph and basically break it up into a number of



different functions, and in this case-- we actually take that time concentration graph and basically break it up to a number of different functions and in this case we would take a function with a concentration of C1 and we would do the evaluation in the Ogata-Banks calculation based on the C1 calculation starting at T0.

We also evaluate the Ogata-Banks equation for a concentration function of C2 starting at T1 and at C3 starting at T2 and we would add those altogether, superimposing them in an appropriate manner starting at the appropriate times corresponding to how we have broken up the input function.

Now, that would allow us to simulate a build up of concentration with time at the input. To simulate the actual decline in concentration with time at the input, we could also calculate a function based on the concentration C4 starting at T3 and rather than adding it and superimposing it on to the previous function, we actually subtract the functions and likewise we would also do that for a function starting at T4 and with a concentration of C5.

Basically we are evaluating the Ogata-

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Banks equation for a variety of concentrations for a variety of time intervals and superimposing them in an appropriate manner to get a resultant model which reflects a changing input concentration. It probably sounds more complicated than it actually is.

Q. Now, which figure in the report is this?

A. This is Figure 3-9 in H-86 and because this was one of the intermediate steps in our evaluation of contaminant migration, it wasn't actually included in H-39, but just to illustrate the effect of linking these component models. Now, this shows the chloride concentration at the top of the granular units and that would be the concentration at this point, at the top of the granular unit or the bottom of the upper part of the lower till.

Q. Approximately 7 metres below the landfill?

A. That is correct. This model actually couples -- for a constant chloride input of 1500 milligrams per litre at the landfill, this couples contaminant migration through the unweathered upper till, it takes the results or the arrival curves from this component model, the upper -- the unweathered upper till component model and inputs it using the



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method of superposition to the lower position part of
the lower till component model and, as you can see,
the arrival curve looks quite similar in shape, it
is an S-shaped curve, and the actual first arrival
being somewhere in this range, somewhere around 60 years,

is not surprisingly the sum of the first arrival
times for the two component models. As you recall,
they were both in the range of 25 to 30 years. So when
we combine them together, the actual arrival time at the base
of the upper part of the lower till after we have
gone through these two components is the sum of the
arrival times of the other two.

DR. KINGHAM: Just so we are clear when
we review the record on this later, all of these curves
you have been discussing from Figures 3-2 to 3-9 are
based on constant contaminant input and that is on an
assumption of a failed or no leachate collection
system in operation?

THE WITNESS: That is correct.

DR. KINGHAM: They refer to this diagram?

THE WITNESS: That is right, an
assumption of no leachate collection and that the
concentration of contaminants in the leachate stays



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constant with time over the length of time of the
simulation, and that will lead me on to my next topic.

Now, looking at this curve in particular we have modelled the contaminant arrival over a period of 200 years. As Mr. Sobanski discussed in his testimony, and as described in our report, there is really no expectation or no reasonable way to expect the concentrations in the landfill to remain constant over that time period and based on information compiled by Mr. Sobanski in Exhibit H-179, and also shown in M-159, there is certainly reason -- from the examination of landfills of various ages in North America there is reason to expect the chloride concentration in a leachate to decline with time and the rate of that decline to be measured over a period of tens of years.

MR. HODGSON: Q. Perhaps you could move on to the coupled model, coupled with declining chloride concentrations to give your conclusions as to the migration times through these various units?

A. I want to make one more comment on this graph before I leave it. Based on a constant input concentration from the landfill, constant with time, you can readily imagine that eventually the input



concentrations of the landfill are going to be found at whatever distance one would like to model, given a sufficient period of time. Due to the effect of retardation and dispersion, you are going to get an S-shaped curve and this S-shaped arrival curve may occur at some great distance into the future, but as long as you have a constant input at your source, sooner or later you will get those same concentrations out at the site boundary or out whatever distance one is trying to assess contaminant migration.

So, as Mr. Sobanski described in his earlier testimony, and this is from Figure 3-11 in H-86, Figure 15, page 110 in H-39, but this shows the declining chloride concentrations in landfill leachate that we have projected to occur based on observations that I believe -- Mr. Sobanski I think compiled information for 15 or 16 different landfills and primarily in Ontario, but also in some other jurisdictions.

This would suggest then that there is a decline in chloride concentrations in the leachate with time and there is a reasonably significant decline over a period of from 20 to 40 years.

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Unfortunately we don't have similar information for trace organics-- volatile organic chemicals in leachates because we have not been studying them for that many years and there are many municipal landfills where those types of chemicals have not even been analyzed for.

So, we were not able to put together an empirical or observational type graph of the decline such as this for volatile organics, but in some ways we can imagine that a similar decline might be expected. The decline in chloride is mainly reasoned to occur because of the leaching of chloride from the refuse itself, and with time the actual amount of chloride remaining in the garbage declines and the concentrations in the resultant leachate also declines, and those leaching-type processes will also effect or will act on volatile organics that happen to be in the leachate or in the refuse.

There are, however, other processes which will not act on inorganics like chloride, but will act on volatile organic chemicals and these processes being biodegradation and biotransformation reactions, but also volatilization into landfill gases



and possibly released to the atmosphere via gas venting systems.

Based on the additional processes that might act on volatile organics, one can imagine that a decline in organics similar to chloride might not be too unreasonable to assume and in some cases maybe one would even expect it is more rapid than chloride, but unfortunately we have no actual information on those rates of decline.

The only exception to that type of estimate would be the case where pure non-aqueous phase chemical liquids were disposed of in the municipal landfill, and those very concentrated sources of liquid chemicals might disrupt this type of decay curve or declining concentration curve for the volatile organics.

So, looking at this curve, you will see there is a significant decline in concentration over a period of tens of years, and in a situation such as at Site D where we have travel times that are also measured in tens of years, you can imagine that this peak concentration that is initially observed in the landfill leachate will be significantly altered by the



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long period of travel through these zones. If you use the principle of superposition and take into account this declining input at the landfill, one can also look then at these component models and these models coupled together to look at the actual resultant concentrations, for instance, at the base of the granular units or in the granular units at the site boundary, taking into account the decline in concentration of the landfill and the effect of coupling each of these models.

Before I actually go on to this pathway we should quickly look at lateral migration through the weathered upper till again, and taking into account a declining source concentration in the landfill. This is Figure 3-12 from H-86 which shows the chloride concentration at the site boundary for migration through the weathered upper till, given the declining chloride concentrations which I just showed in the previous overhead.

Because the travel times through the weathered upper till are reasonably short in comparison to declining concentrations of the source, one sees a fairly high peak chloride concentration at a time



something in the order of 15 years and this peak is a very significant proportion of the peak input concentration initially in the landfill. Because the travel times are short, the initial high levels in the landfill are reflected to a significant degree at the site boundary for this particular pathway, laterally through that to the weathered upper till.

Q. As a hydrogeologist do you regard this as a pathway of concern?

A. Whether this pathway is of concern or not I think depends a great deal on the actual design of the landfill site itself. I am not completely familiar with the landfill design, but it would certainly be my opinion that there are fairly simple engineering things that could be done to cut off this pathway. Because this pathway reflects groundwater flow and contaminant transport primarily through fissures and cracks in the weathered upper till, it would certainly be my opinion that either through excavation or re-compaction of the sides of the landfill, or the installation of some kind of granular drain alongside of the landfill, this pathway can quite effectively be cut off, even in the event there was mounding in the landfill.



Q. Could I ask you to go to your

1 calculation of coupling the models and incorporating
2 declining inputs through the upper till, the lower till
3 and the lateral migration through the granular units
4 to the site boundary?
5

6 A. For the various things I have
7 been describing this morning with respect to coupling
8 these models together and taking into account a declining
9 concentration in the landfill, I would just like to
10 show three overheads which illustrate the contaminant
11 concentrations at the site boundary in the granular units
12 as a result of the coupling of these models and the
13 declining source concentrations.
14

15 This is Figure 3-21 from H-86. This
16 shows the chloride concentrations at the site boundary
17 and, as you can see, the peak concentration, peak
18 chloride concentration occurs at a time, at approximate-
19 ly 110 or 100 to 110 years, which would correspond
20 reasonably well -- it is actually slightly longer than
21 the sum of the travel times for each of the component
22 models. The peak chloride concentration is approximate-
23 ly 300 to 350 milligrams per litre, a reduction by a
24 factor of approximately 5 from the peak chloride
25



concentrations input into the landfill at the beginning of the simulation.

We did a similar coupled model simulation for a weakly adsorbed organic contaminant, and a weakly adsorbed contaminant moving somewhat slower than chlorides through the till units but at approximately the same rate as chlorides through the granular units.

As you can see ...

Q. Which figure is this?

A. This is figure -- actually this isn't a figure in H-39, this is Figure 3-22 in H-86.

Q. What are the inputs on this figure, what is the contaminant input?

A. Identical inputs compared to Figure 3-21 with the exception that a weakly adsorbed contaminant was considered.

Q. You are using 1000 parts?

A. A weakly adsorbed contaminant was considered at an input concentration of 1000 micrograms per litre, reflecting approximately the concentrations of many of the volatile organic chemicals which presently occur in Burlington landfill leachate.

Now, if you recall back to the chloride



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graph which I just showed, the peak concentration of a weakly adsorbed contaminant arrives at something in the order of 120 to 130 years, which is slightly slower than the chloride arrival due to adsorption of these compounds, and the peak concentration is something in the order of 200, approximately 200 micrograms per litre, which is proportionally somewhat lower than the chloride peak mainly due to the effect of that adsorption.

The effect of the adsorption will tend to lengthen the travel times that the peak appears and it will also tend to flatten the peak out and the actual areas under the curves will be comparable, but the shape of the curve changes slightly.

We also ran a similar model for weakly adsorbed contaminants with a different input concentration.

Q. Why is that?

A. Mainly because we used an input concentration of 200 micrograms per litre for a volatile weakly adsorbed organic in 1986 because we weren't particularly sure why such high concentrations were evident in the Burlington landfill, and they would actually



1 be higher than one would normally expect in a typical
2 municipal landfill.

3 So, we also ran the model at an input
4 concentration of 200 micrograms per litre, and it is
5 basically the same form of curve, but the values on the "X"
6 axis are slightly different reflecting the different
7 concentrations, but the arrival times are the same.

8 Q. What were the maximum concentrations?

9 A. Approximately 40 micrograms per
10 litre at the site boundary.

11 Q. That completes the calculations
12 you did at Site D?

13 A. Yes.

14 Q. Have you a copy of Exhibit M-162?

15 A. M-162, yes. Yes, I have M-162.

16 Q. On M-162 Mr. Estrin put to
17 Mr. Sobanski a suggestion that the total travel time
18 through the upper granular unit to the lower granular
19 unit -- sorry -- to the upper granular unit and through
20 the upper granular unit to the site boundary was 10 years.
21 Can you comment on that suggestion?
22

23 A. Nine years actually.

24 Q. I have from the upper -- the time to
25



reach the upper granular unit, the maximum was approximately nine years?

A. Yes, I see that.

Q. And in fact eight years using a different head in the landfill, and you see that in the middle of the page?

A. I see that.

Q. Then the maximum travel time through the upper granular unit was 2.4 years, so the total of 8 and 2.4 is approximately ten years, and I think that's the fastest time calculated on M-162.

A. Yes.

Q. Could you comment to the Board on your view of that travel time in relation to the travel times that you calculated using your coupled model?

A. Well, that travel time is obviously shorter by a factor of approximately 10, the results of the coupled model being approximately 100 years or 110 years, I don't recall exactly, and these being in the order of slightly less than ten years.

Q. Do you accept this calculation on M-162 as being within the range of believability?

A. No, I would not actually. The



1 primary reason being for not agreeing with that estimate
2 lies in the hydraulic conductivity, I believe, of the
3 unweathered upper till and the assumptions made by
4 Mr. Estrin on those calculations.

5 I think, as explained by Mr. Sobanski,
6 the value of 8×10^{-8} centimetres per second reflects
7 the measurements that were conducted in terms of rising
8 head tests or Hvorslev tests in that upper till unit
9 and are reasonably consistent with the estimated
10 groundwater velocity based on the penetration of
11 tritium in the nest of tritium wells, and I can't actually
12 recall the number of that nest at the present time.
13

14 So, the combination of the actual
15 measurements in the upper weathered till and the
16 consistency with the tritium results and the fact that
17 there is no tritium found in the upper granular unit
18 at two different sites -- two different locations
19 at Site D -- would certainly suggest to me that travel
20 times, at least through the upper till unit, are
21 considerably longer than 10 years.
22

23 Q. Based on your work at Site D,
24 have you an opinion as to the suitability of Site D
25 for landfilling?



A. Yes, I do.

Q. Would you give it to us?

A. Well, based on the result of my evaluation of contaminant migration at Site D, it would be apparent to me that for the conditions where the hydraulic trap was in operation, there is very little potential for contaminant migration leaving the landfill site and penetrating downward into the lower granular units. The effective diffusion ...

Q. You said the lower granular units, or is it the granular units?

A. The granular units, excuse me. Diffusion will result in some degree of contaminant movement downward through the unweathered upper till and basically through the unweathered upper till, but based on our simulation of diffusion against the upward flow of groundwater when the hydraulic trap is in operation, I don't feel that the contaminants will actually make it through to the underlying granular units.

So, to summarize that fairly long sentence, in the case where the hydraulic trap is in operation, I don't expect there to be any impact on the



underlying granular units beneath Site D.

1 Now, for the situation where there is
2 no leachate collection system in operation and there
3 is mounding of leachate within the landfill, there would
4 appear to be a definite potential for the movement of
5 leachate out of the landfill, through the unweathered
6 upper till, through the upper part of the lower till and
7 into the granular units and I would believe that the
8 travel times for contaminant migration along that
9 pathway would be measured in tens of years, being in
10 the range of 50 to 60 years.
11

12 At that time the impact on the granular
13 units at the site boundary with respect to chloride
14 would result in an additional chloride loading of
15 several hundred milligrams per litre, which would be
16 combined with the existing several hundred milligrams
17 of chloride in the groundwater in the granular units,
18 and that would increase chloride concentrations in that
19 unit to be greater than the Ministry of the Environment
20 drinking water criteria.
21

22 Likewise, the concentrations of volatile
23 organic chemicals that might be found, or that could be
24 found in the granular units as a result of the leakage
25



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of leachate from the landfill would also -- could also be in the range of several tens, possibly one or two hundred micrograms per litre and, depending on the chemicals, they may also exceed whatever drinking water standards the MOE might feel appropriate to adopt from other jurisdictions.

Q. Now, you modelled your estimates of contaminant migration through the granular units on the basis of the K value of the upper granular unit as received from Mr. Sobanski?

A. That is correct.

Q. Mr. Estrin put to Mr. Sobanski a suggestion that perhaps the upper granular unit wasn't there or wasn't a significant pathway and in that case the pathway of concern would become the lower granular unit. If you were to redo your modelling, your coupled model based upon the K value of the lower granular unit, and taking the lower granular unit as the significant pathway, what effect would that have on your estimates of travel times and quantities of contaminants which would reach the site boundary?

A. If one assumed that the hydraulic conductivity of the granular units as modelled had the



value of the lower granular unit, and I will just go back to my notes here to remind myself precisely what that value was, and as identified by Trow Hydrology Consultants in their field studies, they determined that the hydraulic conductivity of the upper granular unit was the highest at 8×10^{-3} and the lower granular unit was 3×10^{-4} , approximately 30 times lower.

The result of assuming that lower hydraulic conductivity would reduce the groundwater velocities by the same factor of 30 times and would result in travel times from the edge of the landfill to the site boundary...

Q. The edge?

A. The edge of the landfill to the site boundary, a distance of 100 metres, being measured in tens of years rather than in the several years that were modelled in this case.

Q. In the lower granular unit?

A. That is correct.

Q. What would that do to the total coupled model? Can you assist the Board as to whether or not the concentrations at the site boundary and the time of arrival at the site boundary would be



longer?

1 A. It would be considerably longer,
2 in the range of likely 30 to 50 years.

3 DR. KINGHAM: Are you understanding the
4 question clearly in terms of total coupled model through
5 the upper till , the lower till to the lower granular
6 unit and then to the site boundary?
7

8 THE WITNESS: Yes.

9 DR. KINGHAM: That was Mr. Hodgson's
10 question. Your answer is?

11 THE WITNESS: That would add between
12 30 and 50 years to the total travel time, which was
13 approximately 100 to 120 years.
14

15 MR. HODGSON: Q. Would there be any
16 effect, assuming the declining concentrations you have
17 assumed in your coupled model, what would be the effect
18 on the level of concentrations of contaminants reaching
19 the site boundary?
20

21 A. That would also serve to reduce
22 the peak concentrations. I can't precisely tell you
23 how much they would reduce the concentrations, but
24 rather than peak chloride concentrations of 300 to 350,
25 I would expect they would be somewhat less than 300,



probably in the 250 to 300 range, and with a decline
1 in the peak concentrations of the volatile organics being
2 in a similar proportion.

3 Q. To put that in simpler terms;
4 much longer travel time results in somewhat greater
5 attenuation?

6 A. Yes, that is correct.

7
8 MR. HODGSON: If you are planning to take
9 a morning break, Mr. Chairman, this would be a convenient
10 time.

11 DR. KINGHAM: We were, but to clarify
12 you brought into play Exhibit M-162 in putting questions
13 to Mr. Feenstra about time to reach the upper granular
14 unit, but I don't recall, is that time to reach ground-
15 water or contaminants in groundwater? Does anyone
16 recall? It doesn't say on the exhibit.

17
18 MR. HODGSON: What is the distinction:
19 between groundwater and contaminants in groundwater?

20 DR. KINGHAM: Exhibit M-162 just says
21 time to reach upper granular unit and it brings into
22 play the number you used, the 10 years, and I don't
23 know whether that is time for groundwater to reach or
24 the time for contaminants to reach?
25



THE WITNESS: I believe in this case

1 there needn't be a distinction between the two because
2 flow is primarily through the inter-granular pore space,
3 and a non-reactive contaminants like chloride should
4 be moving at the groundwater velocity.

