DEEP GEOLOGIC REPOSITORY

JOINT REVIEW PANEL

HEARING HELD AT

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Thursday, October 11, 2012

JOINT REVIEW PANEL

Ms. Stella Swanson
Dr. Gunter Muecke
Dr. Jamie Archibald

PANEL CO-MANAGER
Ms. Kelly McGee

Transcription Services By:

International Reporting Inc.
41-5450 Canotek Road
Gloucester, Ontario
K1J 9G2
www.irri.net
1-800-899-0006

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Ottawa, Ontario

--- Upon commencing on Thursday, October 11, 2012 at 9:03 a.m.

Opening Remarks

MS. McGEE: Bonjour, mesdames et messieurs. Bienvenue à la réunion publique de la Commission d’examen conjoint pour le projet de stockage de déchets radioactifs à faible et moyenne activité dans des formations géologiques profondes.

Welcome to the second technical information session of the Joint Review Panel for the Deep Geologic Repository Project for Low and Intermediate Level Radioactive Waste.

My name is Kelly McGee. I am the co-manager for the joint review panel. J’aimerais aborder certains aspects touchant le déroulement de cette réunion. The public review and comment period for this project began on February 2, 2012.

Today’s meeting is a technical information session with presentations by the applicant Ontario Power Generation and the Nuclear Waste Management Organization.

During today's business we have simultaneous translation. Des appareils de traduction sont disponibles à la réception. La version française est au poste 2. The English version is on Channel 1. Please keep the pace of your speech relatively slow so that the translators can keep up.

La réunion est enregistrée et transcrite textuellement. Les transcriptions se font dans l'une ou l'autre des langues officielles compte tenu de la langue utilisée par le participant. Les transcriptions seront disponibles sur le site web de la Commission dès la semaine prochaine. Please identify yourself before speaking so that the transcripts are as clear and complete as possible.

I'd also like to note that this session is being video webcasted live and that the webcast will be archived on the CNSC website.

Please silence your cell phones and other electronic devices.

Dr. Swanson, the Chair of the Joint Review Panel, will preside at today's meeting.

Dr. Swanson.

THE CHAIRPERSON: Good morning and welcome to the technical information session of the Deep Geologic Repository Joint Review Panel. My name is Dr. Stella Swanson. Welcome to everyone here today in person and to those joining us via the webcast.

I would like to begin by introducing the Members of the Joint Review Panel. On my right is Dr. Gunter Muecke and on my left is Dr. Jamie Archibald. You have heard from the Panel's co-manager Kelly McGee.

I would like to address a few matters before we begin today's presentations.

At the Panel's two previous public sessions, I stressed the utmost importance that the Panel members place on our impartiality, neutrality, and transparency.

These will continue to be essential measures of the Panel's review until we complete our mandate.

All submissions to the Panel and all of the information requests originating with the Panel are publicly available on the online public registry for this project. Only in exceptional circumstances such as security-related information will a document not be publicly available.

The current public review and comment period does not offer opportunities for face-to-face presentations by everyone who would like to address the Panel. This opportunity will be available at the public hearing. However, it is a cornerstone of this process to encourage everyone's participation including federal, provincial, and municipal government organizations, Aboriginal groups and members of the public.

Through access to documents on the on-line public registry, live webcasts of public sessions such as today's and archived access to both transcripts and webcasts, the Panel is doing everything we can to be open, accessible and transparent.

As an example of this commitment, the Panel's questions today are in relatively plain language in order that the session is as accessible as possible. Accordingly, I ask OPG and NWMO to try to word their answers as clearly as you can and in as much plain language as possible.

When the Panel determines that we have sufficient information to proceed to the public-hearing stage of this review, there will be hearings in Kincardine, Ontario.

The Panel encourages everyone with an interest in this project to regularly visit the on-line public registry for the latest editions. If you have not already done so, please take a minute to register as an Interested Party. This will ensure that all major announcements by the Panel are automatically forwarded to you by email.

The goal of today's information session is to provide additional information on the modelling used by Ontario Power Generation in the preparation of its environmental impact statement. Today’s modelling technical information session will focus on fundamental aspects of the models that contribute to confidence in the model predictions, including calibration and verification of the models and uncertainty analysis. Today’s session will focus on the hydrogeology, repository evolution air quality, noise and radiation dose models.

If at any time during the review, you have information that you wish to bring to the attention of the Panel, please direct your correspondence to the Panel’s co-managers. Alternatives for contacting the Panel’s Secretariat are available on the Canadian Environmental Assessment Registry website for this project. The Panel co-managers, together with other members of the Panel Secretariat, will ensure that information for the Panel’s consideration is brought to our attention and all submissions are posted on the public registry.

While the Agenda for today’s technical information session has generous allotments of time for questions from the Panel, our questions will be limited to those associated with the purpose of today’s meeting. Today’s technical information session was organized to provide an efficient and effective presentation of new information that the Panel requires as part of our public review. The purpose of this session is not to test either the validity of information already on the public record or the new information presented today.