5 DR. KINGHAM: Thank you very much.

6 We will take a break for 15 minutes and then plan to
7 go through to one after the break.

8 ---Recess
9

10 DR. KINGHAM: Thank you, please be
11 seated.

12 MR. HODGSON: Q. Mr. Feenstra, I
13 wanted to ask you some questions about Site F and sites
14 adjacent to Site F, but first I want to ask you to review
15 for the Board or advise the Board as to the documents
16 relating to Site F that you reviewed, Site F and
17 environs which you reviewed prior to attending today
18 to give your evidence on that subject?

19 A. There were quite a variety of
20 reports which I had the opportunity to review regarding
21 the Bayview and Burlington landfill sites prior to today,
22 the first being the master's thesis prepared by
23 Miss Hewetson, Exhibit E-214, the report by Pollutec
24
25



on the leachate treatability and toxicology, Exhibit H-43, the plume delineation study at the Burlington landfill conducted by Gartner Lee Limited, Exhibit H-83, and a report on the Bayview landfill by Conestoga-Rovers which, I understand, has not been exhibit at this stage.

Q. What did you make use of from that report?

A. The leachate analyses, leachate composition, and I believe the data has already been provided on several previous exhibits, I believe N-196.

Q. Thank you. First of all I would like to turn your attention to the existing Burlington landfill site and ask you if you could assist this Board as to what is known about contaminant transport in groundwater at the Burlington landfill?

A. Okay. The first thing I would like to discuss with respect to the Burlington landfill is again to look at the chemical composition of the leachate, and I have a slightly different table here than we presented previously and this is Table 1 from my witness statement, Exhibit H-86A.

There is a variety of information that



exists on the chemical composition of the Burlington and the Bayview landfill leachate. As you will recall, the concentrations of a variety of volatile organic chemicals in the Burlington leachate, a variety were identified by Pollutec in their sampling of October 1985, and these concentrations being in the range of approximately 50 micrograms per litre for trichlorofluoromethane, 222 for tetrachloroethylene, 1400 micrograms per litre for 1, 1, 1-trichloroethane and as high as 2967 for 1, 2 - dichloroethane and 4216 for 1, 1-dichloroethylene, and I think by anyone's standards these concentrations are relatively high for the municipal landfill leachate.

There are other aromatic volatile organics, benzene, ethylbenzene, toluene, xylene in concentrations ranging from several hundred micrograms per litre up to over 5000 micrograms per litre for xylene.

Gartner Lee on behalf of the Region also collected leachate samples from the same location as Pollutec on a variety of occasions between April 1984 and May 1986, and this table shows the minimum concentrations and maximum concentrations identified at that time and the mean concentration in the far



right-hand column of the table. What struck me firstly is the comparison between the Gartner Lee results and the Pollutec results. I understand that all the samples for analysis conducted by Gartner Lee were performed by the Ministry of the Environment laboratories in Rexdale. It is also my understanding that many of these or several of these samples were stored for quite a considerable period of time before they were actually analyzed. The samples collected in December of 1985 were stored for approximately two months before analysis occurred.

The U.S. EPA has a criterion of a maximum storage time of two weeks for water samples intended for the analysis of volatile organic chemicals, and that may be part of the reason why the Gartner Lee results are somewhat lower than the Pollutec results, due to losses during storage, storage in sample containers.

The Pollutec samples were collected and analyzed within 48-hours, I believe, and consequently it is my opinion that we should view the Pollutec results as more reliable results.

From this table it is also apparent that



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there is a significant difference between the leachate composition at the existing Burlington site and samples of leachate collected by Conestoga-Rovers and Pollutec at the Bayview landfill.

Of particular note at Bayview is that there doesn't seem to be any significant concentrations of the chlorinated volatile organics except for dichlorobenzene and chlorobenzene, but there doesn't seem to be any significant level of 1, 1-dichloroethylene, 1,2-dichloroethane, no 1,1,1-trichloroethane. We should keep these concentrations in mind when we are actually evaluating the past influences of contaminant migration at the Bayview and Burlington sites.

Now, Gartner Lee has been conducting an annual groundwater monitoring program at the Burlington site since, I believe, 1981 and as a result of these ongoing studies it has been possible to conclude that the use of general inorganic chemical parameters such as chloride, sulphate and hardness, parameters such as that which are normally good indicators of groundwater contamination by landfill leachate aren't really appropriate for indicators in this type of environment, mainly because of the variable and often very high concentrations



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of these compounds occurring naturally in the ground-water and the shale bedrock, and I think that this is a point that was presented in earlier testimony.

Likewise, there are other general indicators of organic contamination such as the analysis of total phenolics, total or dissolved organic carbon or chemical oxygen demand, which likewise are not applicable for use as indicators in this situation, this situation being the shale environment of the Burlington and Bayview landfills, because of naturally-occurring and quite variable concentrations of these compounds in the shale -- groundwater and the bedrock.

During the late part of 1985, and as reported--excuse me, the latter part of 1986--groundwater samples were collected by Gartner Lee from a series of specially-designed groundwater monitoring wells as part of a plume delineation study conducted for the Region of Halton at the Burlington landfill.

These specially-designed monitors consisted of stainless steel monitoring wells that were pre-cleaned by the manufacturer to remove--with the intention of removing any residual cutting fluids or oils or greases that may have been on the pipes during the



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manufacturing and machine procedures. These stainless steel wells were installed down-gradient of the landfill and one nest of wells was installed up-gradient of the landfill, and it was the intention to provide stainless steel wells for monitoring so that representative groundwater samples could be collected for the analysis of volatile organic chemicals, and that was the intention of the plume delineation study, and the results of the organic analyses conducted by Gartner Lee in their plume delineation work were earlier presented in an exhibit which I believe was numbered N-193, and I may refer to those later, but just to summarize those results, the Gartner Lee monitoring results, I would refer you to a table on page 12 of my witness statement.

This briefly summarizes what concentrations of volatile organics were found in the 1986 monitoring by Gartner Lee, 1, 1, 1-trichloroethane was found in a variety of the wells at the Burlington site and it was identified at low concentrations, less than 5 micrograms per litre, in two of the up-gradient wells, these are wells up-gradient from the landfill which were considered not to be influenced by leachate from the landfill and the chloride concentrations in these



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wells is less than 10 which would certainly support the conclusion that these wells actually do represent background conditions.

1, 1, 1-trichloroethane was also found in several of the wells down-gradient of the Burlington site, at GLA-24, the shallow well, well 3, 25 metres down-gradient from the landfill and where there are small concentrations of 1, 1, 1-trichloroethane. It was also detected near Highway 403 in GLA-26 and 27. Because of the distribution of the 1, 1, 1-trichloroethane in these monitors occurring at low concentrations and also occurring in the up-gradient wells, it was concluded by Gartner Lee that these concentrations reflected not chemicals derived from the landfill but chemicals derived from some type of extraneous contamination, either associated with the monitoring wells themselves or the sampling equipment used to collect the samples, or the sample containers that were used to store the samples.

Two other compounds were identified in 1986 by Gartner Lee, these being trichloroethylene and tetrachloroethylene, and these occurred in the shallow well GLA-24 immediately down-gradient of the



Burlington landfill. This well also had 1, 1, 1-trichloroethane which was concluded to have come from some other source. The trichloroethylene and the tetrachloroethylene at the well nearest the landfill was concluded by Gartner Lee to represent chemicals derived from the landfill itself and, based on the concentrations that were found ranging from non-detectable to 9 micrograms per litre, and recognizing that the concentrations in the leachate were up to several hundred micrograms per litre for these compounds, it was reasoned that these results indicated a significant degree of attenuation of these volatile organics on movement through the shale formations at Burlington.

Now, based on this information and the information available at this time, I would concur with those conclusions and the fact that on the basis of this information it would appear that the 1, 1, 1-trichloroethane is due to some other source as yet unidentified related to the actual well installation/ sample collection and at that time the presence of these two compounds in the well immediately down-gradient of the landfill suggested some movement of volatile organics from the Burlington landfill itself.



Q. Is 1, 1, 1-trichloroethane in

1 common use?

2 A. Yes, it is. It is probably the
3 most common solvent used for cold metal cleaning
4 and cold degreasing. It is also a solvent in a great
5 many adhesives and in other compounds like liquid paper,
6 it is in very large use. I believe it is produced in
7 the United States in quantities of hundreds of millions
8 of pounds per year. It is a very common use solvent.
9

10 Q. You have completed your analysis
11 of that portion of the Gartner Lee monitoring data?

12 A. Actually there is one other thing
13 I should point out with respect to this information. As
14 I noted before, the leachate samples that were collected
15 by Gartner Lee were analyzed by the Ontario Ministry of
16 the Environment laboratories and, with respect to these
17 groundwater samples, they were also analyzed by the
18 Ministry of the Environment, and for this particular
19 set, as reported in Gartner Lee's report, Exhibit H-
20 83, the samples for volatile analyses were stored for
21 approximately two months before analysis took place,
22 and it was my concern, based on that long storage time, that
23 it was possible that these results were actually some-
24
25



what lower than the actual concentrations that may have existed in the sample, and mainly due to losses from the containers which have a teflon and silicone rubber cap which allows some degree of diffusion for long storage times, diffusion out of the samples.

It is my concern that in the well immediately down-gradient from the landfill which did have trichloroethylene and tetrochloroethylene, these concentrations were higher than actually determined. It is not actually possible to estimate how much higher they might have been, but I believe that a factor of ten might be possible.

Likewise in some of the down-gradient wells maybe there were some low concentrations of volatile organics that were not detected because of losses due to the long storage time of the samples. That was the key concern I had with respect to deriving conclusions from this data.

Now, despite that concern or uncertainty, it is possible to conclude that there are not significant or high concentrations of volatile organics in the groundwater down-gradient of the Burlington landfill, concentrations in the range found in the



landfill leachates themselves. In other words, there is no concentrated leachate that exists in the shale bedrock beneath the Burlington site.

Q. What does that mean in terms of attenuation?

A. That means that certainly in the down-gradient well 25 metres away from the landfill, the landfill has been in operation since 1972 and we certainly would have expected some degree of contaminant migration towards that location. The fact that we only see very low concentrations of a few micrograms per litre or possibly a few tenths of micrograms per litre suggests a reasonable amount of attenuation capability in the weathered shale, particularly the weathered upper shale.

Q. Now, since you prepared your witness statement, which is dated the 4th October, 1987, have you received any new monitoring information from Gartner Lee?

A. Yes, I have.

MR. HODGSON: Mr. Chairman, we have the chemistry data that came to us at the end of Friday last week and it is the results, as I understand it, of the



1 latest sampling conducted by Gartner Lee for the
2 purposes of preparing their annual monitoring report
3 on Burlington. It came to our attention that it was
4 available and we felt compelled to give it to this
5 witness and make it available to the other parties
6 at this hearing and we did so this week. I want to
7 now make it available to the Board.

8 DR. KINGHAM: The annual reporting data
9 for the existing landfills done by Gartner Lee.

10 MR. HODGSON: This is the chemical
11 analysis of the samples taken in preparation for the
12 monitoring report for 1987.

13 Q. Mr. Feenstra, when did you receive--
14 perhaps we should mark this as an exhibit?

15 DR. KINGHAM: H-246.

16 MR. ESTRIN: Could we describe it?

17 MR. HODGSON: H-246 is Burlington
18 Landfill 1987 Monitoring Chemistry Data.

19
20
21 ---EXHIBIT NO. H-246: Burlington Landfill 1987
22 Monitoring Chemistry Data

23 MR. ESTRIN: Mr. Chairman, on my sheet the
24 main heading is cut off and it doesn't say Gartner Lee
25 and at the bottom it says Mann Testing Laboratories Ltd.,



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and there are six sheets and is this what it consists of?

1 DR. KINGHAM: That's what my copy has
2 as well.

3 MR. HODGSON: Q. When did you receive
4 a copy of H-246?

5 A. This past Saturday night.

6 Q. Have you had an opportunity to
7 consider this data in the context of the work you had
8 previously done with respect to data accumulated on
9 contaminant hydrogeochemistry at the existing Burlington
10 landfill?
11

12 A. I have had a chance to briefly
13 evaluate this data, yes.

14 Q. Now, perhaps before you tell us
15 anything about your conclusions as to what this data
16 means, perhaps you could describe for the Board what
17 they have in H-246 and where the samples came from and
18 how they were taken, when they were taken and then
19 describe the results briefly, if you would.
20

21 A. Was this H-246?

22 Q. Yes.

23 A. I didn't write that down. Well,
24 it is my understanding from discussions with Gartner Lee
25



Limited that these samples were collected on September --
submitted to Mann Testing on September 15 of this year,
being collected several days prior to September 15,
and from the existing stainless steel monitoring wells
at the Burlington landfill site and from three stainless
steel wells and one PVC well installed by Hydrology
Consultants, Hydrology Consultants' well nest HC15.

Q. The pages are numbered in this
document.

A. Can you correct me, is that page 5?

Q. HC-15 appears on page 5 of H-246.

A. Right. Thank you very much.

In addition to the existing or the stainless steel
wells installed by Gartner Lee in 1986 and the Hydrology
Consultants cluster of wells, there were, I believe, six
additional stainless steel monitoring wells installed
by Gartner Lee, one nest of three wells on the southwest
corner -- southeast corner, down-gradient of the landfill,
and two additional shallow monitoring wells on the
western margin of the Burlington landfill.

It is my understanding that these samples
were all collected using a Waterra ...

Q. Perhaps I could stop you there.



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We have in evidence Exhibit H-83, Gartner Lee's plume delineation study for 1986, and it has on it a map showing the wells that existed at the time of the preparation of H-83. Could you indicate to the Board, either on this map or on the map -- I think it would be more appropriate if you took this map from H-83 and marked on it the location of Gartner Lee's two new nests of monitoring wells. This is Map 2. Could you describe the map?

A. This is Figure 1 called the Site Plan for the Plume Delineation Program, which I assume is from the Gartner Lee report.

MR. HODGSON: Perhaps we should have that map marked as H-83-1.

DR. KINGHAM: Very well.

---EXHIBIT NO. H-83-1: Figure 1 - Site Plan for Plume Delineation Program

MR. HODGSON: We will have the witness mark in red on H-83-1 the location of these new monitoring wells.

Q. For the record, Mr. Feenstra, the nests of wells marked on Exhibit H-246 are identified on H-246 as 32, and they are located approximately near



the weigh scales on the existing Burlington landfill?

1 A. I beleive that that is correct.

2 Q. Could you describe for the record
3 where 33 and 34 are located?

4 A. 33 and 34 -- let me check the
5 scale on this map. 33 is located approximately 50
6 metres from the western edge of the Burlington landfill,
7 and I am not quite sure how to describe its longitudinal
8 location.
9

10 Q. I don't think the longitudinal
11 location matters because it is on the map, but what I
12 really want you to describe for the record is what is
13 the nature of the terrain, and you can give the
14 approximate distance from the road that goes up the
15 left side of the Burlington landfill site, but what is
16 the nature of the terrain where 33 and 34 are located?
17

18 A. Both locations seems to be down
19 in the valley or ravine of what I believe is Falcon
20 Creek, downhill from the landfill.

21 Q. Can you locate 33 in relation to
22 SW-15?
23

24 A. It is immediately adjacent to
25 SW-15 which, I understand, is a surface water sampling



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location.

1 Q. All right. Would you then please
2 advise the Board, first of all, as to how to read
3 Exhibit H-246 and then would you help us interpret the
4 results as identified on H-246?

5 A. H-246 is the table of results
6 provided to Gartner Lee Limited by Mann Testing Labora-
7 tories. Mann Testing is the private analytical labora-
8 tory who performed these analyses for Gartner Lee. If
9 you recall the dates these samples were submitted, on
10 September 15, and the analyses reported this past Friday,
11 approximately three weeks later, it is my understanding
12 these samples were actually analyzed within or very
13 close to the two week maximum holding period suggested
14 by the U.S. EPA for samples intended for the analysis
15 of volatile organics.

16 Looking at page 1 on Exhibit H-246, it
17 shows a list of volatile compounds that were analyzed
18 for and the next column -- this list includes all the
19 chemicals -- included within this list are all the
20 volatile organic chemicals that have been previously
21 identified or would have been previously identified
22 in the Bayview or Burlington landfill leachates.
23
24
25



The column immediately to the right of the list of volatile compounds is the detection limits in parts per billion which is the same thing as micrograms per litre, and the detection limits are ranging from .5 micrograms per litre for benzene, toluene, xylene, to one microgram per litre for most of the compounds up as high as 2 micrograms per litre for some of the more volatile compounds like vinyl chloride and chloroethane which are at the top of the list.

In the column immediately adjacent to the detection limits is a column labelled TB which refers to a trip blank. That is a sample of organic free water from Mann Testing Laboratories that was placed into the same type of container used for storage of all the groundwater samples and that sample was prepared in Mann's Laboratory, sealed in the laboratory and was transported to the field, to the Burlington landfill and the sampling locations with all the other sample containers. It remained sealed and was returned back to the laboratory in that condition and was then analyzed. The intention of a trip blank is to identify any contamination, extraneous contamination that may have been introduced to the groundwater samples during actual sample's



transport.

1

DR. KINGHAM: Did you say trip or trick?

2

THE WITNESS: Trip, trip blank.

3

DR. KINGHAM: I wondered.

4

MR. HODGSON: It may turn out to be both.

5

THE WITNESS: I won't comment on that.

6

7

MR. HODGSON: Q. While you are stopped

8

for a second, could you help us where under trip blank

9

we find three TR designations and TR at the bottom of the

10

page equals trace amount detected. Now, let's take

11

benzene, the detection limit is .5 and then it shows

12

beside that on a trip blank a trace amount was detected

13

and is the trace amount less than .5?

14

15

A. Less than .5. It was a peak

16

identified in the chromatogram, but it was less than

17

.5 and it was determined by the analyst that they

18

couldn't quantify the actual amount, but it was less

19

than .5.

20

Q. Please continue.

21

22

A. So, looking at the results of the

23

analysis of the trip blank, the column labelled TB,

24

you will see there were traces of dichloromethane, which

25

is the same synonym for methylene chloride, chloroform



at 1.74 micrograms per litre, a trace of benzene and a trace of toluene and this suggests then that these compounds may have either been associated with the glassware, in the sample containers used to collect -- used for this trip blank or the groundwater samples, or it may have been introduced to the samples during transport.

To find chloroform in a trip blank is fairly unusual. Chloroform was not actually identified in any of the landfill leachates at Bayview or Burlington. The remaining columns on Table 1 illustrate the results of the analyses from Gartner Lee well No. 23, which is the up-gradient well, the well located north of the Burlington landfill, and it shows the results for wells 1, 2 and 3, I understand 1 being the deepest and 3 being the most shallow groundwater monitor.

We can see in these wells, particularly in the shallow well, 23-1, that there are low concentrations of 1, 1, 1-trichloroethane, dichloromethane, chloroform, benzene a trace of toluene.

Q. How does that compare with what was found in 1986 as shown on your table?

A. In 1986, in 23-3, nothing was found,



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nothing was detected. In 23-2 and 23-1 there were traces of dichloromethane and traces of toluene, and in 23-1 there was 2.24 micrograms per litre of trichloroethane and that is in the deep well. That is in the same range as what was found in 1986, and in 23-1 trichloroethane was detected at 1 to 2 micrograms per litre.

So, aside from the detection at this point of dichloromethane and benzene, these results are similar to what was found at GLA-23 in 1986.

The chloroform which is identified in GLA-23-3 is approximately the same level as what was detected in the trip blank and so it is possible, I think it is fairly safe to conclude that the chloroform results in 23-3 and in some of the subsequent samples we will look at, are likely derived from some sort of trip-induced contamination rather than derived from the actual groundwater.

Q. Could you describe the results as reported on Exhibit H-246 and compare them to what was found in 1986 as shown in the figure from page 12 of the witness statement?

A. For the wells down-gradient?



Q. Yes. Referring first of all to

well No. 24 where amounts were found in 1986.

A. In well GLA-24 there were no volatile organics detected in wells 1 or 2, but low levels of 1, 1, 1-trichloroethane was detected in 24-3 and in the 1987 results, as indicated on page 2 of the exhibit. we are considering now, H-246, there are concentrations of trichloroethane ranging from 2.7 at 24-1 to 3.7, approximately 3.7, in 24-3.

There is also concentrations of dichloromethane ranging from 1.5 at 24-1 to 2.7 in 24-2. Here again the concentrations of 1, 1, 1-trichloroethane, certainly in 24-3 that were detected in 1986 are consistent with those detected in 1987, although some additional compounds were also detected in 1987 at that particular location.

You can do a similar comparison for GLA-26 where some small concentrations of 1, 1, 1-trichloroethane was detected in 1986, and again trichloroethane was detected in all three wells at that location in concentrations ranging from 3 to 5.4 parts per billion, or micrograms per litre, and again dichlormethane and, in this case, some dichloroethylene, 1, 1-dichloro-



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ethylene, were also detected in this well.

1 DR. KINGHAM: Just so we understand
2 clearly, if they don't appear on your witness statement,
3 page 12, what you are showing us on the wall, then there
4 was none detected in those years?

5 THE WITNESS: That is correct, yes.

6 MR. HODGSON: We have looked carefully
7 a wells 23 and 24. Could you just summarize the results
8 that were found on H-246 for the other wells tested
9 by Gartner Lee?
10

11 A. In general, concentrations of 1, 1,
12 1-trichloroethane ranging from -- in some cases they were
13 non-detected, but up to approximately 6.8 micrograms per
14 litre were detected in most of the remaining wells.
15 In some of the remaining wells, some other constituents
16 such as 1, 1-dichloroethylene and dichloromethane
17 were also detected, but with only a few exceptions,
18 those exceptions being two of the wells at HC15,
19 1, 1, 1-trichloroethane was detected in the majority
20 of the wells, both up-gradient and down-gradient of the
21 landfill.
22

23 Q. What, in your opinion, should be
24 concluded from the results as reported on H-246?
25



A. In my opinion the distribution of

1 contaminants or volatile organics identified by
2 Gartner Lee in the 1987 sampling, the pattern being
3 that low levels, less than approximately 5 micrograms
4 per litre, occur in wells both up-gradient and down-
5 gradient of the landfill and one compound in particular,
6 trichloroethane, it seems to occur in the majority of
7 the wells. It would be my conclusion that rather than
8 these chemicals reflecting actual groundwater concentra-
9 tions, that they reflect some degree of extraneous
10 contamination from either the well installations or
11 the sampling equipment that was used in the collection
12 of these three groundwater samples.
13

14 Now, the sampling equipment would
15 be the tubing used and the pumps themselves or the
16 sample containers.
17

18 Q. Could you explain fully to the
19 Board why it is you have that opinion?

20 A. The principal reasons for that
21 opinion are that the levels are low and the possibility
22 of contamination from extraneous sources at those
23 levels is really quite high and the fact that the
24 chemicals are found in the up-gradient wells, actually
25



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even in the shallow and the deep up-gradient wells --

particularly in the shallow and the deep wells --

there is no particular pattern to the

levels of concentrations, that is in the monitoring wells

down-gradient of the landfill, the concentrations in the

wells nearest to the landfill are in no way higher than

the concentrations detected at 300 or 600 or 700 metres

downgradient, which would not be the case or which

would not be expected if in fact these chemicals were

landfill - derived.

Q. What would you expect if they were
landfill-derived?

A. I would expect there to be higher
concentrations close to the landfill, particularly
because the concentrations identified at the present
time in the Burlington landfill leachate are very much
higher than the concentrations that we see in the
groundwater, and I would expect to see lower concentrations
at some distance from the landfill itself.

Q. Now, in addition to what it is
that was found on H-246, there is also some distinction
on what was found in H-246 and what was found in H-83,



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1 the 1986 plume delineation study. Can I take you back
2 now to your figure from page 12. Trichloroethylene
3 and tetrachloroethylene were found in GL-24-3 in 1986
4 and you have already told us in your evidence that
5 you concurred in Gartner Lee's conclusion that the
6 finding of those substances suggests migration of
7 leachate through the shale to that monitor at that
8 time?

9 A. That is right.

10 Q. How does H-246 affect your
11 previous conclusion in that regard?

12 A. Well, the results shown in H-246
13 indicate that trichloroethylene and tetrachloroethylene
14 were not detected in GLA-24 or any other well for that
15 matter, and that would tend to suggest that possibly
16 the identification of trichloroethylene and tetrachloro-
17 ethylene in the 1986 sampling was in some way spurious,
18 possibly as a result of some kind of sampling-induced
19 contamination.
20

21 There is one other conclusion I would
22 actually like to make based on the results in H-246,
23 and that was relating back to my concern from the 1986
24 sampling where I suggested that possibly the concentrations
25



1 of some of these volatile organics, particularly in
2 GLA-24, and maybe in some of the other wells down-
3 gradient, may in fact have been higher because of the
4 very long storage times of the samples.

5 In the 1986 samples, they were analyzed
6 within the recommended storage time.

7 Q. 1987?

8 A. Sorry, excuse me. The 1987
9 samples were analyzed within the recommended two week
10 holding time and although there are low levels of
11 various chemicals in various wells, nowhere are there
12 significantly higher concentrations, concentrations
13 in tens of micrograms per litre or even hundreds of
14 micrograms per litre anywhere, which would suggest
15 to me that even though the source of the chemicals
16 identified in 1987 can't be precisely determined,
17 I think it is quite reasonable to conclude that
18 particularly at the wells close to the landfill there
19 is no evidence of significant contaminant migration of
20 these chemicals from the landfill itself. The
21 concentrations are considerably lower than the concentra-
22 tions we see in the landfill leachate at Burlington.

23
24
25 Q. Then taking together the data from



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1986 and the data from 1987 as reported in H-83 and H-246, what is your conclusion as to the extent of contaminant migration from the Burlington landfill site?

A. My conclusion would be that there has been no significant migration of volatile organic chemicals from the Burlington site.

Q. All right. Notwithstanding that conclusion, I want you to assume that in fact the substances detected on H-246 are in fact substances that are landfill-derived. If that were the case, you told us it is your opinion that that is not the case, but if it were the case, what conclusion would you draw from that as to the nature and extent of contaminant migration from Burlington?

A. If we considered or assumed that the concentrations reported in H-246 reflected actual groundwater concentrations, then I think we would have to assume that the leachate that originated from the landfill has actually influenced really quite a large volume of groundwater surrounding the site down-gradient and, if one believes these numbers, up-gradient also.

However, the concentrations -- that would suggest reasonably high groundwater flow rates and



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what the evidence shows is that there is a very significant degree of attenuation from the concentrations observed in the landfill leachate and the concentrations observed in the groundwater.

Although you have asked me to make that assumption, I find it difficult to make the assumption that these values are correct.

Q. "These values" being from H-246?

A. The values in H-246, because at the present time I couldn't envision any kind of attenuation mechanism that would allow a very significant reduction of concentrations in the landfill leachate as it passed into the groundwater system and no further reduction in concentrations many hundreds of metres down-gradient. I can't envision what kind of mechanism could cause that kind of attenuation.

Q. Now, going back to your original conclusion as to the nature and extent of contaminant migration from Burlington, what in your opinion, or what is your opinion of the characteristics of Burlington as a landfill site?

A. Based on the information at the present time, it would certainly suggest that the shale underlying the Burlington landfill has a significant



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capacity or capability of attenuating leachate

1 constituents when these constituents migrate through the
2 subsurface.

3 Q. Thank you. Now, Mr. Feenstra,
4 I want to take you to the Bayview landfill, and I want
5 to ask you the same question; what is known about
6 contaminant transportation in the groundwater at the
7 Bayview landfill?
8

9 A. The majority or the bulk of the
10 information with regard to groundwater quality and
11 contaminant migration at the Bayview site is derived
12 from work done by the University of Waterloo, I believe
13 of the period approximately 1982 to 1984. During the
14 course of this work a variety of people were involved,
15 and these investigators being Professor Cherry, Dr.
16 Cherry of the University of Waterloo, Jim Pankow of the
17 Oregon Graduate Centre in Beavertown, Oregon and the work
18 conducted at the Bayview site ultimately culminated
19 in the preparation of a Master's thesis by Miss Hewetson
20 on hydrogeology and contaminant migration through
21 the shale at the Bayview site, which I believe is
22 Exhibit E-214.
23

24 Q. That is correct.
25



A. The purpose of the research done

1 by the University of Waterloo at Bayview was to investi-
2 gate the general hydrogeologic conditions in the fractured
3 shale at the Bayview site which involved evaluating the
4 hydraulic conductivity, hydraulic head relationships,
5 groundwater velocities, and groundwater samples were
6 also collected from a variety of installations to
7 evaluate contaminant migration at the site.
8

9 During the course of the research at
10 Bayview, two new techniques or fairly novel techniques
11 were used as part of the study. The first novel
12 technique was the use of multi-level piezometers called
13 the Waterloo multi-level -- actually called the Waterloo
14 multi-level piezometers at this stage -- which were
15 installed in the Bayview site, and I believe the second
16 example of their use after it being conceived and
17 developed in the early 1980's.
18

19 In earlier discussions, earlier testimony
20 by Mr. Sobanski, these wells were referred to as the
21 WAT series wells, the W-A-T wells, and we will discuss
22 those in a little more detail later. A second method
23 or technique that was new or novel that was applied
24 in the research done at Bayview relates to the actual
25



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collection of the groundwater samples and in the collection of samples from both the large diameter Morrison Beatty wells and the Waterloo multi-level wells, a technique which involved the actual capture or adsorption of the volatile chemicals present in the groundwater on basically absorbent tubes which were lowered down the borehole; that method was employed to actually collect the samples for analysis rather than recovering groundwater samples and transferring them to a container and bringing the container back to the laboratory for analysis.

The down the hole sampling device I believe is referred to as the ATD method, which refers to adsorption, thermal desorption and these tubes contain absorbent material called Tenax and I believe there is some granular activated carbon in there as well, and these cartridges are lowered into the borehole below the groundwater level and groundwater is allowed to pass through the tubes and any volatile organic chemicals present in the groundwater are adsorbed onto the Tenax and retained on that absorbent material.

The tube itself is removed, it is capped in a very small tube and it is transported to the



laboratory for analysis. In the laboratory the actual organic chemicals are thermally desorbed by heating up the tubes and allowing the desorbed volatiles to enter into a gas chromatograph for analysis, and this method is quite a novel method and actually has not been used in many cases since and I believe it was the first of its kind at the time, but it allowed extremely low detection limits, very low detection limits were capable using this method. The nominal detection limits for most of the compounds identified was something in the .001 microgram per litre range, which is extremely low.

At the time of the Waterloo work in 1982 and 1983, if one had collected a groundwater sample and sent it to a commercial laboratory your detection limit would have been 10 micrograms per litre, so the sensitivity of the method that was used was several orders of magnitude lower than what standard practice was at that time.

During the course of the University of Waterloo work, approximately 35 piezometers were sampled, this being a combination of the conventional Morrison Beatty wells that were installed in I believe 1980 and 1981 and several of the Waterloo multi-level wells.

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Virtually all the samples were collected in either duplicate or triplicate, which is actually very unusual for a groundwater study.

On page 14 of my witness statement I have made a brief summary of the results of the UW research and a variety of compounds were analyzed for, and I didn't mention but I should probably note that the analyses were actually performed by Dr. Pankow and his associates at the Oregon Graduate Centre and he was responsible for the analytical procedures and, to some degree, was responsible for certainly the quality control and development of the analytical procedures.

In the thesis presented by Miss Hewetson, which is Exhibit E-214, the presence of three particular compounds in the groundwater was evaluated and these compounds were 1, 1-trichloroethane...

Q. 1, 1, 1-trichloroethane?

A. 1, 1, 1- quite correct, trichloroethane, chlorobenzene and 1, 4-dichlorobenzene, which is the chemical jargon for the paradichlorobenzene referred to a little earlier in testimony at this hearing. There were a variety of other compounds also



1 identified in the samples at that time and identified
2 by Dr. Pankow, particularly benzene, toluene, ethyle-
3 benzene, trichloroethylene, tetrachloroethylene and
4 1, 2-dichlorobenzene. Dr. Pankow provided the analytical
5 results to Miss Hewetson for her thesis work and it
6 was his interpretation at that time that benzene,
7 toluene and ethylbenzene were probably derived from
8 naturally-occurring compounds in the groundwater in
9 the shale.

10 Q. What did that cause him to do?

11 A. Not to send her the data -- to
12 suggest not using this data in terms of interpretation
13 of contaminant migration from the landfill.

14 Q. Have you more data than she did?

15 A. There is considerably more data
16 at the present time which allows us to evaluate this
17 information than existed in 1983 and 1984, and that is
18 consisting of the landfill leachate analyses, the
19 Gartner Lee monitoring and the analyses done by
20 Hydrology Consultants in HC15 and HC9. There is
21 a considerably larger body of information available now
22 than there was at the time that this work was prepared.

23 Q. With respect to the information



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collected by the University of Waterloo -- when was it,
1983, or '84?

A. Yes.

Q. Is there more information available
now than there was available at one time. Did you
receive new information?

A. Yes, I did actually. As a result
of the research that was done at Bayview, several papers
were prepared, two papers which described the analytical--
the sampling and analysis techniques that were used at
the Bayview site, and those were published in the
Journal of Groundwater in, I believe, 1984 or 1985 and
another recent paper which was published in the Journal
of Contaminant Hydrology which compared contamination
at the Bayview site with a comparable site with
fractured porous materials in Oregon. As a result of
my -- I did read Miss Hewetson's thesis and acknowledge
the discussion of these three compounds, but it wasn't
until the summer when I was reviewing the analytical
papers by Dr. Pankow and his various co-authors that
I noted that other compounds were also detected and
this was in a discussion of the actual detection limits.
and-- basically detection limits I guess was what was



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being discussed. I had not quite recognized that
these compounds were also detected.

Q. "These compounds" being benzene?

A. Benzene, toluene, ethyl benzene
and a few of these other chemicals like trichloroethylene.
I contacted Dr. Pankow and spoke to him about it and
got him to send me all the data and I received that
data on September 17th of this year.

Q. Did you make that data available
to other parties in this proceeding?

A. At the time I received it the
data was included in a letter addressed to Dr. Cherry
and copied to Miss Hewetson, so I gave Miss Hewetson
a copy when I received the original information and it
was also my understanding that John Petrie from
Conestoga-Rovers had previously requested the data
from Dr. Cherry and for a variety of reasons he did
not actually get it, so I gave him a copy immediately
also.

The total of the information from the
Bayview site that I got from Dr. Pankow is included in
my Table No. 2 in my witness statement.

Q. What did you conclude from all of



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this data that had been collected from the University of Waterloo?

A. I would first like to describe the overall results of the analyses. This shows the table of the various compounds that were detected in I believe it was close to 100, approximately 100 ground-water samples collected from the 35 wells and, as I mentioned, most of them were in duplicate or in triplicate, and concentrations from most of the compounds ranged from non-detectable, which is something less than a very very small number due to the sensitivity of the analysis, to levels of 29, a maximum of 29 micrograms per litre for trichloroethylene, 13.6 for chlorobenzene, 1.57 for 1,4-dichlorobenzene, 24 for benzene, 133 for toluene and 7.7 for ethylbenzene and a variety of others.