The public was invited to attend this session either in person or by watching the webcast. The Panel encourages anyone that has questions arising from today's session to forward the questions in writing to the Panel Secretariat. The Panel will review all questions relating to information presented at today's session and determine if an answer to the question is required in order for Ontario Power Generation to fulfil its obligations under the Environment Impact Statement Guidelines.

In addition to submitting questions arising from today's session, the ongoing public review and comment period is an opportunity for everyone to provide their views to the Panel on whether the Environmental Impact Statement and documents submitted in support of the licence application adequately address the Guidelines issued to Ontario Power Generation.

While the end of the public review and comment period was expected to end on August 3rd, 2012, this end date has been extended to accommodate the time required by OPG to respond to information requests from the Panel. The new comment period deadline will be announced at a later date and interested parties will be given one month's notice before that end date.

Before I call on Ontario Power Generation to begin their presentation, the Panel would also like to note that we'll be pausing after each subsection of your major parts of the presentation in order that there is a greater opportunity to keep track of the information as it's being presented and ask questions on the subsections of the presentation. I will give the presenters a heads up when -- at the end of your presentation and we're due for questions on that subpart.

So with that, I would like to call upon Ontario Power Generation to begin their presentation.

Mr. Sullivan, the floor is yours.

MR. SULLIVAN: Thank you, Dr. Swanson, and good morning.

For the record, my name is Gord Sullivan, Project Manager for the Deep Geological Repository Project and Ontario Power Generation.

We are pleased to be here to provide the Joint Review Panel with additional information on modelling used and the preparation of the Environmental Impact Statement and the Preliminary Safety Report as requested in your July 31st letter to Ontario Power

Generation.

I am accompanied here today, on my far right, by Frank King, Vice President and Chief Engineer, Nuclear Waste Management Organization. On my immediate right is Marc Jensen, Director DGR Geoscience and Research at the Nuclear Waste Management Organization who will be leading part 1 of our 4-part presentation. Parts 2 and 3 will be led by Dr. Paul Gierszewski, Director Repository Safety at the Nuclear Waste Management Organization and part 4 will be led by Diane Barker, Manager Environment Assessment at the Nuclear Waste Management Organization.

We also have other individuals here today who will be making presentations and they will be introduced later.

I will now ask Frank King, NWMO, to start this session by providing a brief introduction on the role of the computer models in developing a safety case for OPG’s DGR.

MR. KING: Frank King, for the record.

The computer models to be discussed in Part 1, 2 and 3 of the presentation today were used in developing the safety case for OPG’s Deep Geologic Repository or DGR. The safety case is summarized in Chapter 14 of the Preliminary Safety Report.

Two key elements of the DGR safety case are the pre-closure safety assessment and the post-closure safety assessment where pre-closure refers to that time period prior to the facility decommissioning and shaft sealing and post-closure refers to the time after extending many hundreds of thousands of years.

The computer models MicroShield, MicroSkyshine and MCMP and the non-human biota dose assessment to be discussed in Part 3 of the presentation were used in support of the pre-closure safety assessment. The computer models AERMOD and CADNA/A to be discussed in Part 4 of the presentation were used to assess environmental impacts during site preparation and construction, DGR operation and DGR decommissioning.

The safety objective for the post-closure period in all Deep Geologic Repositories is to provide isolation and containment of the waste. Isolation is achieved in the case of OPG’s DGR by emplacing the waste 680 metres below surface. Containment is achieved by emplacing the waste in a stable rock formations where contaminant transport in the rock mass is controlled by diffusion, an extremely slow process, and by assuring that the back-filled shafts also provide an effective deterrent to contaminant transport to the surface environment.

The use of computer models to be discussed in Part 1 of the presentation today, together with information collected during the borehole drilling program at the cite, conducted between 2006 and 2010, have resulted in the conclusion that contaminant transport in the rock mass is diffusion controlled.

The use of the FLAC3D computer model to be discussed in Part 2 of the presentation contributed to the conclusion that shaft seals will provide an effective long-term barrier to contaminant transport.

The other computer models in Part 2 have been used to estimate potential dose impacts to future receptors under expected and hypothetical "what-if" scenarios to demonstrate the robustness of the design.

Mark Jensen will be introducing Part 1 and making the first presentation.

ORAL PRESENTATION PART 1: GEOSCIENCE MODELLING

MR. JENSEN: Mark Jensen, for the record. Thank you, good morning.

In Part 1 of today's presentation the application of numerical models in the DGR-GF Science Program will be discussed. The presentation has been divided into four sections. The first section addresses geology and the development of a regional scale stratigraphic model known as the three-dimensional geologic framework model, or 3DGFM.

The second section involves a description of hydrogeologic numerical modelling at Michigan Basin, Regional and DGR site scales using the code FRAC3DVS-OPG.

The third section is an exploration of groundwater system properties and phenomena contributing to the observed under pressures within the Ordovician sediments that are proposed to host and enclose the DGR with the code TOUGH2-MP.

And the final section, the fourth, will investigate or describe a natural site-specific analog that explores processes governing mass transport within the Ordovician sediments through an assessment of environmental tracer distributions with the code MIN3P.

In addition to these numerical codes FLAC3D was also used in the geosciences program to explore long-term DGR shaft seal and excavation damage zone evolution. This code will be discussed in Part 2 of this second technical information session presentation devoted to repository evolution.

Within the geosciences work program numerical models are used in a variety of ways to aid in developing confidence in the interpretation and understanding of geoscience or geosphere properties, behaviour and stability as it may influence long-term DGR performance and safety.

While numerical codes are typically used for forward prediction in geosciences the codes have been used for other purposes as well.

Key applications include: Conceptual groundwater system development. The purpose here is to use numerical models to test for internal consistency when multi-disciplinary datasets are integrated; can those datasets coexist?

Second, groundwater system boundary conditions. This is necessary to run models to establish a recent basis for establishing boundary conditions for long-term groundwater system analyses.

Illustrative simulations. The necessity here is to provide illustrative simulations of groundwater system properties, boundary conditions or phenomena, at time and space scales not otherwise possible, and to compare these predictions to site observations.

This approach is helpful in contributing to a sense of confidence supporting the sensibility and reliability of groundwater system interpretations.

Hypothesis testing. To test and illustrate the validity of hypothesis regarding groundwater system stability and evolution. The key example here is the diffusion dominated transport hypothesis, that was one of seven hypothesis explored by the geosciences work program.

Paleohydrogeology. Paleohydrogeology speaks to the use of numerical codes to examine the response of the groundwater systems to external perturbations, for example glaciation and permafrost.

These codes are particularly useful at demonstrating the performance and resilience or stability of the groundwater system to these external changes.

And lastly, system uncertainty. Sensitivity and bounding analyses or assessments that assist in developing confidence in site datasets and overall groundwater system behaviour is relevant to DGR safety.

In other words, that the repository is situated at 680 metres below ground surface in an ancient deep-seated extremely permeability groundwater system in which mass transport has remained diffusion-dominated for geologic periods of time, which is a key element to the DGR safety cases described by Mr. King.

It should be acknowledged that while the application of numerical models has been particularly useful in the testing of notions of groundwater system property stability and behaviour, the interpretation of the confinement provided by the geosphere is not based on numerical models alone.

The understanding of geosphere barrier performance is the combined result of regional and site-specific multidisciplinary data interpretation and integration, coupled with numerical simulations.

It is this coupled understanding as summarized in the geosynthesis document that has been used to directly support realizations of the DGR concept and safety analyses and the predictions of effective containment and isolation.

I'm joined here today by Professor John Sykes from the Department of Civil and Environmental Engineering at the University of Waterloo. Professor Sykes will present Parts 2 and 3 of this presentation. And I'm also joined by Professor Tom Al from the Department of Earth Sciences at the University of New Brunswick, who will present section 4.

I would like to begin with section 1, the overview of the three-dimensional geologic framework model.

MR. JENSEN: Mark Jensen for the record.

The 3-DGFM, or three dimensional geologic framework model was designed to develop a three-dimensional geologic framework that describes a sedimentary bedrock stratigraphy in geometric continuity or traceability within a 35,000 square kilometre region enclosing the DGR and Bruce site.

The intent was to develop and informed basis using historical geologic information that was used in two ways. First it was used to test the hypothesis about the lateral continuity of the bedrock units as they occur, and the second was to allow an informed geologic stratigraphic model that could be used for paleohydrogeologic simulations.

The model boundaries, just for framework is shown here on the lower left, the red box. It shows the 35,000 square kilometre region, and a cross-section through that, A-prime is shown from the 3-DGFM model on the right.

I would like to point out the location of the deep geologic repository in the blue mid-Ordovician sediments there that you can see directly beneath the site. You will hear the term "Ordovician sediments" used throughout this morning's presentations, and it refers to the sediments, the sedimentary of a 400 metre thick sedimentary package that includes 200 metres of shale overlying 200 metres of carbonate or dolsotone and limestone rocks. These are the rocks that host and enclose the repository.

In terms of the datasets that were used for the development of the stratigraphic model a key dataset was the Ontario Oil, Gas and Salt Resources Library, Petroleum Well Subsurface Database, that records information from subsurface boring, between a period of 1930 to present.

In addition to this Ontario Geological Survey Digital bedrock maps providing seamless coverage were used at a scale of 1 to 50,000. This data is up to date to 1988. Historic borehole geophysical survey logs were used to confirm historic picks within the historic borehole well logs.

Ontario Geological Survey Open File Report 6191, An Updated Guide to Paleozoic Stratigraphy of Southern Ontario, was also used in assessing the acceptability of the interpretations of the stratigraphy on the site. We also ensured that the nomenclature, the stratigraphic nomenclature, matched what was provided within this report.

Beyond the boundaries of the Regional Study Area, we also used to inform the process, well records from the Michigan Department of Natural Resources in their petroleum well database; 70 plus wells were used. Ontario Geological Survey digital bedrock topography and overburdened thickness maps were also used in preparing the three dimensional model as well as NOAA, or National Oceanic and Atmospheric Administration bathymetry mapping data for Lake Huron and Georgian Bay were also incorporated into the model.