The mean concentrations or the geometric mean for these concentrations is considerably lower than the maximum and in the final column of this table I indicate the respective drinking water standards for most of these chemicals. As I mentioned once before, I believe, the Ontario Ministry of the Environment doesn't have drinking water standards -- I don't believe they have for any volatile organic chemicals of these



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classes, and so I went to the literature and got information on drinking water standards from the U.S. EPA and from the New York State Department of Environmental Conservation. Even if you compare the maximum concentrations identified for any of these constituent compounds with, I believe, one or two exceptions, the concentrations are less than their respective drinking water standards.

The only cases where the results exceed drinking water standards are for benzene in the four intervals in WAT 4, for toluene in one instance in Morrison Beatty 17-2 and for tetrachloroethylene on only one occasion in MB-15-3.

In my discussion of the chemical contaminants in my witness statement I mentioned that trichloroethylene, tetrachloroethylene and 1, 2-dichlorobenzene, although detected in some cases, suffer from some deficiencies. The analytical results were not reproduceable and there were cases where triplicate analyses for tetrachloroethylene, for example, showed a non-detected, a measurable value but less than the maximum blank value, and a value of 3.7.

Q. What is a triplicate?



A. Repeated samples taken at the same

1 time. So, in theory they should give quite comparable
2 results. The fact that one of the samples gave quite
3 a significant number and the others were non-detected
4 would suggest that possibly the chemical was derived
5 from some other source other than the actual groundwater
6 samples. For those reasons, given that the concentrations
7 were all quite low and quite sporadic, they are not
8 particularly reproduceable and Dr. Pankow concluded
9 that trichloroethylene, tetrachloroethylene and 1, 2-
10 dichlorobenzene probably don't reflect actual ground-
11 water concentrations in any way and are a result of
12 some other type of extraneous contamination, and I would
13 concur with that conclusion.
14

15 Now, based on this information and
16 the variety of other information that was described,
17 the monitoring at Burlington in the groundwater, the
18 sampling and analysis of volatile organics conducted
19 by Trow Hydrology Consultants, the analyses of landfill
20 leachates, I took a very careful look at these results
21 and I did come to a conclusion with respect to these
22 analyses and my conclusion is that these results in
23 my opinion most likely reflect, or most likely do not
24
25



reflect actual groundwater concentrations and are likely due to extraneous contamination from the monitoring well installations and I would like to just go over a variety of points to support that conclusion.

Q. Please do.

A. I am actually going to go through things in the same order that I presented them in my witness statement, so if people would like to follow along they can turn to page 15 and I can go through these point by point.

The first point I would like to make is that the Waterloo multi-level piezometers which were installed in, I believe it was 1983 and it might have been 1982, I can't recall exactly, but in the Morrison Beatty wells installed prior to that were constructed of PVC pipe, plastic pipe, with solvent-welded couplings and the pipe was not cleaned prior to use in the sampling installations.

At the time those piezometers were installed it was generally not common practice to do that, not common practice in terms of hydrogeological investigations. There were not many investigators ...

Q. Do you mean to clean the pipe?



A. To clean the pipe, that is right.

1 There were very few investigators who were actually
2 evaluting the presence of low levels of organic
3 chemicals in groundwater at that time and it was
4 certainly not common practice to take those precautions.
5 I am quite sure that the installations installed by
6 Morrison Beatty in the early 1980's were never intended
7 for use for specifically sampling for levels of organic
8 contaminants, and I am also quite sure that that was the
9 case for the University of Waterloo multi-level piezo-
10 meters.
11

12 Since that time it has become evident
13 in a variety of cases that there is significant
14 potential for contamination of groundwater samples from
15 pipe that is not cleaned prior to use and from the
16 use of solvent-welded joints where the sections of
17 PCV pipe are joined together in the monitoring install-
18 ations.
19

20 In the Waterloo multi-level piezometers
21 that were installed and as noted in Miss Hewetson's
22 thesis on page 7, there were significant leakages
23 detected between the different sampling intervals and
24 that, I believe, was reflected by the fact that the water
25



levels measured in the sampling tubes within the Waterloo piezometers all showed the same level which I assume also reflected the level of the water inside the monitoring installation.

Those leakages were in fact corrected by filling up the inside of the monitoring well casing with a thick bentonite grout, as explained in the thesis, but given the fact that only small quantities of water were flushed from the sampling intervals prior to sampling and the fact that you can't really move a lot of water from many of the shale horizons, the likelihood that the water from the inside of the casing that leaked out into the formation initially may not have been entirely flushed out, there is a good possibility that there was water introduced into the formation and into the intervals sampled for groundwater analyses later, and that may have been contaminated by materials on the inside of the well installation.

The benzene and toluene and ethylbenzene that were detected in the shale bedrock may have represented or may represent chemicals that occur naturally in the shale. It is certainly my experience.



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having analyzed water samples from the lower part of the Lockport formation, which is the cap rock on the Niagara Escarpment, and the underlying Rochester shale, which is a similar shale to the Queenston shale we are dealing with at Bayview, that you can detect or can identify concentrations of benzene, toluene and ethylbenzene up to concentrations of approximately 10 micrograms per litre.

So the fact that these compounds may occur in shale is reasonably well known. Unfortunately none of these chemicals -- the concentrations identified in the shale bedrock here aren't unreasonable and this 133 micrograms per litre is rather high, but that may not even be out of the realm of possibility for naturally-occurring chemicals.

Unfortunately none of these other compounds were detected at particularly significant levels in the Gartner Lee monitoring wells in 1986, or in 1987 for that matter, at the Burlington site or in the Trow monitoring well HC15 which was sampled in 1986 and again in 1987, HC15 being located on the south side of Highway 403 approximately -- I believe that's about 800 metres, between 600 and 700 metres from the



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Burlington landfill.

1 Q. You are now referring to Figure 5?

2 A. Figure 2.

3 Q. Figure 2 from H-40?

4 A. H-40. Similarly, referring to the
5 same figure, Figure 2 from H-40, there was no benzene,
6 toluene or ethylbenzene detected in Trow Hydrology
7 Consultants' well HC9, which is immediately adjacent
8 to the Morrison Beatty well 18, and in the Morrison
9 Beatty 18 well location it detected concentrations of
10 toluene at 7 and approximately 22 micrograms per litre
11 were detected in the UW study and no concentrations
12 were actually detected in HC9 which, although the
13 well was of PCV construction, was constructed with
14 threaded joints, it was cleaned first and there were
15 no solvent-welded joints in that installation.
16
17

18 Probably one of the most significant
19 points related to my conclusion that these concentrations
20 reflect or are artifacts of the sampling installations
21 rather than reflecting actual groundwater concentrations
22 is the occurrence of many of these chemicals which
23 were identified in the subsurface in the background
24 monitoring wells, these background monitoring wells
25



being MB-5, which is located right here on the proposed Site F between the Burlington and Bayview landfills, Morrison Beatty 14, which is not actually marked on this map and which is right in this area here, I believe, and that is actually shown -- I will find it in a moment, but it is on a figure in E-215.

Q. On page 24?

A. 24?

Q. OW14.

A. Yes and which would put it approximately in this area right here (indicating), again between the Burlington landfill and the Bayview landfill. The other background installation or the groundwater monitoring installation which was used to evaluate background concentrations is the multi-level WAT-2 which was installed at the north end of the Bayview landfill.

The overhead I am now showing you is from page 16 of my witness statement, Exhibit H-86A, and it illustrates the chemical compositions identified in the four background wells, the two Morrison Beatty wells and the two intervals from WAT-2. As you can see, 1, 1, 1-trichloroethane was detected at MB-14 WAT-2-3



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and WAT-2-7 and the concentrations ranging from 3 to 5 micrograms per litre and there was no 1, 1, 1-trichloroethane detected in MB-5, however. There was no chlorobenzene detected in any of the background wells. There was 1, 4-dichlorobenzene detected in all four background wells, ranging from .0004 up to .22 micrograms per litre. There was toluene detected at all four background monitoring wells, ranging from .35 micrograms per litre up to 4.2 micrograms per litre.

It was on this basis, the fact that the background concentrations of many of these chemicals-- I forgot to mention benzene also occurs in two of the background monitoring wells. The occurrence of the chemicals that were identified down-gradient also occurring up-gradient and in the background monitoring wells suggested that the chemicals themselves were not in fact landfill-derived.

There are several other points relating to the occurrence of these chemicals in the groundwater down-gradient of the site. Trichloroethane was one of the most commonly encountered, commonly identified chemicals in the various sampling installations down-gradient of Bayview, and in an analysis of landfill



leachate from six wells installed by Hydrology Consultants

1 and Conestoga-Rovers, no 1, 1, 1-trichloroethane was
2 ever detected in the present-day landfill leachate and
3 likewise none of the common degradation products of
4 1, 1, 1-trichloroethane were detected in the groundwater
5 detected in the leachate at the Bayview Park landfill.
6

7 Q. What are the common degradation
8 products of 1, 1, 1-trichloroethane?

9 A. 1,1-dichloroethane and 1, 1-
10 dichloroethylene, chloroethane and vinyl chloride and
11 likewise, along a similar line, although 1, 1, 1-tri-
12 chloroethane was identified in the groundwater samples
13 south of the Bayview site and down-gradient of the
14 Bayview site in the shale, none of the common degradation
15 products that one would expect to be present are
16 present either. It is just trichloroethane.
17

18 So, based on the preceding discussion
19 of various points and various evidence, I came to the
20 conclusion that either most or possibly all of the
21 concentrations of volatile organic chemicals that were
22 identified in the UW study do not reflect the ground-
23 water concentrations and are likely the result of
24 extraneous contamination from the piezometer
25



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installations.

1 Now, unfortunately when you have a
2 level of contamination effecting your groundwater
3 samples and you have determined that, what you can't
4 separate out are any actual concentrations. What
5 you can conclusively say is that there are no real
6 groundwater concentrations which would exceed any of
7 those values. Incorporated into some of these
8 concentrations there may be a reflection of naturally-
9 occurring benzene, toluene and ethylbenzene, and that is
10 possible, although we did not find much over at the
11 Burlington landfill site it still can't be ruled out.
12 and likewise in the monitoring wells close to the
13 Bayview site there may be an influence of leachate
14 migration through the shale, but it would be at levels
15 lower than those detected and we are just not sure how
16 low because of the effect of extraneous contamination.

17 Q. What then is your final conclusion
18 as to the extent of contaminant migration from Bayview?
19 Is it occurring?

20 A. My conclusion for the Bayview
21 landfill is similar to my conclusion for the Burlington
22 landfill; in my opinion there doesn't appear to be
23
24
25



significant groundwater contamination emanating from the Bayview site.

Q. Have you an opinion as to the characteristics of the Bayview site for a landfill?

A. Based on the age of the Bayview site and the calculations of groundwater flow rates, groundwater flow velocities, one would certainly have expected to see a degree of contamination, particularly in the weathered moderately fractured shale that reasonably shallow depths. The fact we don't actually see that or the fact that these concentrations occur at very low levels suggests that the shale environment has a good capability for attenuating contaminant migration.

MR. HODGSON: I am changing subjects now, Mr. Chairman, and this would be a convenient time.

DR. KINGHAM: I think this would be a convenient time to break for lunch. We will resume at two o'clock.

MS. CRONK: Just before you rise, if I could address the Board on one matter and I have alerted my friends, my friend Mr. Hodgson on this, and this may not be a difficulty but it may so I am bringing



to your attention. As Mr. Feenstra pointed out,
1 some of the information contained in his witness state-
2 ment derives from data obtained from Dr. Pankow and he
3 has now given evidence on that and he indicated that
4 it was set out or provided to him in the form of a
5 letter that Dr. Pankow had written and he provided it
6 to others who were affected by it.
7

8 I have through the witness statement
9 and my colleagues have most of the information because
10 it is set out in the witness statement and we have had
11 that since the witness statement was produced a couple
12 of weeks ago, but since that time my clients' experts have
13 been trying to reconcile those numbers in some respects
14 with the numbers which appears in the thesis and we
15 were unable to do that. I learned this morning that that
16 is because of some information in the letter which was
17 not provided to us that we didn't have. I have it now,
18 I got it at the break this morning, so I am presented
19 with the difficulty that the data is under review and
20 I raise it frankly because there may not be sufficient
21 time between now and the time I am reached in the order
22 of cross-examination for us to complete reviewing that
23 data. If that is the case, I will regretfully ask to be
24
25



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stood down until Monday morning to do my cross-examination and as the Board I think knows from remarks already made this morning, certain other information, the Gartner Lee results were only recently provided to the Region's counsel and we got them yesterday morning. So again we have the same problem and it may be it won't present any difficulty in cross-examination, but I wouldn't want to confront you with that as you expected us to rise.

DR. KINGHAM: Thank you for alerting us to that and we appreciate the difficulty.

MR. HODGSON: I anticipate that it will probably take until the afternoon break to finish this evidence-in-chief so there won't be a lengthy period of time for cross-examination and I assume my friends will find some areas for cross-examination that will be fruitful but won't touch on the issues they now find themselves having the problem with.

MS. CRONK: That may or may not be so.

MR. ESTRIN: I have also indicated to Mr. Hodgson that I would like to have a copy of the paper the witness said he reviewed and commented on and which he gave evidence about, the Sarnia results,



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before I cross-examine on that topic and if that could
be provided say at the lunch break it would certainly
facilitate things and if I can't be I will have to
leave that part of my cross-examination until that has
been provided.

DR. KINGHAM: Is it possible?

THE WITNESS: Yes.

DR. KINGHAM: Any other observations?

MR. HODGSON: Mr. Chairman, could
we let this topic of the paper sit until after lunch so
I can discuss the matter with both Mr. Feenstra and
my friends ? If we can't reach an agreement then that
will be brought to your attention and someone will seek
the appropriate ruling at that point.

DR. KINGHAM: Yes, I think that would
be sufficient.

---Luncheon Adjournment at 12:47 p.m.

---Upon resuming at 2:00 p.m.

DR. KINGHAM: Thank you, please be
seated. We couldn't help but notice how many counsel
were slaving away over lunchtime while we were enjoying
our lunch. Maybe that augers well for progress this
afternoon.



MR. HODGSON: I guess that means I should
sit down right now and let cross-examination begin on
the assumption that they are all ready.

MS. CRONK: You will waste a lot of
money on that.

MR. LANCASTER: I rather expect it will
stretch into Monday.

MR. HODGSON: What Monday of what month?

MR. LANCASTER: I won't say that.

MR. HODGSON: Two things. No. 1 is
with respect to the draft paper referred to in evidence
this morning by Mr. Feenstra and the request for it
just before the break, I am trying to sort that out
with my friends so we can find a mutually-acceptable
way of dealing with it and I hope to do that over the
weekend and, if not, then on Monday somebody will bring
it to your attention. I think it has been laid to rest
for the moment.

The other thing is that Ms. Cronk has
asked that the letter from Dr. Pankow at the Oregon
Graduate Centre to Dr. Cherry incorporating all of
this data having to do with the Waterloo University
studies at Bayview which has been referred to in



evidence, it is available and she would like to have it made an exhibit and she would also like to have this witness explain the differences between the way the data is reported in this letter and the way it is reported in the witness statement and in fairness I am happy to do that.

I don't think there will be any objection to that. If this could be the next exhibit, a letter from Dr. Pankow to Dr. Cherry dated the 1st of March, 1984.

DR. KINGHAM: That will be H-247.

---EXHIBIT NO. H-247: Letter from Dr. Pankow to Dr. Cherry dated March 1, 1984

MR. HODGSON: Q. Could I just ask you, Mr. Feenstra, if you could assist Ms. Cronk and my other friends as to how the other data is reported in -- I am sorry, what was the number?

DR. KINGHAM: H-247.

MR. HODGSON: Q. How the data is reported in H-247 and how that is similar or different to the way in which you have reported the data. Perhaps we could number the pages.

DR. KINGHAM: Including the letter?



MR. HODGSON: Including the letter.

1 There was a problem with this at one time because it
2 was photocopied and a page was missing and it was
3 distributed to some parties with the page missing and
4 my copy has seven pages.

5 Q. Do I understand that is the complete
6 document, Mr. Feenstra, H-247?
7

8 DR. KINGHAM: Let's make sure we have
9 the pages numbered in the same order. The third page
10 would start with the number in the upper left under the
11 heading CART being No. 455 and I wonder if you want to
12 do it that way. Is there any order to those numbers
13 or does it matter?
14

15 THE WITNESS: No, I don't think there
16 is any particular order.

17 DR. KINGHAM: Page 3 will be the page
18 with the 455 in the upper left column. Page 4 will be
19 the page with 431 in the upper left column; page
20 number 5 will be the one with 420 in the upper left
21 column and page 6 is the last page with the short four
22 lines of data on it.
23

24 MR. LANCASTER: Do you have a seventh
25 page, Mr. Hodgson?



1 MR. HODGSON: That was a mistake. I
2 am just learning to count. I actually only have 6.

3 DR. KINGHAM: We all have the same
4 six pages.

5 MR. HODGSON: Q. Could you help the
6 Board as to what use you made of the data in Exhibit
7 H-247?

8 A. Okay. In Exhibit H-247, for example,
9 we can all look at page 3 or the first page of the
10 tables. On that table you will see a column labelled
11 CART which refers to the cartridge number, the absorbent
12 cartridge that was used for collecting the volatiles
13 from the groundwater samples for analysis, and VOL is
14 the volume of water actually passed through the
15 cartridge and then there is a well identifier in the
16 next column and then the results of the various
17 volatile organic chemicals identified in each of the
18 cartridge samples.
19

20 When I received this information, that
21 is the information in Exhibit H-247 from Dr. Pankow,
22 I transcribed that information on to my computer and
23 I sorted the information as shown in Table 2 of my
24 witness statement, and that is Table 2 that follows page
25



13 in my witness statement. So, I sorted the various results from the duplicate and triplicate samples of the monitoring wells and all the blank analyses and put them into what now forms Table 2.