Move to Slide 5. As part of the process in developing the stratigraphic model, there was a data verification step. This data verification step involved screening of the information available from the historic well logs. Three issues were examined. In particular, work was done to detect historic well log airs. This would include no data, incorrect stratigraphic contact elevations, or incorrect collar ground surface elevations within the records themselves.

Secondly, the determination of correct stratigraphic relationships were recorded correctly in the well logs, and this was done by comparison of adjacent well logs to ensure that there was consistency.

Lastly, when available, geophysical well logs were used to confirm stratigraphic picks and to ensure that the geophysics and the picks were consistent with that proposed by the OGS Open File Report 6191. As a result of this data screening process, of the 341 well records that were within the Regional Study Area, 299 were accepted.

All of the decisions with regards to the screening are documented in a report that supports the geosynthesis document that is publicly available and listed in Appendix C of that report.

Slide 6. The 3-DGFM modelling approach involved a workflow involving first source well data verification from which the input of the confirmed or confident formation top picks was used. That was used; those formation picks were used to develop a surface for that particular -- an upper surface for that formation. The information was then used at these different spatial or punctual locations to calculate the thickness of the overlying bedrock. That was then added to the underlying unit to develop the surface of the overlying unit.

In generating these surfaces, the model GOCAD, or the commercially available software, this is a three dimensional visualization software package, was used to create the surfaces. Once the surfaces were created there was manual intervention by a geologist based on geologic knowledge of certain issues with regards to the stratigraphy, in particular, to ensure that erosional contacts or pinchouts or that pinnacle reefs or barrier reef type structures were properly represented within the structural -- the stratigraphic model.

On the right, you can see an ISOPAC or a thickness model of the Ordovician shales that exist at the DGR and elsewhere within the Regional Study Area.

In terms of model testing, testing was done at two scales, the regional and the site specific. In this figure, on Slide 7, what is shown is the data sets that we had with verified data or the screened data. Two-thirds of that data set were used to create the surfaces. In this case, for the Sherman Fall Formation, which is directly beneath the Cobourg Formation in which the repository is –- would be constructed. Once that surface had been created, the remaining third of the data were compared to the surface to see how well the fit is.

The red-dashed line in this Slide 7 represents a one-to-one correlation, and as you can see, those 15 data points, that were left out and then brought into check for correlation, show extremely good matches over a regional distance. Typically, on the order of several metres.

At the site scale, we had better control on understanding stratigraphy due to the fact that we were -- had rock core. What is shown in Slide 8 is a table of a comparison of the 3-DGFM predicted picks for Borehole DGR-4. This was a vertical cored borehole on the Bruce site, and in the far right column, you can see the airs between the predicted and the observed. This was a prediction done in advance of drilling DGR-4.

The only air, it's an enlarged air of 16 metres, is shown there in the red box, occurred during site -- during core workshops that we held. We held four core workshops that involved Canadian Geological Survey or the Geological Survey of Canada, the Ontario Geological Survey, and the Ontario Ministry of Natural Resources, where we developed a consensus on the formation contact picks, and this air resulted from that process, but it does not materially affect the 3-DGFM as it was used within the paleo-hydrogeologic simulations.

In Slide 9, a confidence assessment is discussed. There are particularly five items, six items, excuse me, that I would like to mention.

The first is, is that confidence is instilled through the data screening process of the historic oil, gas, and salt resources library well logs.

Second, model verification was vetted using three dimensional visualization techniques. This allowed well log data to be checked against published well reference data. Model formation surfaces reflect all the reference data points and contacts that were within the screened data sets, and the model formation surfaces were manually refined to reflect current geologic understanding within the Regional Study Area.

The three dimensional geologic framework model is consistent with published bedrock geology, bedrock topography, and Lake Huron Bathymetry data sets.

Fourthly, the model passes both regional and site specific performance tests as required for its usage.

Second to last, peer review, and this included the four workshops that we held at the Bruce site where all the core was placed out and made available for review by geological surveys to develop a consensus on the picks to ensure consistency in all the work that was done on the Bruce site.

Lastly, the data that was used in the model is publicly available in the report for independent assessment and improvement.

The last slide, Slide 10, provides a listing of relative contributions to confidence. You will see in all of the presentations today a slide like this will be presented. In terms of relative confidence, the system is used as lower, one cross, two crosses represents medium, and three crosses represents higher.

In this particular case, I've divided the relative contribution, both at the regional scale and at the site scale. Data verification in terms of the screening provides a moderate degree of confidence certainly that the represented stratigraphy model developed is correct. The core workshop consensus was particularly useful at the site scale at ensuring that we had consistency in core picks at the site with the rock core that we obtained.

Data calibration with the ability to check nearest neighbour boreholes a lower degree of confidence was instilled form the geologic data, or the borehole dataset given the distance between the wells, but clearly at the site scale it is extremely high given that the wells are separated by distances of around 1.2 kilometres.

In terms of data certainty, moderate to high confidence is available at regional and site scale. Overall model confidence is moderate with regards to the regional scale model, but extremely high with respect to the site-specific model.

This is in particular case with regards to the lateral stratigraphic traceability of formations throughout the regional area and the site-specific area. Estimated thicknesses, a slight decrease in relative confidence within the regional study area, but extremely high in the site-specific area where formation thicknesses, and strikes, and dips remained constant throughout the Ordovician sediments and the Silurian sediments that overlay.

Structurally the 3-DGFM model cannot be used to do structural interpretations given the limitations in the borehole data, but certainly at the site scale the high quality data that was obtained can be used to make decisions with regards to structural framework.

I'd like to end the presentation here. Thank you.

QUESTIONS BY THE PANEL ON PART 1:

THE CHAIRPERSON: Thank you very much. So this will be the first pause for questions from the panel. In this case related to the 3-DGFM modelling.

Dr. Muecke, would you like to start the questioning?

MEMBER MUECKE: Yes, thank you.

Mr. Jensen, if you could go back to slide 3, please. And we see that the information is largely concentrated on site and regional areas. However, in some of the slides you showed cross-sections which involve basin scale.

So my question is; where are the basin scale data coming from, and what is the data distribution when you look at a basin scale? And how confident can you be when you extrapolate into the basin as is done in some of the hydrogeological studies?

MR. JENSEN: Mark Jensen for the record.

The 3-DGFM model focuses on the regional study area of course, and that is the northeastern flank of the Michigan basin. You are right, in the hydrogeologic modelling that Professor Sykes will be describing, in one particular case we looked at a cross-section through the entire basin with a distance, or a diameter of approximately 575 kilometres.

The stratigraphy in that is based on an understanding in published literature, both within Michigan and elsewhere and is listed within, and cited within the hydrogeologic modelling report, which is one of 14 supports the geosynthesis.

The confidence there is that the geometry of the Cambrian through Carboniferous units is sufficiently correct for purposes of doing that hydrogeologic modelling. But you're right, the confidence would be low to moderate.

MEMBER MUECKE: Thank you. And can you give me any idea of the size of the database that's involved, in addition to what is incorporated into the regional model? And secondly, the model that was used for the basin scale is the same model as was used for the regional and site scale?

MR. JENSEN: The basin scale model used the data that was in the 3-DGFM and of course extended that towards the west going through the centre of the basin over to its western flank, was using data that came from -- in published literature, scientific journals, peer review journals, and was based on borehole records throughout Michigan, and Wisconsin, and Illinois.

MEMBER MUECKE: Did that data undergo the same verification procedure as was for the regional?

MR. JENSEN: No.

MEMBER MUECKE: And if you could look at slide number 5 now. One notices that a majority of the available boreholes are clustered in the southwest corner of the region. And the data is rather more sparse by the time one gets to the region of the DGR.

So how confident are you that your interpolation methods can deal with this distribution? And what does it say about the confidence once one gets into a DGR site?

MR. JENSEN: Mark Jensen for the record. You're correct, the historic borehole records that are in the oil, gas and salt resources library database were drilled primarily for three reasons; 1) for salt exploration; 2) for oil and gas exploration within the Silurian, which is why they're sort of clustered down to the southwest. And for exploration within the Ordovician carbonates, the Black River and the Trenton groups.

In terms of the confidence that we have

what we tried to do, and which I tried to explain in the datasets that we've used, is to constrain the understanding of the stratigraphy in addition to these borehole records.

So for example, the 3-DGFM replicates closely the understanding of the subcrop and outcropping of the units at surface. It remains faithful to the bedrock typography and bathymetry.

It remains faithful to the cross-sections that are provided in Ontario Geological Survey Open File 6191, to ensure that there is consistency between these standardized geologic interpretative type well logs and whatnot.

So I think with the constraints that we have on surface bedrock geology, the historical database and consistency with published information within the last five to seven years are the most, not readily available, but the most recent interpretations. I believe that there is a moderate degree of confidence in the representation of the stratigraphy within this model.

MEMBER MUECKE: I believe the interpolation method that was used and it was kriging. Am I correct on that?

MR. JENSEN: Mark Jensen for the record. That is correct.

MEMBER MUECKE: And in kriging is it possible to evaluate the uncertainties quantitatively? In other words when you generate a service what is the possible error in the level of the elevation?

MR. JENSEN: I'd like to refer to Dr. Jon Sykes.

DR. SYKES: Jon Sykes for the record.

With kriging it is possible to estimate the variance. And two characteristics of this basin, one would be the top of any formation, the second would be the thickness. But the top of the formation is very, very predictable. The uncertainties in fact for the prediction are very, very small.

For the thickness there is a bit more of a variance there. And in fact, as you move to the east the standard deviation of the prediction can start to approach the mean. But there are four attributes of this basin that are very important to us. First of all is the top and that top is very, very predictable. Even when the data is sparse we could estimate where that surface is and you could put a hole at that location and you would be confirmed that in fact your estimate was correct.

The second one is the predictability that the formations, particularly for the Ordovician are always there. The Ordovician formations do not pinch out within the domain. They're continuous across it, and so there's no problem there.