On the first page of Table 2 in my witness statement all the blanks are shown together and a maximum blank concentration reported at the bottom of the column of results. Likewise all the results from the Morrison Beatty wells are listed together on the bottom part of the first page of my Table 2 and the top part of the next page and all the WAT multi-level piezometer results are also grouped together, not necessarily sorted in an efficient way, I didn't sort it out quite as well as I wanted to on my computer, but at least all the Morrison Beatty wells are together and all the WAT wells are together and all the blank concentration values are together.

DR KINGHAM: Are the OW observation wells Morrison Beatty wells?

THE WITNESS: Yes, that is correct. OW was the designation I believe Morrison Beatty used in the initial investigations of the site and since then there have been such a number of different

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investigators working at various sites, people have denoted a prefix either MB or HC or GLA indicating who actually installed the wells.

In the assessment that Dr. Pankow undertook to determine which of the chemical results were analytically significant, it involved looking at the concentrations measured in the blank cartridges and to do that, as reported in the paper which he published in the Journal of Ground Water in December of 1985, he described how he determined what the minimum detectable limit was for each of the compounds based on the blank analyses.

The method he used he assumed the concentrations results were normally distributed, he calculated a mean value for the blanks for each compound and then on the basis of, I believe, three standard deviations greater than the mean, determined what the maximum detectable limit was for each of the different chemicals.

It was on that basis I believe that he determined which of the analytical results from the monitoring wells were significant from an analytical pointview and a statistical viewpoint.



1 The statistics that Dr. Pankow performed
2 were based on the assumption that the data, the blank
3 concentration values were normally distributed, and that
4 is an assumption that is usually made in most statistical
5 analysis of real data. Unfortunately when you plot
6 a histogram of the blank samples, they are not normally
7 distributed and they appear to be very close to being
8 log normal distributed which is not your symmetric,
9 is not a symmetric bell curve but a curve which is
10 skewed with a peak to the left towards the low values
11 with proportionally a higher number of higher values
12 considerably above the mean.

14 I didn't really want to go into a
15 statistical re-evaluation of that information, so I
16 felt it would be an appropriate assumption and a appropriately
17 conservative assumption to consider the lower technical
18 limits for the chemicals to be the maximum blank
19 concentration analyzed, and that maximum concentration
20 is shown on my Table 2.

22 With that in mind, everywhere on Table 2
23 you see the designation LTB which stands for less than
24 blank, when the results were transmitted in Dr. Pankow's
25 letter, H-247, where they were less than the maximum



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blank value, I reported that as LTB and that should
account for any differences one would see between
my Table 2 in my witness statement and the table in
Dr. Pankow's letter.

Q. Mr. Feenstra, do you know when
these samples that are reported on H-247 were taken?

A. I would have to look that up. I
can't recall offhand.

Q. Perhaps you could look that up
and tell us after the break?

A. I could determine that from E-214,
if you really need to know.

Q. Sure.

A. Yes. I believe the analyses
reported in Dr. Pankow's letter were what is referred
to as the tube and cartridge method, and that sampling
was undertaken in November of 1983 as indicated on page
36 of Miss Hewetson's thesis. This letter from
Dr. Pankow to Dr. Cherry is dated March 1, 1984 and
summarizing the results of that sampling and analysis.

Q. Finally, Mr. Feenstra, turning
again to H-247, page 4, in the middle -- right in the
middle of the left-hand column under CART, halfway down
the page, we find the equivalent of a paragraph that begins



with the 415P?

1 A. Yes.

2 Q. Two columns over we have -- sorry,
3 the next line is 681S and what do P and S stand for?

4 A. Okay. I am sorry I didn't explain
5 that. For several of the samples the sampling procedure
6 involved connecting two sampling cartridges together
7 and going down the hole for collection of the sample,
8 so there would be a primary absorbent cartridge
9 designated by a P connected to a secondary absorbent
10 cartridge designated by the letter S for those samples,
11 and I believe that was done on four or five sampling
12 locations. The purpose was to look at the efficiency
13 which the primary cartridge could actually remove
14 volatile organics and both cartridges were analyzed
15 and it was the expectation that the majority or
16 virtually all of the organics should be absorbed to
17 the primary cartridge, but then the secondary cartridge
18 was analyzed just to determine whether there was
19 actually a breakthrough or migration of volatiles
20 through the primary cartridge that weren't absorbed
21 at that time.

22 I might point out on Table 2 I only
23
24
25



showed the reports of the primary cartridges.

1 Q. Now that we have gone back into the
2 data collected from the wells in Morrison Beatty and
3 WAT, the University of Waterloo, I would like to have
4 you assist the Board with an explanation of a series
5 of documents you prepared called chemical variation
6 within well clusters. Perhaps this could be marked
7 as the next exhibit, Mr. Chairman.
8

9 DR. KINGHAM: This chemical variation
10 within well clusters will be Exhibit H-248.

11 MR. HODGSON: If we could just number
12 the pages again, I get six again. I get six this
13 time, not again.
14

15 ---EXHIBIT NO. H-248: Chemical Variation
16 within Well Clusters

17 MR. HODGSON: Q. Would you explain why
18 it is you prepared H-248?

19 A. The reason I prepared this exhibit,
20 H-248--the reason I prepared the graphs was to basically
21 evaluate the hypothesis that the chemical concentrations
22 detected in the Morrison Beatty and the WAT wells
23 were actually derived, or are artifacts from the sampling
24 installations rather than reflecting actual groundwater
25



concentrations.

1 Now, to do that, as shown -- actually
2 before I actually show you the graphs, I would just like
3 to go over the actual -- the differences between the well
4 construction between the Morrison Beatty wells and the
5 WAT wells.
6

7 Q. Would it be acceptable if we
8 turned out the lights again so we could see this over-
9 head?

10 A. Thank you very much. This is a
11 picture of a conventional piezometer nest that is of
12 the type installed by Morrison Beatty, and this is
13 from Figure 3, page 23 of Miss Hewetson's thesis, and
14 this shows the Morrison Beatty style monitoring wells which
15 are individual wells constructed with PVC pipe in
16 individual boreholes and, as I mentioned before, the
17 PCV pipe was not cleaned prior to use and the sections
18 of pipe used to construct these piezometers were
19 connected together with solvent cements. I am not
20 actually sure if the Board has seen what the Waterloo
21 multi-level piezometers are actually like.
22
23

24 Q. This again is from ...

25 A. Figure 3, page 23, Exhibit 214.



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The Waterloo multi-level device consists of one main PCV casing which I believe is approximately two and a half inches in diameter and the sections of PCV pipe are connected with solvent-welded couplings and each of the test intervals which would be -- this would be a test interval and this would be another interval, but it is sealed into the borehole with a special type of packer device installed at various locations along the casing and this packer consists of a short piece of perforated PVC pipe so there are holes leading to the centre of the pipe and around the pipe is a sleeve of a special polymer substance that is a proprietary substance produced by DOW Chemical called Dowell, and this is a substance that looks like a hard jelly and it actually forms a cohesive sleeve but it is really quite soft and flexible and it expands when it is brought into contact with water, and then the Dowell is covered by a rubber membrane, and I think at that time I think it was made out of rubber band type rubber.

These packers can seal the different intervals in the boring and when you fill up the inside of the multi-level casing with water, water goes through the perforations in the pipe and contacts the Dowell material. The Dowell material swells, it



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stretches the rubber membrane and actually pushes against

1 the wall of the borehole and expands with a very
2 significant swelling pressure measured in hundreds of
3 p.s.i., but I don't remember precisely what it is.

4 In the laboratory if you allow a packer
5 like this to swell into a 3-inch diameter pipe or
6 plexiglass tube it is just to impossible to remove.
7 It is a very tight fit.

8 So, on the inside of this casing coming from
9 the ground surface and going down through the inside of
10 the casing and connecting to the actual interval between
11 the packers you would like to sample, and these tubes
12 lead down to a small elbow when a hole is drilled
13 through the PVC casing and at this stage, and as I
14 mentioned this was the second time these kind of devices
15 were put into the ground, and at that time I believe
16 all the joints were solvent welded and these couplings
17 were all solvent connected and I believe at this stage
18 this elbow was glued into the PCV casing and the tubing
19 going up to the ground surface was polyethylene tubing,
20 either 3/8ths or 1/2 inch diameter.

21 So, given the hypothesis that the
22 chemical concentrations we have detected in the groundwater
23
24
25



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samples collected at these intervals and likewise
1 from the groundwater samples from the Morrison Beatty
2 wells are a result of contamination on the pipe which
3 was not cleaned before it was used and possibly chemicals
4 -- the residuals from these solvent-welded couplings,
5 one could reason that at any particular location, at
6 any particular Waterloo multi-level piezometer, the
7 level of contamination you would identify, extraneous
8 contamination from the pipe at any particular interval
9 should be relatively comparable because you are dealing
10 with the same piece of pipe, probably dirty to the same
11 degree up and down the length, and the joints were
12 put together in the same way and initially many of these
13 test intervals were actually interconnected and there
14 were leakages in between.
15
16

17 So, you could reason that the chemical
18 variation if it was truly due to the installation and
19 not the actual groundwater conditions, should be
20 relatively similar within any given Waterloo multi-level.
21

22 Now, conversely in a nest or cluster of
23 Morrison Beatty monitoring wells, they are separate
24 pieces of pipe, they may have been from the same batch
25 or the same source or not, and installed in different



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holes and also they have been subject to probably a much greater degree of flushing because there are larger volumes of water inside these pipes and I believe that these piezometers were probably sampled many more times also. So they could have quite a different history in terms of their installation, how they were sampled and there was probably no reason to expect why the level of contamination from extraneous sources in this piezometer should be comparable to that one or should be comparable to that one, or not to the same degree as one would expect in the different depth intervals of the same Waterloo piezometer.

When you actually plot the concentrations or the range in concentrations of the various chemicals in the Morrison Beatty wells separately, and the WAT wells separately with -- there are some exceptions, but in general you can see that the range of concentrations at a particular cluster of Morrison Beatty wells is usually quite a bit larger than the actual variation in concentrations in the WAT wells and that applies for most of the chemicals.

Q. Now you are referring to page 1 of H-248?

A. Yes, that's right. Page 1.



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Now, that is for trichloroethane. It is more striking if you look at chlorobenzene and see that the concentrations one gets in a WAT well and at various depths but in any particular installation the ranges always fairly narrow and in general they are always higher than in the Morrison Beatty wells.

Q. Higher than or higher in?

A. Higher than. It doesn't show up quite as nicely for dichlorobenzene, but you can't see the same trend all the time. The concentrations of benzene also suggest that there is a difference between the Waterloo piezometers and the Morrison Beatty piezometers and toluene, which is page ... Can you tell me because I don't have my pages numbered?

Q. Page 5.

A. Page 5. It also shows a difference between the Morrison Beatty wells and the WAT wells quite distinctly and would at least support the hypothesis that the contamination, the extraneous contamination evidenced in these wells is consistent with the overall construction and the differences between the two types of wells.

Q. What do you conclude from the data



on H-248?

1 A. Exhibit H-248?

2 Q. Exhibit H-248.

3 A. I believe these data support the
4 hypothesis or support the hypothesis that the chemical
5 concentrations identified in the Morrison Beatty and
6 WAT wells around the Bayview landfill site are due to
7 artifacts of the sampling installations rather than
8 reflecting actual groundwater concentrations.
9

10 Q. Thank you. Now, can we turn to
11 Site F? Have you evaluated the potential for contaminant
12 migration at proposed Site F?

13 A. Yes, I have.

14 Q. Perhaps we could go back to your
15 Exhibit H-86 and perhaps you could take us through
16 your modelling of potential contaminant migration at
17 that site and explain your conclusions to the Board?
18

19 A. Okay. I would like to point out that
20 the evaluation of contaminant migration we performed
21 for Site F was conducted in 1986 and reported in H-86.
22 The conclusions and the interpretation I have presented
23 this morning and earlier this afternoon with regard
24 to the Burlington landfill and the Bayview landfill have
25



developed only in the past month on the basis of the additional data with which I was provided for both those landfill sites, so the evaluation I am going to talk about now in terms of what was conducted at Site F preceded that interpretation.

Q. Perhaps we can come back at the end to relate the two.

A. The evaluation of contaminant migration conducted at Site F was comparable to the procedures used at Site D I have already described and I don't have to again go through my description of the Ogata-Banks equation and how I coupled the models and all that type of detail.

We considered the migration of leachate out of the landfill at Site F along two primary pathways based on the hydrostratigraphic interpretation of the site; lateral migration through the weathered shale which wasn't considered to be a significant pathway due to a combination of the effect of near-surface discharge from the weathered zone close to the landfill and the collection of a proportion of that migration from a perimeter drain.

So, in terms of my contaminant migration



models, I only considered this deep pathway downward from the landfill, through the weathered shale, weathered moderately fractured shale, downward through the weakly fractured shale and laterally away from the site through the highly fractured shale zone.

Now, in the discharge zone interpreted to be south of Highway 403, we also coupled in upward migration through the glacial till strata that occur in that area. I will now very quickly go through each of the component models just to illustrate the relative travel times in the different components.

Q. The first is downward migration of contaminants through weathered shale?

A. That is correct. The first component we will look at is the downward movement through the weathered moderately fractured shale, and this is Figure 3-25 in Exhibit H-86, and this is with the appropriate estimates of the hydraulic conductivity below effective porosity of .001 and, as you can see, the travel times downward through this weakly fractured or weathered, moderately fractured shale are quite rapid, measured in terms of days.

DR. KINGHAM: Just so we can keep this in



perspective to what you told us this morning, is this
a case where there is no interception of leachate or
is this a case where there is interception of leachate?
You will recall this morning we talked about constant
contamiant input and uncoupled models, no hydraulic
trap and what are we talking about here?

THE WITNESS: This is a case where a
small proportion of the leachate within the landfill
is not collected by the underdrain system.

DR. KINGHAM: This is the drain system
working and 5 per cent loss?

THE WITNESS: A five per cent loss
or a small percentage of loss entering into the
weathered moderately fractured shale at a constant
concentration. It is a small volume but a constant
chemical concentration of leachate.

DR. KINGHAM: I hesitate to raise this
at this stage, but I am trying to understand how we
on the Board relate this order of presentation to the
order of presentation at Site D. Should we be looking
for the kind of information on contaminant migration
that would correspond; no drain system equals no
hydraulic trap or should we not do that comparison?



1 THE WITNESS: I don't think you can do
2 that because even when the drain system at Site F is
3 functioning as designed there is and it is interpreted
4 there will be some small amount of leakage which
5 by-passes the collection system.

6 DR. KINGHAM: Thank you.

7 THE WITNESS: Does that explain it?

8 DR. KINGHAM: I still don't quite
9 understand what we are getting here. You gave us
10 your illustration of Site D when the hydraulic trap
11 was not working and then when it is working.

12 THE WITNESS: That is correct.

13 DR. KINGHAM: You are now giving us
14 Site F not when the hydraulic drain system is not
15 working, but rather when the hydraulic drain system is
16 working but losing 5 per cent.

17 MR. HODGSON: At Site F there is no
18 hydraulic trap designed.

19 DR. KINGHAM: Is there no hydraulic
20 drain? I guess that's what I'm looking for.

21 THE WITNESS: It is, but it is only
22 partially effective in intercepting the leachate and
23 there will always be some leachate that by-passes that
24
25



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drain system.

1 DR. KINGHAM: To make myself clear, I
2 understand that what we are trying to get at, or what
3 the Board is trying to understand is that in one
4 scenario you paint a picture of a hydraulic trap failing
5 and this is what happens to contaminants or the
6 hydraulic trap works and this is the result, but in
7 another scenario you have an underdrain system, and not
8 a hydraulic trap but an underdrain system, and you will
9 describe to us now what happens when the underdrain
10 system is working but losing some small percentage
11 of the material that it doesn't catch, but you don't
12 feel it is necessary for us to know what happens if
13 the underdrain system is not working?

15 THE WITNESS: If the underdrain system
16 is not working, there will also be movement of leachate
17 into the subsurface, but the actual limit on how much
18 will penetrate into the subsurface is really controlled
19 by the actual hydraulic conductivity of the underlying
20 zones.

22 Let me think of an analogy. The majority
23 of the water, the majority of the water for the case
24 where the underdrain system is working will be diverted
25



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laterally from beneath the landfill through the under-
1 drain system and I believe Mr. Sobanski has done
2 calculations of what relative percentages will be collected
3 by the underdrain system and what relative percentage
4 will penetrate downward into the underlying units.
5

6 In the situation where the underdrain
7 is not functioning at all, I believe the case would
8 be such that there will be a higher level of mounding
9 within the landfill and to some degree an increase in
10 the volume and the groundwater velocity in terms of
11 what penetrates into the subsurface, but still the
12 largest proportion of the leachate generated will be
13 diverted laterally through the weathered shale rather
14 than downward because of the relatively low permeability
15 of the units underlying the landfill.
16

17 I can't tell you the exact percentages;
18 they will obviously be bigger than the 95 collected
19 by the underdrain system and the 5 per cent calculated
20 to go down.

21 DR. KINGHAM: But for the purposes of
22 Mr. Hodgson's examination, your models will deal with
23 contaminant migration with the underdrains assumed
24 operating and some small losses to the subsurface strata,
25



and that is how we are to understand this presentation.

1 THE WITNESS: I believe that that is
2 correct and if I could just take the opportunity to
3 check the hydraulic gradient that we used. I am afraid
4 I would have to consult with Mr. Sobanski on precisely
5 what scenario we looked at and what degree of mounding
6 we assumed for these model conditions.

7
8 Unfortunately, all I have in my report
9 are the hydraulic gradients that were assumed.

10 DR. KINGHAM: Perhaps we could return
11 to that.

12 MR. HODGSON: Q. Would you please
13 explain the figure on 3-25, your estimation of
14 contaminant migration through the weathered shale at
15 the surface of Site F?