The third thing are the attributes of the formations themselves. Very, very predictable. So the hydraulic conductivities, porosities are very constant within, sort of geologic terms, across this basin.

And, then the fourth is, of course, the thickness and that one there, there is some variation, but when you start looking at the flow attributes, there are two components to that; the first one is going to be the hydraulic conductivity or, the resistance to the water in that unit, very predictable, then it’s times the thickness, which even if there’s a little bit of an error, is actually very well-known relative to the hydraulic conductivity.

So, in the end, in spite of the scarcity of the data and in spite of the interpretation methods used, the system is actually very, very predictable and it should lead to confidence in the results.

MEMBER MUECKE: Thank you, Dr. Sykes. That was very informative, which brings me to my last question here and, Dr. Sykes may have partially addressed it already. Any geological formations at a site, scale and regional scales, as you know, I’m not totally homogenous, the layer, the formations, the layers, there are variations and, an extreme example being, for instance, in the Silurian, you have the highly permeable pocket reefs and, surrounded by less permeable layers.

So, my question is where is this variability when there is variability, where is this variability captured in the geoframe's modelling?

MR. JENSEN: Marc Jensen for the record. The variability is certainly within the modelling hydrogeological modelling is captured by the stipulation of the three dimensional hydro stratigraphy which is linked directly to the stratigraphic model and, then the assignment of properties.

In particular, what we have done is we've assigned the properties of the different stratigraphic units, there are 34; we have assigned the properties to them based on what we have observed at the Bruce site and, then we have modified them at near surface within the upper 20 metres or so, of the bedrock surface to enhance hydraulic conductivity and the like.

There was also a wide number of 36 simulations performed by the University of Waterloo. It looked at variable hydraulic conductivities and, variable 'what if' cases to look at different permeability distributions within key parts of the ground water system that were used to kind of illustrate what the impact of those changes in hydraulic conductivities would be on the diffusion dominated hypothesis within the Ordovician sediments.

So, it’s through that process that we looked at special variability.

MEMBER MUECKE: Yes, I understand that on a site scale because you have controls by the bore holes, obviously, you know, that didn’t previously exist. How far regionally can you extend that sort of confidence?

MR. JENSEN: Within the numerical models, we have assumed that, that based on the hydro geochemistry that we see at the site, based on the traceability of the bedrock units that we see beneath the site and, beyond the site boundaries that the properties that we observed are transferrable throughout the base.

As I suggested, we’ve done these ‘what if’ type scenarios that look at different permeability distributions within the different bedrock strata to try to get a better sense on how spatial variability might influence our predictions or upset our predictions.

In most cases, in all cases, clearly the conditions on spatial variability and hydraulic conductivity and the like, produced no material change in the understanding of ground water or mass transport within the Ordovician sediments. I might like to ask Professor

Sykes if he would like to add something, thank you.

DR. SYKES: John Sykes, for the record. The Cobourg formation is the host formation for the DGR. There's actual experience with that unit across the province, in particular, Darlington, there was experience in measuring the characteristics, properties of that unit. And the units there at Darlington are very consistent with those observed at the DGR.

The Ordovician units themselves, again, the characteristic are very predictable across the province; you tend to see hydraulic conductivities that are very, very low, consistently. And, any analysis that you do at the DGR, you'll find, in fact, that if the attribute that you're looking at is solute transport, that that attribute is very insensitive to large changes, even, of the hydraulic conductivities at distance from the DGR in the same unit.

And, so, that the two sides to this is the predictability of it, it is there for the Ordovician and, then whether model or any analysis is censored to it, and in that one, the answer is no.

MEMBER MUECKE: Thank you very much, Jon.

DR. SYKES: All right.

THE CHAIRPERSON: Thank you, Dr. Muecke. I have a question for Mr. Jensen on slide 10 please?

First of all, these summary slides are very useful, thank you very much. I think as a relative lay person when it comes to the geosphere, I would like to ask a question that represents, again, the Panel's need for some transparency and, some plain language, understanding of your rankings.

So, in slide 10, the highest ranking of relative contribution to confidence is assigned for all lines of evidence at the site scale, even though for me, as a biologist, it looks like there were relatively few bore holes at the site scale. In contrast, you gave a lower rating of confidence at the regional level despite the existence of a much larger data set and the validation as illustrated in slide 7, for example.

So, for the benefit of those of us who aren't as proficient in geological specialties, could you explain in a bit more detail why you are, as you said, have an extremely high level of confidence at the site scale, especially with respect to how sure you are on the data quality at the site scale, and how well those data truly cover the range of site scale variability in the lateral connections between the bedrock units, the thickness and the structural framework?

MR. JENSEN: Marc Jensen for the record. Thank you. The geoscience studies at the site were conducted over a four year period during which time we drilled six deep wells. These wells were cored, so we obtained rock core as a record of what we intersected in drilling these wells.

This information, coupled with geophysical logging of the bore holes themselves so that we can see geophysical signatures from the rock and, with respect to its mineralogy and properties, physical properties, porosity and the like, coupled with the two dimensional seismic surveys, reflection surveys that we conducted in the first phase of the work program coupled with the hydraulic in testing that we did, we did over 80 tests in 30 metre intervals to understand the hydraulic conductivity of the units; this work, all combined, provides us with a high degree of confidence at the system properties.

With regards to the stratigraphy, the distance between the wells is about 1.2 kilometres. We can trace individual marker beds between the three wells with a high degree of accuracy and predict within metres, their location.

The fact that we had the core workshops, where we had independent people from the geologic surveys and the Ministry of Natural Resources, check and confirm picked well formation contacts, was enormously reassuring to the program.

So, the rock core provided a strong degree of confidence that the stratigraphy and the bedrock formations and, even the faces changes in assemblages within, or the changes in the rock types within those formations were consistent across the site.

Formation thicknesses were typically within a metre or so, in difference across the site and the depth of these formations was consistent throughout the Ordovician section, and even into the solarium section above.

So, the core logging, the understanding of bedrock and confirmation of bedrock formation contacts, the thickness, the constant consistency in strike and dip, the low hydraulic conductivities that were measured, all paint a very confident picture at this particular site.

I would add that this work was all done under as quality assurance process. There were more than 49 test plans that were developed to assure that the work was conducted in a consistent fashion, and coupled with these multiple lines of geologic reasoning, the QA plan, I believe, justifies this extremely high degree of confidence that the site is how it is. And that the bedrock at the repository horizon, the Cobourg Formation, the overlying 200 metres of shale, the underlying 150 metres of carbonate rock are low hydraulic conductivity and diffusion dominated.

THE CHAIRPERSON: Thank you.

So I understand from your response that you are highly certain that there is a very low chance of a nasty surprise?

MR. JENSEN: Marc Jensen, for the record.

That is correct.

THE CHAIRPERSON: Thank you.

We will now proceed with -- oh, excuse me, Dr. Archibald.

MEMBER ARCHIBALD: Yes, I would just like to address one short question to Mr. Jensen. This was also mentioned by Mr. King.

You had mentioned that the site scale geosphere data was derived from borehole drilling conducted between 2006 and 2010 for a limited series of boreholes, 6 in number, and was used for the geoscience and repository evolution modelling at the site.

Has any more recent drilling data been achieved for the purpose of modelling, as we're discussing here, and for verification purposes of the previous data?

MR. JENSEN: Marc Jensen, for the record.

In 2011, boreholes were drilled with --

inside the perimeter at the main and vent shafts.

At the main shaft, cored borehole was placed down to about 720 metres to the bottom of the main shaft. My understanding is, is that the stratigraphic information was obtained in that -- is consistent with what we saw from the outer periphery. All the work that we had done previously had been done at least 100 metres away from the footprint of the repository, and now we had a borehole in the centre. So there was consistency and verification of what we had thought from the periphery.

My understanding is, is that this report is available and was discussed during the last Technical Information Session and was to be provided to you.

MEMBER ARCHIBALD: Yes, it was provided.

I believe my question was, has any of this been used to validate your previous modelling exercises?

MR. JENSEN: As the information was consistent with what we had seen from the work done in the submission, it remains conf'd (sic), yeah.

It has not been used to update it, but the information in terms of the stratigraphy shows that the site is consistent and we would not expect any material differences in what was submitted.

MEMBER ARCHIBALD: Thank you very much.

THE CHAIRPERSON: With that, if we can now proceed with the next session of the Part 1 Presentation. Thank you.

MR. JENSEN: Marc Jensen, for the record.

I'd like to ask Professor Jon Sykes to lead this second session of this first part. Doctor Sykes?

DR. SYKES: Thank you. For the record, my name is Professor Jon Sykes.

The purpose of this modelling work program was to conduct hydro-geologic analyses at different scales to develop and test the understanding of long-term, shallow, intermediate and deep groundwater system properties and behaviour relevant to illustrating DGR safety.

An issues-based approach was adopted in this modelling program to explore and examine groundwater system evolution and the impact, if any, of system property uncertainty on the performance of the DGR.

The analyses approach involved the investigation of the long-term behaviour of the groundwater system as constrained by both local-scale and regional-scale observation data sets.

Specific simulations included the investigation of density dependent flow at both the regional scale and the site-specific scale and the investigation of two-phase gas and water flow in one-dimensional columns representing the DGR site.

In paleo-hydrogeolic analyses, the impact of glacial ice-sheet perturbations on groundwater system stability and resilience was examined.

Referring to Slide 13, FRAC3DVS was first released to the public in 1995. The model has been the subject of many journal and conference papers. The model has a large user base that includes universities, consultants and government agencies throughout the world.

In 2001, Ontario Power Generation began to support the development of the model through contracts with both the University of Waterloo and with Laval.

The OPG version of FRAC3DVS has a comprehensive user manual. Quality assurance and quality control of the code is facilitated by a version control system at the University of Waterloo. There are 35 verification tests for the code.

FRAC3DVS-OPG simulates three-dimensional, density dependent flow and solute transport in variably saturated porous media.

Solute transport processes included vection, mechanical dispersion and diffusion. The impact of mechanical loading on groundwater flow is included in the model using the literature standard glaciation studies that assumes that loads are aerially homogeneous.