16
17 A. Yes. This figure, Figure 3-25,
18 shows the results of the Ogata-Banks solution
19 for contaminant migration through this weathered shale,
20 this upper weathered shale. As you can see, because
21 the shale has a reasonable hydraulic conductivity,
22 and I believe it was assumed to be 10^{-5} centimetres
23 per second, and a low assumed transport porosity of
24 .001, the velocities downward through the relatively
25



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thin weathered zones of 6 metres, the velocities are very rapid and measured in terms of days. As we discussed this morning with Site D, it has to be remembered that this component model does not take into account the effect of matrix diffusion for adsorption on the fractured surfaces because we did not feel it was possible that we could quantify those in any rigorous way or rigorous manner.

So, the effect of matrix diffusion would serve to increase the apparent effective porosity for a given contaminant and increase the travel times through this zone.

Now, one of the very key components in the evaluation we performed for contaminant migration from Site F is the movement of contaminants through the weakly fractured shale unit. This weakly fractured shale has a fairly low hydraulic conductivity of 10^{-7} and in this zone we expect that the majority of groundwater flow occurs through the inter-granular pore space rather than through fractures and, consequently, we can take into account the effects of adsorption on the shale for the weakly adsorbed contaminants and this shows the results of that simulation and indicating



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arrival times in the order of 25 to 30 years for the non-adsorbed contaminants such as chloride and something in the order of 40 years for weakly adsorbed contaminants such as 1, 2-dichloroethane.

I should point out that the curves we have presented include a non-adsorbed contaminant such as chloride, but in this particular case the actual evaluation of chloride isn't particularly relevant because there are such high concentrations existing naturally in the shale bedrock -- in the groundwater in the shale bedrock -- but as a reference case I have continued to calculate a chloride-type curve representing a non-adsorbed contaminant.

Q. Before you leave that, Mr. Feenstra, do you recall that during Mr. Sobanski's evidence he introduced a new run of the model which became Exhibit H-221 in which some of the inputs to the calculated K values at Site F were changed and, in particular, I believe there was a change to the K value of the weakly fractured shale unit?

A. Yes. That K value ...

Q. Do you recall what the change was?

A. I believe that would have been a



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change in the vertical hydraulic conductivity down to 10^{-8} centimetres per second.

Q. If it should turn out that the K value of the weakly fractured shale is 10^{-8} rather than 10^{-7} how does that effect this calculation as presented on Figures 3-26?

A. The use of a hydraulic conductivity of 10^{-8} compared to 10^{-7} , a factor of 10 lower, would increase the travel times from the order of 25 years or so to approximately 200 to 250 years for a non-adsorbed contaminant and approximately to 400 years for a weakly adsorbed contaminant.

Q. That is for a C over C_0 of .1.

A. Yes.

Q. Those travel times are significantly longer.

A. Significantly longer.

Q. What did you model next?

A. As one further example of the weakly fractured shale, for a moderately adsorbed contaminant, the degree of retardation or attenuation is significantly greater than a non-adsorbed or weakly adsorbed contaminant as I just illustrated and I did it



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on a separate scale. So this is a graph with the same component which shows the first arrival of a moderately adsorbed contaminant such as trichloroethane or xylene to be somewhere in the range of 500 years. If we changed the hydraulic conductivity down to 10^{-8} , then that would become thousands of years.

I don't like to be specific when I state numbers greater than 1000 years.

Q. Did you next model what has been called in this hearing the highly fractured shale units?

A. Yes, I did. We ran a similar component model for the highly fractured shale assuming a hydraulic conductivity of 10^{-2} centimetres per second and an effective porosity of .01, .01 still being relatively low compared to the inter-granular porosity of the shale, but reflecting a fairly highly fractured zone.

Q. What distance are you measuring this run of contaminant?

A. This is Figure 3-29 from H-86, and this distance is 1400 metres extending from -- I believe we took it from the centre of the landfill to the interpreted discharge zone between Highway 403



and the CNR tracks.

1 Q. Now, what did you assume as the K
2 value of the highly fractured shale unit?

3 A. 10^{-2} centimetres per second.

4 Q. Do you recall that in Exhibit H-221
5 Mr. Sobanski assumed a K value for the highly fractured
6 shale unit of 10^{-4} .
7

8 A. Could you repeat that?

9 Q. Let me show you the exhibit,
10 H-221, the K value used to model the highly fractured
11 shale.

12 A. Yes, I see that.

13 Q. Which is?

14 A. 10^{-4} centimetres per second.

15 Q. First of all, have you an opinion
16 independant of the opinion expressed by Mr. Sobanski
17 as to what in fact the K value is for that highly
18 fractured shale unit?
19

20 A. I have an opinion based on
21 my interpretation of the pumping test results, yes.

22 Q. Based on your interpretation of
23 Mr. Sobanski's data?
24

25 A. Yes.



1 Q. In your opinion what is the
2 appropriate K value to assign to the highly fractured
3 shale unit?

4 A. In my opinion the appropriate
5 hydraulic conductivity value to use as a result of
6 the pumping test at PW-1 would be approximately 3×10^{-4}
7 centimetres per second.

8 Q. How do you arrive at that conclusion?

9 A. It was based on the actual
10 conversion from a transmissivity value, which is the
11 actual hydraulic parameter calculated from the pumping
12 test, and dividing by rather than .3 metres, which was
13 performed in Exhibit H-40, but dividing by the entire
14 thickness of the zone that was pumped and that is a
15 difference in interpretation and my reasoning is that
16 the zone that was pumped was considered to be sufficiently
17 highly fractured to be considered to be a porous medium,
18 and for that reason I would consider it more repre-
19 sentative to divide by the entire screen thickness
20 of the pumping well and that gives a proportionately
21 lower hydraulic conductivity.
22
23

24 Q. I take it that the calculation
25 that appears on Figure 3-29 of Exhibit H-86 represents a



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calculation with a K value of 10^{-2} ?

1 A. That is correct.

2 Q. If you used the K value which you
3 in your opinion would appropriate assign to this unit
4 of the underlying strata, how would that effect the
5 calculation presented on Figure 3-29.

6 A. In this case changing the hydraulic
7 conductivity by a factor of 100, two orders of magnitude,
8 I don't think would actually necessarily reflect a
9 similar increase in the groundwater velocity, the
10 linear groundwater velocity, largely because that
11 change in hydraulic conductivity I think would lead
12 one to reinterpret what the effective porosity was,
13 and going back to Exhibit H-221 -- let me just check --
14 but using the same fracture frequency in quite a
15 different hydraulic conductivity would lead one to
16 assume -- 244 -- would lead one to assume that the
17 effective porosity is also somewhat lower. So I
18 would think the result of the recalculations would
19 give you groundwater velocities that were about a
20 factor 10 slower and that would make the first arrivals
21 at 50 years -- rather 50 days become 500 days which
22 is slightly more than a year, a year and a half.
23
24
25



Q. Would those slower travel times

1 affect in any way attenuation that may or not occur in
2 that unit?

3 A. I would also like to point out
4 in this component model that it does not take into account
5 the effect of matrix diffusion which will serve to attenuate
6 contaminant migration through the fractures in this
7 highly fractured shale and a reduction in the actual
8 groundwater velocity or flow rate through the fractures
9 will enhance the effect of matrix diffusion.
10

11 In other words, if the groundwater is
12 moving at a slower rate, the contaminants are given more
13 of an opportunity to diffuse out of the fracturing
14 into the matrix.
15

16 Q. What other unit of the geological
17 strata did you interpret?

18 A. If I might make one more point
19 with respect to assuming different hydraulic conductivity
20 values for the weakly fractured shale. Although assuming
21 a value of 10^{-4} or something in that range for the
22 hydraulic conductivity may not appear to affect the
23 actual groundwater velocities to as significant a degree,
24 it will have the same direct impact on the actual volume
25



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1 tric flow of groundwater through that zone, because the
2 volume of groundwater flow does not depend upon the
3 actual transport porosity but depends on simply the
4 hydraulic conductivity and the gradient.

5 If we change our hydraulic conductivity
6 by a factor of 100, or close to that, that will result
7 in a reduction of the actual groundwater flow rate
8 through that zone by a factor of 100.

9 Q. Are you saying the speed would
10 be somewhat slowed but the quantity of water would be
11 significantly diminished?

12 A. That is correct.

13 Q. The quantity of contaminant
14 moving through the groundwater system?

15 A. I believe the estimates for the
16 degree of groundwater flow through the highly fractured
17 zone was measured, and I can't remember the exact number,
18 but measured in gallons per minute. A reduction in
19 the hydraulic conductivity of that zone would make
20 that figure several hundredths of a gallon a minute.

21 Q. Hundredths?

22 A. Hundredths.

23 Q. Did you also model movement of
24
25



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contaminants through the till unit to the south of
Site F?

1
2 A. Yes. We did a similar evaluation
3 for the movement of contaminants upward through the
4 discharge zone till. The organic carbon content
5 of this discharge zone till wasn't measured specifically,
6 it was assumed it would be similar to the clayey tills,
7 clay silt tills in the Site D area, and for an organic
8 carbon content of .3 and there is a reasonable
9 attenuation of the weakly and moderately adsorbed organic
10 contaminants and travel time through this discharge
11 zone till would be something in the order of 25 to
12 30 years for a non-adsorbed contaminant and a weakly
13 adsorbed contaminant.
14

15 Q. Each of the models you have shown
16 at Site F are both uncoupled transient models with
17 constant contaminant inputs?
18

19 A. That is correct.

20 Q. Did you also couple the models
21 at Site F and did you also change the contaminant
22 inputs or vary the contaminant inputs?
23

24 A. Yes. Without going over precisely
25 how I coupled these models together and the pattern of



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chloride decline with time in the leachate, I would just like to say that for Site F we assumed the same pattern of chloride decline with time as we did at Site D.

Q. Chloride and other contaminants as well?

A. Chloride and other contaminants as well, correct, and we coupled the actual component models together in an identical manner. The only difference at Site F is that although there are four components noted in this pathway downward and outward from the landfill, the groundwater velocities downward through the weathered shale and laterally through the highly fractured shale are significantly higher than the groundwater velocities through the weakly fractured shale and upward through the discharge zone till. For that reason, and to make the calculation -- to simplify the calculation somewhat, we chose to ignore these two components.

Q. "These two" being?

A. These two being the weathered shale and the highly fractured shale and assumed that contaminant migration through those zones were basically instantaneous because the travel times were measured in



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days or just a year or two in these zones and tens of years in these two zones. For simplicity sake we took this component or took the landfill coupled it to this component and coupled it to this component, this component being the discharge zone.

MR. McQUAID: Which zone?

THE WITNESS: The weakly fractured shale, the other component that was coupled.

MR. HODGSON: Q. When you coupled these components and omitted lateral migration through the highly fractured shale, what was your opinion as to the hydraulic conductivity in the highly fractured shale unit?

A. The runs were performed with a hydraulic conductivity of 10^{-2} centimetres per second.

Q. Now that you hold the view that the appropriate value is 3×10^{-4} , if you were now, -- if you were doing this over -- would you couple into your model the run through the highly fractured shale unit of the contaminant?

A. I have actually tried to do that, and that increases the travel time of the highly fractured shale unit from fractions of a year to just



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a couple of years and it still has no real significant affect because of the fact that we don't take into account matrix diffusion or any other attenuation mechanisms.

Q. It has no significant affect on total travel time?

A. On travel time, no, correct.

Q. What does it have an effect on?

A. As I just mentioned, it has an effect on the actual volume of water you can physically move through this highly fractured zone.

Q. Therefore the volumes of contaminants?

A. The volume of contaminated water that will move from beneath the landfill off-site.

Q. Would you show us your coupled model, please?

A. The results of the coupled model for Site F -- oops -- that is actually a component. That was the concentration at the base of the weakly fractured shale and I will go the results at the discharge zone. This shows the resultant arrival curve for chloride or for a non-adsorbed chemical such as chloride, although chloride is not relevant in this case,

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but at the discharge zone. The peak arrives at approximately 100 years and the peak concentration is actually very similar to the peak concentration predicted at the site boundary at Site D, being somewhere between 300 and 350 milligrams per litre, a reduction of approximately of 4 to 5 times from the peak input concentration from the landfill.

We will just look at one other curve which shows the same coupled model and the same assumptions for a weakly adsorbed organic contaminant which is subject to some adsorption in the weakly fractured shale and the discharge zone tills. You will see the peak is considerably lower relative to a non-adsorbed contaminant, being five times or so lower than the input, and the first arrival will be somewhere in the order of 100 years and the peak concentrations would not occur until approximately 150 years.

Q. That is with the declining concentration, but what is the initial concentration?

A. 1000 micrograms per litre which reflects the concentrations observed at the present time in the Burlington landfill leachate.



Q. Did you do a calculation with a lower condition?

A. Yes, we did that calculation and, as I mentioned for Site D, the actual pattern of the curve is identical and the typical values on the "X" axis are lower, reflecting a lower input concentration. In this case the peak concentration at the discharge zone is something around 30 to 40 micrograms per litre.

Q. Now, having performed those calculations and having now studied contaminant migration at sites adjacent to the proposed Site F, the Bayview landfill site and the Burlington landfill site, how do your estimates of contaminant migration at Site F relate to your studies pertaining to migration at Burlington and Bayview?

A. The results of the contaminant simulations we prepared last year for Site F would suggest that over a period of several tens of years, and certainly very quickly after a landfill was established in this area, you should start to see contaminant migration in the weathered moderately fractured till underlying the landfill. Over a period of several tens of years one would also expect

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to see evidence of contaminant migration downward
through the weakly fractured shale.

At the Burlington landfill, which is
approximately 30 years old -- sorry, the Bayview landfill
which is approximately 30 years old, and the Burlington
landfill which is approximately 15 years old ...

MR. McQUAID: How old?

THE WITNESS: 15. At the present time
it is my opinion that there is very little evidence
of contaminant migration or no evidence of significant
contaminant migration either in this weathered shale
zone or deeper downward into the highly fractured shale
and what that suggests to me is that the contaminant
simulations we performed in 1986 were highly conserva-
tive in the fact that they cannot take into account
the effect of matrix diffusion and I suspect that
that is the primary situation in this environment.

MR. HODGSON: Q. What is your opinion
of the suitability of this environment, Site F for
landfill?

A. I would consider that the shale
bedrock underlying the proposed Site F has a good
capability for attenuation of contaminant migration.



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derived from the municipal landfilling at this site.

1 Q. How does that affect its suitability
2 for landfill?

3 A. That makes it suitable for
4 landfilling.

5 Q. Have you a copy of Exhibit WB-227?

6 A. Can you refresh my memory on what
7 that is?

8 Q. I will give you a copy.

9 A. Oh, I know which one.

10 Q. Have you had an opportunity to
11 review Exhibit WB-227?

12 A. I have examined that exhibit, yes.

13 Q. Could you comment to the Board
14 on the significance of this exhibit?

15 A. Well, the data presented in this
16 exhibit, that is the chloride and sulphate concentrations
17 in a variety of domestic water wells south of Site F
18 and the Burlington landfill, together with analyses
19 performed previously by Trow Hydrology Consultants
20
21 in several of the domestic wells and in several of
22 their own monitoring wells, indicate that in the
23 shallow groundwater, the groundwater which occurs -- the
24
25



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groundwater which occurs in the overburden, the
glacial deposits south of Site F, and this is actually
south of the CNR tracks also, but in the shallow shale
bedrock is of quite reasonable quality and, in fact,
it seems to be used for drinking water supply by
a number of residents in the area and with chloride
concentrations being below Ministry of the Environment
drinking water standards, the standard being 250, and
typical values in this area in the shallow groundwater
being 500 milligrams per litre.

This is in direct contrast with the
high concentrations of chloride which occur deeper in
the shale, even directly in that area itself. If I
could just refer to one other exhibit which is drawing
21...

Q. This has been referred to in
evidence but I don't think it has been separately
exhibited. It's drawing 21 from Exhibit H-40 and it
could be marked for our purposes as H-40, and I
forgot how we were doing it, I think it was D-21.

DR. KINGHAM: Drawing 21? Our copies
of drawing 21 don't have the blue line shown on this
mounted version.



1 MR. HODGSON: I think the blue line is
2 a line that is on there that is highlighted.

3 THE WITNESS: It is a highlight of the
4 1000 milligram per litre contour.

5 DR. KINGHAM: Let's mark this in any
6 event as H-40-D21.

7 ---EXHIBIT NO. H-40-D21: Drawing 21 from
8 Exhibit H-40

9 MR. HODGSON: Q. Would you explain what
10 this exhibit is?

11 A. As I was just mentioning, in this
12 area in the vicinity south of the CNR and in the vicinity
13 of Plains Road, which is near Hydrology Consultants'
14 monitoring well nest 10 and 12, and I believe on the
15 cross-section No. 11 is in this area but displaced
16 westward somewhat, in the shallow groundwater in the
17 overburden and in the shallow shale -- the shallow
18 groundwater in the shale -- concentrations of chloride
19 are quite low and, as I just mentioned, typically being
20 approximately 50 to 100 milligrams per litre. At
21 only slightly greater depths of possibly 10 to 15
22 metres into the shale, the chloride concentrations
23 are considerably higher and in HCl2 being 15,300.
24
25



Within this particular zone ...

Q. What zone?

A. This particular zone south of the CNR in the vicinity of the Hydrology Consultants well nest 10, 11 and 12 there are upward hydraulic gradients indicating a potential for upward flow of this salty groundwater from deeper in the shale, upwards towards the ground surface and the shallow groundwater in these zones. The fact there is such a significant difference between the deeper shale and the shallow groundwater in this zone suggests that even though gradients indicate there is groundwater discharge upward in those areas, the actual volume of groundwater discharge is so small that the chloride is significantly diluted by shallow local flow and infiltration in the immediate area south of the CNR in the vicinity of HCl0, 11 and 12.

That degree of dilution comparing concentrations of 10,000 or so, approximately 10,000 milligrams per litre to 50,000 milligrams per litre suggests a dilution factor of at least 100 to 200 times. In the event that any contaminants did leave or do leave the Bayview landfill or Burlington landfill



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or a landfill proposed at Site F, those chemical concentrations would be subject to the same degree of dilution upon discharge if there was discharge upward from the deepest shale groundwaters into the shallow groundwaters in this zone.

On that basis that would also support my conclusion that the potential impacts -- there would be no significant environmental impact from landfilling at Site F.

Q. Now, looking at page 4 of Exhibit 227 which shows within a box drawn on the exhibit chemistry data from certain wells in this area south of proposed Site F, but do any of the substances reported on there assist you in advising the Board as to where the water that is being sampled is coming from?

A. Yes, indeed. As you can see, and I believe that is page 4 in that exhibit, but if you look under the column of nitrate, the concentrations of nitrate in the groundwater. As you can see, the nitrate concentrations range from .5 milligrams per litre in sample 7 to 29.1 milligrams per litre in sample 17.



Now, if you note for a moment that sample

1 7 comes from a water supply well located up-gradient
2 of the Bayview site as indicated on the placemap, the
3 previous page, that is by fair the lowest nitrate
4 concentration and that is the type of nitrate concentra-
5 tion one would expect to find at fairly significant
6 depth in most groundwater systems, with nitrate being
7 the oxidized form of nitrite which would appear to be
8 quite readily reduced to nitrogen by de-nitrifying
9 bacteria in the transition zone where groundwaters
10 go from aerobic to anaerobic. So it is quite
11 unusual or is typical to find low concentrations of
12 nitrate in deeper groundwaters and the fact we see
13 significant nitrate concentrations in the shallow
14 groundwaters in the area around HC10, HC11 and HC12
15 in the area of the domestic water supply wells suggests
16 that the main origin of that water is relatively shallow
17 water, water that has not come up from deep in the
18 groundwater flow system.

19
20
21 The nitrate that occurs in that shallow
22 zone is likely due from the use of fertilizers in the
23 area and possibly leakages from sewer lines and things
24 like that.
25



MR. HODGSON: Mr. Chairman, those are
1 my questions of this witness.

2 DR. KINGHAM: I think this would be a
3 good time for us to take a break and then begin cross-
4 examination. Have you arrived at some conclusion as
5 to the order of cross-examination for this witness?
6 I take it that his evidence is as was stated by
7 Mr. Sobanski leading to a preference to Site F, so in
8 that case we would follow the traditional order.
9 Is that your assessment, Mr. Hodgson?
10

11 MR. HODGSON: I don't think this witness
12 has -- I don't know if he has an opinion as to which
13 site is preferable because that is something I didn't
14 explore with him and I certainly did not seek to put
15 such a fact in evidence, but Mr. Sobanski had an opinion
16 and since it originally formed part of Mr. Sobanski's
17 report, it falls within the scope of Mr. Sobanski's
18 opinion on that subject, and perhaps the order of cross-
19 examination should be changed.
20

21 DR. KINGHAM: That would have been our
22 tendency for those same reasons. So, we will resume
23 at about 3:30 and we will follow that order.
24

25 MR. ESTRIN: Could we make it a 15-minute



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break that is all, or add five minutes.

1 DR. KINGHAM: All right, twenty-five
2 minutes to four.

3 ---Recess

4 DR. KINGHAM: Thank you, please be
5 seated.

6 CROSS-EXAMINATION BY MR. ESTRIN:
7

8 Q. Mr. Feenstra, I am going to start
9 with something that you said yesterday in respect to
10 Site D and I think in sort of a quick phrase you said
11 you modelled for a large scale failure of the hydraulic
12 trap at Site D?

13 A. That is correct.

14 Q. I guess what I want to do is
15 start at the beginning of that topic and what specific
16 modelling did you do in respect of the hydraulic trap,
17 and what I mean by that is in respect of a failure of
18 the hydraulic trap, what kind of a head were you
19 looking at and where are those results?
20

21 A. The actual head that was used,
22 the head of leachate within Site D that was used to
23 simulate the condition where the hydraulic trap
24 was not in operation, wasn't actually specified in the
25



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report but reflected in the hydraulic gradients that are indicated on -- if I can remember the numbers, I can't remember the table numbers off by heart, -- on Table 10, page 88 of H-39. The hydraulic gradient downward through the upper unweathered till was .85.

Q. Let's look at Table 10 on page 88.

You are saying that when you modelled for a large scale failure of the hydraulic trap, and I just want to understand, the hydraulic gradient you used was .85?

A. That is correct, .85 across the unweathered upper till.

Q. Where did you obtain that number of .85 from?

A. I was given that number by Hydrology Consultants to model the scenario where the hydraulic trap was no longer in operation. It is my understanding that that hydraulic gradient would reflect a level of leachate mounding as high as the current ground surface elevation, which would be a total leachate mound of approximately 6 metres above the base of the landfill.

Q. When you say that that is your understanding, is that understanding available to be



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looked at in any of the documents or is that something
that you calculated?

A. It is not something that I calculated.
ed.

Q. Who calculated the six metre mound,
Mr. Feenstra?

A. That was definitely determined
by Hydrology Consultants and I think it was Mr. Beechinor
in conjunction with Mr. Sobanski.

Q. Have you looked at the calculations
and does the six metre mound give a gradient of .85?

A. It does.

Q. You looked at a couple of the
documents introduced into cross-examination, M-166,
a sketch illustration of the hydraulic trap, and you
have that there?

A. I have it in front of me.

Q. On the left-hand side we see
as assumed by Trow and on the right-hand side we have
the scenario of the failure of the trap due to a
couple of assumptions. Have you done anything to
calculate what the gradient would be if -- have
you modelled anything but a mounding of six metres?



1 A. We modelled the conditions for
2 when the hydraulic trap is in operation and in that
3 case there is a hydraulic gradient upward into the
4 landfill and the value that was used for the upward
5 hydraulic gradient in that condition was approximately
6 .2 as identified in Table 10, page 88.

7 Q. You have not, I take it, done any
8 modelling of a mound greater than -- is it six metres?

9 A. That is correct, and, no, I have not
10 modelled a mound higher than 6 metres.

11 Q. Have you looked at the calculation
12 for the gradient given on the right-hand side of
13 Exhibit M-166 to determine whether that is the gradient
14 that one would arrive at if in fact mounding went to
15 the average height indicated on the right-hand side of
16 the page?
17

18 A. I haven't checked that calculation
19 but I can do so now if you wish.

20 Q. Perhaps that is something you can
21 do -- if you want to do it that fast, sure.

22 A. That is correct as stated on M-166,
23 that gradient being actually approximately seven times
24 less, between six and seven times less than the gradient
25



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that was modelled.

1 Q. Now, may I suggest that you have
2 not really modelled for a large scale failure of the
3 hydraulic trap?

4 A. "A large scale failure"?

5 Q. Those were your words.

6 A. Correct, those were my words.

7
8 If you look at the right side, on the right side figure
9 on M-166, for case II or ii, case B, this was a
10 calculation that was done to determine the height of
11 the mound for a failure of two-thirds of the leachate
12 collection tiles.

13 Q. In a cell?

14 A. In a cell and a two-thirds
15 failure, a failure of two out of every three leachate
16 collection tiles, would result in a mound of only 4.5
17 metres.

18
19 Q. Above the waste?

20 A. Above the waste, correct.

21 The case we modelled represented a mound of six metres
22 and that naturally implies greater than two-thirds
23 failure rate of the leachate collection tiles and I
24 would certainly consider that a greater than a two-
25



thirds failure could be considered a large scale failure.

1 MR. HODGSON: I am a bit confused. The
2 suggestion was above the waste, but is it possible to
3 have it above the waste?

4 MR. ESTRIN: Within the waste, the bottom
5 of the waste.

6 Q. So, your large scale is a six
7 metre mound?
8

9 A. That is correct.

10 MR. ESTRIN: Mr. Chairman, just to get
11 out of this topic for a second, you said the order of
12 the Board with regard to the composition of the panel
13 is available, but where is it available before I forget?
14

15 DR. KINGHAM: We have it here.

16 MR. ESTRIN: If that could be left on
17 the table so it is available overnight...

18 DR. KINGHAM: The original is in the
19 file in our retiring room and the copy is here.

20 MR. ESTRIN: It is just that it is next
21 in my notes.

22 MR. HODGSON: By all means ask away.

23 DR. KINGHAM: I hope that has nothing
24 to do with catastrophic failure or two-thirds of the
25



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collection tiles...

1 MR. LANCASTER: Or even waste space.

2 MR. ESTRIN: That shows you how quickly
3 I went through yesterday's testimony and arrived at
4 9:30 this morning.

5 Q. One of the next topics you
6 testified about was porosity and the results of the
7 University of Waterloo study and I will be looking
8 at that article over the weekend and determine if
9 I have any questions arising out of that.
10

11 One thing as a general principle with
12 regard to porosity. If I understand what you said,
13 you were conservative because you used the number of
14 .001 rather than .0001, or did I hear that right?

15 A. That is not correct.

16 Q. Putting it another way ...

17 MR. HODGSON: I don't think I heard
18 the rest of the answer.
19

20 MR. ESTRIN: If you want.

21 THE WITNESS: I felt that the value of
22 .001 was conservative because we have a full expectation
23 that matrix diffusion will be a fairly significant
24 attenuation mechanism in a fractured porous medium. What I
25



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wanted to use the example of the University of Waterloo study as an example of is that the effective apparent porosity for contaminant migration through a fractured weathered clay or clay till is likely to be substantially higher than .001, and therefore assuming .001, I considered it to be a conservative assumption.

MR. ESTRIN: Q. Coming at it another way, if there is a possible range of .001 to an even smaller number, then a smaller number would be more conservative?

A. A smaller number would certainly be more conservative, yes.

Q. Well, I will come back to that. I just want to clarify something else you said. You were asked by Mr. Hodgson about comments on Exhibit M-162, the chart of numbers that would recalculate the travel time, and Mr. Hodgson added up a couple of numbers and suggested that one of the combinations would have the leachate off the site in about ten years and that was ten times less than the travel time used in your model. Do you recall that?

A. Could you repeat that, I didn't hear the numbers.



Q. If you look at Exhibit 162,

1 Mr. Hodgson referred you to that and added up eight
2 years and 2.4 years and suggested that was about 10 years
3 which is ten times faster travel time than you used
4 in your model?

5 A. I don't believe it is ten times
6 faster. I believe the travel time is -- I will look it
7 up.
8

9 Q. It takes ten times less time to
10 get there?

11 A. Not quite as fast as ten times.

12 Q. Well that is correct but it's in
13 that vicinity and it is not the exact number that
14 really matters for the purposes of the question.

15 A. It is faster.

16 Q. You were asked whether such a
17 travel time was believable and you said it wasn't and
18 you gave a reason. Then I thought what I heard as your
19 reason -- give me your answer again, why isn't it
20 believable?

21 A. Well, the travel times presented
22 on M-162 are based on different input values for the
23 hydraulic gradient reflected by the level of mounding
24 in the landfill, but also ...
25



Q. Only in part?

1 A. Only in part, but I will continue;
2 but also the hydraulic conductivity assigned to the
3 unweathered upper till.

4 Q. Okay. You were saying that the
5 conductivity of the unweathered or weathered upper till?
6

7 A. Unweathered upper till.

8 Q. Okay.

9 A. Which we assume to be 8×10^{-8}
10 centimetres per second reflecting the results of the
11 Hvorslev tests in the piezometers and consistent with
12 the depths of penetration of tritium through the unweath-
13 ered till and the findings that there is no tritium in
14 the upper granular unit which I think are all consistent
15 with the value of hydraulic conductivity for the
16 unweathered upper till in the area of 8×10^{-8} rather
17 than 7×10^{-7} as suggested in the third option on M-162.

18 Q. You head the evidence of
19 Mr. Sobanski and it went on at great length between the
20 various people who asked, and Mr. Tidball was first and
21 I was perhaps the second with respect to the different
22 values in the conductivity one gets between using
23 Hvorslev and pump tests, and we talked about a range of
24
25



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four orders of magnitude and the smearing that occurs and the potential difficulties with Hvorslev, but in respect of the answer you have given why you tend to think that 10×8^{-8} is a good number, which do you place more reliance on, Hvorslev or tritium?

A. First of all, I would like to point out that the difficulties in looking at the hydraulic conductivities calculated by the Hvorslev tests are most predominant in trying to determine a hydraulic conductivity for a reasonably permeable unit. In other words, if you have a reasonably permeable unit where the actual hydraulic conductivity is 10^{-4} or 10^{-5} , it is not really difficult to get the movement of fines or finer materials from the formation around the well intake and to reduce the apparent hydraulic conductivity of a value which is relatively high.

The problems with Hvorslev results in low permeability materials such as in the range of 10^{-7} or 10^{-8} is far less apparent because in some ways dislodging some fine-grained materials and moving it into a filter pack or sand pack around the well in a clay till to begin with really won't affect the overall permeability of the zone to any great degree and the value of



hydraulic conductivity of 8×10^{-8} in the texture
of this clay silt till is entirely consistent.

Q. You are saying you would place
most reliance on the Hvorslev and not the tritium or
give them equal value?

A. I would say it would be difficult to
compare them. I would say that they are comparable.

Q. You are saying by either method,
Hvorslev or tritium standing independently -- I want to
understand what you are saying, you would rely on
either method independently to corroborate your opinion
that it is 8×10^{-8} ?

A. Obviously one individually does not
bear the same weight as two in combination, the degree.

Q. Well, if you didn't have -- if
you have a choice and only had to rely on one, which
one would be more reliable; that is really what I am
asking and it is fairly simple?

A. If I had the choice
between one Hvorslev test ...

Q. Take all the Hvorslev tests pertain-
ing to this unit and the tritium tests.

A. It is not exactly comparable because



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obviously I like tritium data at more than one location
also, if I was being rigorous about the comparison, but
just to compare apples to apples, if I had one Hvorslev
test and one tritium test and I had to choose between the
two of them, I would probably give them equal weight.

Q. I don't see how that chooses between
them.

A. No. I would consider them both
to be equally reliable. I would choose either one.

Q. Let's put it this way; you have
more Hvorslev values on this site than you have tritium
and in fact the tritium results at Site D you agree
come from one location?

A. Yes.

Q. About the size of this table
or something like that.

A. Something of that order.

Q. Are you saying, and we suggested
there were some of those Hvorslev values which were
obtained were not really from the unit they were
assigned to, and I don't know if you were here for that?

A. I recall discussions on that and
I also recall the one measurement in particular related to a
particularly sandy zone in an area identified as the



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upper till in the boring logs. I would certainly concur with the response Mr. Sobanski gave, that although on the boring logs this was drawn as being part of the upper till, it is certainly not clayey silt till and I don't think it should be included in the calculations of the hydraulic conductivity of the clayey silt upper till.

Q. What does it constitute?

A. I would think it constitutes a sandier facies of that till unit.

Q. If it occurs once, you would have to agree it is going to appear in all likelihood in more than one place in that 250-acre site?

A. In fact it seems to occur at the bottom of the upper till when you move into the sandier lower till in most areas. The contact between the upper till and the lower till isn't a sharp demarcation, and to some degree there is a distinction between the actual geological units that one identifies at a site like Site D and the hydrostratographic units as described, and they don't always coincide exactly.

Q. That area we have just been discussing geologically is the area of the interface



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between the three till units?

1 A. That is correct.

2 Q. That is also the area where the
3 so-called thin bed of silt is identified which has been
4 said to have, in Mr. Sobanski's view, no hydrogeological
5 significance. Both of you have said that at that
6 interface, or at least one location picked up by one of
7 the borehole logs, there is this sandier phase with a
8 hydraulic conductivity which is unrepresentative of
9 the unweathered upper till and that is a higher
10 conductivity than the weathered upper till?
11

12 A. That is correct.

13 Q. Coming back to the question of
14 Hvorslev and tritium, do you have any concerns at
15 all that Hvorslev values are possibly -- should
16 possibly and most accurately be assigned a range. What
17 is the reliability of a specific Hvorslev value
18 considering there may be some smearing of the hole in
19 which it is put?
20

21 A. I think that is fairly difficult
22 to quantify, what that range would be, but the range
23 exhibited by the measured values would probably be
24 an appropriate number to look at and an appropriate range
25



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to look at, the maximum amount to be determined to be representative of the upper till, but given the fact that the hydraulic conductivity will vary from place to place, and to do a calculation one has to assume a certain value, although one could do calculations for a range of values, but I don't think it is inappropriate to calculate the mean value for the purposes of calculations, keeping in mind that in some areas it may be higher and in other areas it may be lower.

Q. Let's say you have one Hvorslev test and that is what I am asking you. Are you saying the number that pops out of that test should be taken as the gospel truth and it has no area of significant deviation that there isn't some range that might reasonable be assigned to that?

A. There certainly is a range.

Q. Tell me in your best opinion, and be as helpful as you can to myself and the Board, and I know you are trying to be, but tell us what that range would be?

A. The actual range that you would estimate I would think would depend to some degree on what type of formation you were in. Different subsurface



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units have different degrees of heterogeneity and with respect -- with respect to a clayey silt till from work at this site and possibly other sites, the range might be a factor of 3 between the maximum and the minimum or maybe slightly more than that. It is very difficult to tell and I would be reluctant to actually give a range.

Preferably you should, you know, strive to have more than one measurement so you can actually define what your range may be.

Q. Right, and we may be talking at cross-purposes when we say range because I was thinking of one Hvorslev measurement at one borehole. I am saying the number that comes out of that test, is it not, or should we not consider that number subject to some range? If it is 2.5×10^{-8} , what is the plus or minus factor in your best opinion, knowing the factors that may affect the actual measurement in a Hvorslev test, are you saying -- how much variation would be fair to ascribe to that one number?

A. I think to some degree that is reflected in the way I would present the results of a Hvorslev test. I would never put a decimal point behind



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the first digit. In terms of the repeatability of Hvorslev testing at a given piezometer, I would hope that you could reliably be within a factor of 2 at a given piezometer in a given situation.

Q. Have you --

A. I obviously don't have data I could show to you to support that view, but that would be my opinion.

Q. In Exhibit 154, the reasonable use policy of the MOE at page 6 -- if you have it?

A. No, I don't have it. Which is it?

Q. The reasonable use policy.

A. The exhibit number?

Q. 154, and it starts off with the Ministry of the Environment form and then continues into the actual document and there is a blue page, or there may be a blue page.

A. There is not a blue page in my copy.

Q. Turn over about five or six pages and you will see a page that looks like this, the incorporation of the reasonable use concept.

A. December 1986?



Q. Yes.

A. Yes.

Q. You recognize that this is the current, seemingly the current policy of the Ministry of the Environment with respect to groundwater management activities in relation to such matters as waste disposal?

A. Yes, I recognize that.

Q. And did you by any chance have an opportunity to participate in the development of this or to comment on it?

A. No, I did not.

Q. Would you look at page 5? The Ministry states at the bottom of the page that a number of general technical considerations have been taken into account in the development of the document and A says the Ministry considers that the following positions represent good groundwater management practice. Then we come down to B on page 6 and there is a statement I want to draw to your attention, that is not generally possible with present technology to estimate accurately the quantity or quality of contamination which will discharge from a waste disposal facility and uncertainty factors on the order of at least 5 times are common in the measurement of parameters such as hydraulic



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Feenstra, cr ex (Estrin)

conductivity and therefore large safety margins should
be incorporated into all estimates of contaminant
discharge?

A. Yes.

Q. Do you agree or disagree with the
statement that uncertainty factors on the order of at
least 5 times are common in the measurement of parameters
such as hydraulic conductivity?

A. With respect, we were just talking
moments ago about two different things and one was the
actual uncertainty in a single Hvorslev hydraulic
conductivity measurement and the other is the range
in hydraulic conductivity that one would expect to find
in a particular geological unit.

Q. Yes, there was elements of both
of that in our discussion.

A. I would say there is certainly a
large range, or you may refer to it as a degree of
uncertainty in the values you would get for a particular
geological unit.

Q. All right. Let's take the
geological unit I have directed your attention to, the
unweathered upper till, the number ascribed as 8.0×10^{-8} ?



A. Yes.

1 Q. First of all, you said the
2 significance of the 8.0, I think we should consider it
3 as just 8?

4 A. I wouldn't report it as 8.0.

5 Q. You would report it as 8?

6 A. Yes.

7 Q. That means it is plus or minus
8 what?
9

10 A. It depends on what your value is
11 because the difference between 1 and 1.5 is not the
12 same as 8 and 8.5 as a percentage, but ...

13 Q. Are you prepared to agree or dis-
14 agree that in reporting the value of 8.0, that that number
15 should be considered to have at least an uncertainty
16 factor on the order of at least 5 times and if not ...

17 A. No, I don't think I would
18 because of the additional evidence we have from the
19 tritium information and the fact there is no tritium --
20 you see, every time you get an additional piece of
21 information the level of uncertainty hopefully declines.
22

23 Q. Okay. Mr. Feenstra, I want you
24 to just for the moment assume that the tritium data is
25



not valid or isn't even there. Make that assumption because that may be less objectionable to assume it doesn't exist, just for the moment?

A. I will make that assumption if you wish.

Q. What certainty or uncertainty factor would you put on 8×10^{-8} derived from Hvorslev?

A. Derived from Hvorslev for that unit?

Q. For that unit.

A. I probably wouldn't dispute a factor of 5.

Q. Now, let's talk about the tritium?

A. Are we finished with this?

Q. I don't know, but we are moving on to tritium for the moment. The tritium results at Site D you have just reminded us are taken from a very small area of the site, there are about 3 or 4 tritium holes in a very small geographic area?

A. I believe there are 6 tritium holes and they are all within one borehole location.

Q. Yes, okay. Mr. Feenstra, if the -- the determination of hydraulic conductivity based on



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tritium numbers is dependent not only on the tritium numbers that are actually measured, assuming they are accurate, but also on what you say is the hydraulic gradient at that location?

A. That is correct.

Q. Therefore if the gradient -- you have to put together the gradient and an assumed porosity?

A. That is correct.

Q. Now, I take it that in the tritium results reported for Site D a certain gradient is used?

A. That is correct. The gradient measured between those particular wells that were sampled for tritium.

Q. If the gradient -- are you able to reasonably quickly put your finger on what that gradient is?

A. I was just going to do that right now. I managed to locate the gradients, Exhibit H-181, but was there also an exhibit showing the calculation of the penetration depth that went in with that exhibit? I think there was and if I could just see this for a



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moment.

1 Q. In any event, we need not get into
2 exact numbers we are just speaking in general principles
3 at this point, but go ahead if you want to check some-
4 thing out. My question is simply if the gradients
5 can be shown to be different because, for example, the
6 different -- because of the way in which the gradients
7 were measured, for example, then that could have some
8 bearing on what inferences one draws from the tritium
9 values?
10

11 A. If the gradients were substantially
12 different, they would, yes, because they were input
13 parameters for that calculation.
14

15 Q. If the gradients weren't as much
16 downward as was assumed in this exhibit, that could --
17 Exhibit 181 -- that could account for why the tritium
18 hasn't gotten as far as one might otherwise say it
19 should?
20

21 A. That is correct.

22 Q. Similarly, if in fact there were
23 upward gradients at Site D in other locations than
24 where the tritium tests were taken, say upward from
25 the upper granular unit to where the tritium -- to say



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the upper weathered till -- the upper unweathered till,
that could also affect the validity of using any
results ascribed to the tritium locations where the
gradients were down?

A. That is also correct. Would you
have any information for me that shows those upper
gradients?

Q. Not at the moment.

A. Okay.

Q. Are you saying that you are not
aware of any upper gradients at Site D?

A. I can't recall any at the present
time.

Q. But, you are the one who asked
me.

A. Fair enough.

Q. I take it you were a bit surprised
by the suggestion that it could be?

A. A little bit surprised, yes.

Q. But that wasn't an area you were
asked to specifically address?

A. I did not specifically review that,
no.

Q. Mr. Feenstra, let's come to the

14B



1 Gartner Lee 1987 results. What I find a little
2 puzzling is that Gartner Lee's installations, as I
3 understand it, for the plume delineation study, and
4 those were used again as I understand it in 1987 plus
5 some new ones, but they were constructed of stainless
6 steel?

7 A. That is correct.

8 Q. What is it in your view that
9 could give rise to contamination of these samples?

10 A. Stainless steel wells are obviously--
11 as was described earlier in these proceedings -- the
12 preferable material for installation of monitoring
13 wells for the analysis of organic chemicals, primarily
14 because there are no organic compounds inherent in the
15 steel itself. However, in the machining, particularly
16 the threading of the coupled ends of stainless steel
17 well screens and stainless steel casings, quite a wide
18 variety of cutting oils or cutting fluids are used and
19 many of these cutting fluids contain some of the
20 solvents, particularly 1, 1, 1-trichloroethane, that is
21 of concern in groundwater at this location and in
22 other locations also.

23 So, it is quite important that stainless
24
25



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1 steel wells be very thoroughly cleaned before they are
2 installed. In the projects I have been involved in where
3 we have installed wells specifically for the purpose of
4 monitoring low levels of organic contaminants, we have
5 cleaned the pipe in the field with a portable steam
6 cleaning device which allows initial cleaning of the
7 pipe with high pressure, high temperature water with
8 detergent added, and then very thorough rinsing without
9 detergent and we have had very good success cleaning
10 installations in the field immediately before lowering
11 them into the borehole and installing them in the ground.

12 It is my understanding that this wasn't
13 actually performed by Gartner Lee at the Burlington
14 site and the steel casing, the steel pipe, was cleaned
15 by the manufacturer prior to being delivered on-site.
16 I understand the cleaning methodology was referred to as
17 a hot caustic bath which would be basically a hot
18 strong detergent, and many detergents being quite caustic,
19 and with the intention of moving any residual cutting
20 fluids or other oils. We have seen pieces of pipe
21 which have been lying around the warehouse for a
22 while and you know how dirty they can be, they are
23 greasy on the inside and the outside, and that material
24
25



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has to be removed before you install it. I am not entirely sure of the effectiveness of this kind of cleaning procedure and that is a possibility at the Burlington site. I don't have personal experience with that type of cleaning methodology by the manufacturer.

Q. Aside from contamination you just described with the installation of the stainless steel pipe, is there any other source of potential contamination when one goes to actually take the samples?

A. There certainly is and in fact there are many possible sources. The Gartner Lee installations installed in 1986 and sampled in 1986, the samples were actually recovered from the wells by using either a piece of teflon tubing in the shallow wells and the recovery of the sample with a peristaltic pump, which is a small pump with a rotating head on a flexible tubing, and it is basically a vacuum pump, but the pumping mechanism doesn't contact directly the water passing through it, it just squeezes the tubing and creates a vacuum in that manner.

It is my understanding that dedicated



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pieces of teflon tubing were used and in that particular well the tubing used was not used in another well later. In other wells, deeper wells, something called a Waterra pump was used which is basically a hand-operated lift pump which has a small flapper valve on the bottom and a pump assembly and it actually moves the tubing with the flapper valve on the bottom up and down and, as you can imagine, when it goes down the flapper valve opens and when it opens it closes and brings the column of water up.

Waterra pumps are constructed of, I believe, polypropylene tubing and dolrane plastic, but in general it is my understanding that solvent cements and other types of compounds aren't using in the construction of Waterra pumps and I understand some kind of chemical testing has been undertaken on the Waterra pumps to see if they are subject to contamination, extraneous contamination of water samples collected, but I have not seen the results of those tests.

Another potential -- obviously any time you use tubing that comes in contact with the water samples or pumps that come in contact with the water samples, you must also be sure they are absolutely clean



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because they can impart contaminants to the water
samples you collect with them.

Q. How do you make sure the tubing
is absolutely clean?

A. It is difficult. It is difficult.
Generally to clean materials or to clean sampling
materials for sampling for trace organics, what is
often done is to rinse the material, the plastic
material or stainless steel or whatever your device is
made of, with laboratory grade methanol which is a
good solvent and it will tend to remove any of the
organic chemicals that are of concern in groundwater,
with methanol very seldom being a pollutant of concern
but also methanol is water soluble and after the
methanol rinse it can be effectively washed away
taking with it any other residual chemicals with
organic-free laboratory grade water or de-ionized water.

There are better solvents for removing
surface contaminants on materials but most of those
aren't soluble in water and they themselves are not
easily removed. Now, if I could continue, there is
another possible source of contamination for volatile
organics and that rests with the actual sample containers,



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the sample vials that are used. The general practice is to rinse -- the general practice, aside from the Ministry of the Environment, I understand, but is to use a 40 ml volatile vial, and they use a slightly different sample container and I am not sure of the rationale for that, but the typical container for the analysis of volatile organics in groundwater is a 40 ml vial which is about this high.

Q. Three inches?

A. Three inches high and cylindrical in shape and about an inch in diameter and it is capped with a cap with a hole in the top and on top of the actual bottle rests a septum, teflon lined on the inside and silicone rubber on the back and the cap goes on top over the septum. When the sample container is filled it's filled up to the top so there is no air space and the septum is put on and it is tightly capped, and the only reason for a septum cap is that in a laboratory the chemist can go in with a needle and syringe and withdraw an appropriate volume of sample for analysis and he never has to open the bottle again.

The difficulty with the septum cap is that although it is quite impermeable to volatile



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organic vapours, you can get diffusion through that septum and that is why there is a minimum holding or a maximum recommended holding time prior to the analysis of volatile organics, that being two weeks.

DR. KINGHAM: Could you just repeat that statement you just made?

THE WITNESS: The last statement?

DR. KINGHAM: Although there is no diffusion through the septum?

THE WITNESS: Although the septum is relatively impermeable, there is the potential for the diffusion of the volatile organics in the long-term, in terms of several weeks.

DR. KINGHAM: I didn't hear the relatively.

THE WITNESS: In terms of the sample containers themselves, the standard practice is obviously if they are new containers or used containers, containers that have been used for prior samples, they would be washed in detergent and water and rinsed off with de-ionized water so they are physically clean, but they would also be rinsed with again a water-soluble solvent like acetone or methanol to try and clean off any



organic constituents which might be absorbed or adhering to the inside of the jar and at that stage the jars are put in an oven and basically baked for several hours to make sure residual solvents used to clean the bottles is gone and any other volatiles which might have been present are also removed and they are baked at about 250 degrees Celsius for several hours.

So, there are a great number of procedures one has to follow to ensure that you get groundwater samples that actually reflect the constituents present in the groundwater.

MR. ESTRIN: Q. Given all those potential sources of contamination, are they of the sort in your experience or in your opinion that could give rise to two or three or four parts per billion of the various things that were on the overheads you showed to the Board?

A. They certainly are, yes.

Q. What would be a reasonable range for sampling -- installation and sampling contamination, even assuming stainless steel installations. Have you any basis for ascribing a range beyond which you might say it is not sampling, it has got to be, you know,



something you are measuring?

1 A. That is reasonably difficult to
2 say because the level of contamination will depend
3 upon what level of contamination was physically on the
4 well material you used or the pumping used, but
5 it also relates to the geological environment it is
6 in in terms of how much water you have removed from the
7 monitoring well before you sample. It is quite possible
8 that installations in a reasonably low permeability
9 shale are much more subject to the effects of extraneous
10 contamination than a well in a sand aquifer where there
11 is a lot of water going by and where you purge the well
12 prior to sampling and you flush out much more water,
13 because the more water you flush through the well
14 casing or your sampling pump before you sample the
15 less should be the degree of any extraneous contamination.

16 It is really quite variable. The maximum
17 range I would expect would be something -- probably
18 tens of micrograms per litre. It would be a very rare
19 situation I think where you could explain hundreds of
20 micrograms per litre in terms of equipment contamination,
21 unless absolutely no precautions were taken.

22 Q. Looking at Exhibit H-246, the
23
24
25



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Gartner Lee data just for a second...

1 DR. KINGHAM: The number again?

2 MR. ESTRIN: Q.H-246, the table from the
3 Mann Laboratories and just say the first page, and
4 looking at benzene for the moment, as I understand
5 this the method detection limit was .5 ppb and then
6 in piezometer whatever it is, sampling location 23-3,
7 the measurement was .55 and that is just over the
8 detection limit?

9
10 A. Yes.

11 Q. What margin of error in your
12 opinion is there in a figure such as .55. How high
13 or how low should we ...

14 A. It is quite possible that the
15 level of precision or reproducibility of that analysis
16 was probably in the order of something like 10 to 20
17 per cent. That is very close to the detection limit.

18
19 Q. So, it might not be there at all?

20 A. That is a possibility and certainly
21 in my opinion as I was mentioning earlier about not
22 expressing a decimal point in hydraulic conductivity
23 measurements, I would not report chemical analyses like
24 this with three significant figures. I would only report
25 two. In other words, the 3.69 would not show up in one



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of my reports but would be 3.7.

1 Q. Then, you gave us various reasons
2 why the results in H-246 in your opinion reflected
3 some degree of extraneous contamination from sampling
4 or equipment or whatever and there was one other reason
5 that I wanted to ask you about to consider in this and
6 that was retardation factors. Do you understand what
7 I mean by that and you probably understand it more than
8 I understand it?
9

10 A. That is true. It is true that
11 I probably understand it more, but I think I understand
12 your question. With respect to the variety of organic
13 chemicals identified in the leachate, the volatile
14 organic chemicals, although we expect there to be a
15 range in the degree of retardation in each of those
16 compounds, in general terms their behaviour will
17 be relatively similar. In a monitoring well close
18 to the landfill that we expect would be fully
19 impacted by leachate after 15 or 30 years since the
20 landfill has been in operation, we would expect
21 to find most of the chemicals at a monitoring location
22 such as that which were identified in the landfill.
23
24

25 In other words, the differences in

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retardation are such that at a point close to the landfill you should expect to see what is basically in the landfill leachate and in terms of the results then in GL-24, the 1986 data, the fact we only see trichloroethane and dichloromethane and chloroform makes one wonder why on earth we do not see the 1, 1-dichloroethylene which is present in very high concentrations in the leachate, and you would expect it to be as mobile or more mobile than some of the other compounds, and why we only see small concentrations of benzene and we don't see any xylene and we don't see any 1, 2-dichloroethane which is also present in several thousand micrograms per litre in the leachate.

So, it is an additional point, a point that in the monitoring well particularly close to the landfill, GL-24, the fact we don't see the compounds we would expect based on what's in the leachate gives further support to the conclusion that the concentrations we do see may be extraneous contamination.

One other point I should make and I am not sure I made it earlier this morning is with respect to the chloroform that is found in many of the wells. It was also found in the trip blank and so it is quite



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1 certain that that chloroform represents some sort of
2 contamination either in the laboratory or with respect
3 to the sample containers. It is also possible that
4 the dichloromethane which is basically -- chloroform is
5 trichloromethane and dichloromethane is a reasonably
6 common degradation product of chloroform and that is
7 generally bacterially mediated, or in other words a
8 biotransformation, and I am not very certain whether
9 it is possible for that to happen during sample storage,
10 but that is another factor that one might consider, that
11 dichloromethane and chloroform might somehow be related.

12 MR. ESTRIN: Even if we went to
13 five o'clock I won't be finished this afternoon so I
14 am at your pleasure.

15 DR. KINGHAM: I understand there may be
16 a time limit on this and we are prepared to continue
17 on Monday morning.

18 MR. ESTRIN: Whichever.

19 DR. KINGHAM: We will adjourn until 9:30
20 Monday morning. Thank you very much.

21 ---Adjournment at 4:35 p.m.

22 Certified Correct

23
24
25 

C. F. Nethercut, C.V.R.

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