The performance measures in the code include the water mean-life expectancy; what we refer to as MLE.

Slide 14. The steps of the modelling processes are outlined. All modelling problems follow five basic steps.

The first step is the selection of the computational model that is capable of representing the processes occurring. Model uncertainty is related to the physics described by the computational model.

The remaining four steps of the development of a numerical model are, first, the specification of geometry. In the case of the DGR, this is the 3D geologic framework model stratigraphy.

Secondly, the selection of parameters and constitutive laws that represent the system.

Third, the specification of the boundary conditions, and in the case of transient problems, the specification of the initial conditions.

And, finally, the use of appropriate discretization for both space and time.

In the DGR study, a FRAC3DVS-OPG computational model was applied following an issues-based approach for data analysis for the synthesis of data that cannot be measured directly and for hypothesis testing.

Referring to Slide 15, confidence in the hydro-geologic modelling study using FRAC3DVS-OPG is provided by the use of two different computational models so that model uncertainty could be addressed. In addition to FRAC3DVS-OPG, the two-phase gas and water compositional model, TOUGH2-MP, was also used in the study. FRAC3DVS-OPG was used with and without mechanical coupling.

Parameter uncertainty was investigated using sensitivity analyses that explored the parameter space. ‘What if’ or hypothetical scenarios were also developed.

The important part of the work is estimating the degree to which the uncertainty in a given parameter impacts the performance measures for the DGR. An example performance measure includes solute transport processes in the Ordovician sediments at the DGR and mean-life expectancy.

Confidence was also developed through sensitivity analysis for the boundary conditions selected for the description of the flow domain.

The hydro-geologic modelling study describes 36 scenarios that were used to explore groundwater-system, parameter-space boundary conditions and physics.

The design of the hydro-geologic modelling study is described on Slides 16 and 17.

Data synthesis was an important aspect of our issues-based approach. An important component of the work is the synthesis of the vertical hydraulic conductivities for the Ordovician sediments.

The measured pressures in the DGR boreholes were used to guide this work. The depth of penetration of glacial meltwater was investigated in paleo-geologic simulations that included a comprehensive parameter sensitivity analysis.

The study design investigated the cause of the abnormal pressures observed in the Ordovician sediments. The computational model FRAC3DVS-OPG was used to simulate saturated waterflow, while TOUGH2-MP was used to investigate the impact of the presence of an admissible gas phase.

FRAC3DVS-OPG was used in numerical experiments to investigate 'what if' scenarios, for example, to assess the impacts of enhanced Precambrian surface hydraulic conductivities on DGR and groundwater system performance measures.

The impact of boundary condition conceptualation (sic) on DGR performance measures was specifically investigated, referring to slide 17. Two conceptual models were used for the work, with multiple scenarios being developed for each. The boundary conditions for site scale analyses were defined using both the imbedment and the nested model approaches. Both lateral and surface boundary conditions were varied in the study.

The site scale analyses were developed to investigate the impact on the DGR of hypothetical transmissive fractures that vertically connect the permeable Cambrian sandstone and the Niagaran dolomite. Data for the DGR site were used to guide this work. The study also included parameter sensitivity studies to explore the impact of parameter pertubations on groundwater system barrier and repository performance.

The four conceptual models that were developed in the study design are highlighted in slide number 18. The conceptual models include a regional scale domain of more than 18,000 square kilometres, that extends from the deepest parts of Lake Huron, and in Georgian Bay, to the eastern edge of the surface water basin in which the DGR is located. The site scale model has an area of approximately 400 square kilometres and a finer special discretization.

The Michigan basin cross-section, shown in the lower left corner of slide number 18, extends from the

Algonquin arch to Wisconsin, and includes the deepest layers in the basin.

The fourth conceptual model, shown in the lower right-hand corner of slide 18, investigated fluid flow and solutransport in one-dimensional columns representing the DGR site. This work was done for TOUGH2-MP.

The numerical modelling discretization shown in a block-cut view, on slide number 18, on the right-hand side, explicitly used all of the 31 stratographic layers identified in the 3D geologic framework model, and that model is shown on the left-hand side of the slide. The result is a representation of the regional hydrostratigraphy.

Slide number 20, in referring to it, an important aspect of the design of the numerical modelling study was the use of the laboratory and field data gathered at the DGR site to constrain and guide the selection of model parameters. This minimizes the impact of parameter uncertainty on the study performance measures. Important parameters include the horizontal hydraulic conductivities estimated, from the in-situ straddle-packer test in the DGR boreholes, as summarized on slide number 20.

These results, from these tests, provide confidence in the hydraulic conductivities used in the model.

The simulation of density dependent flow requires estimates of the total dissolved solids distribution in all of the hydrostratigraphic layers. TDS data were obtained from the DGR rock core pour fluid analyses and the groundwater sampling. The measured TDS distribution for the DGR is shown on slide number 21.

The methodology used to calculate fluid density minimizes the impact of parameter uncertainty on the system performance measures, referring to slide number 22.

Further minimization of the impact of parameter uncertainty was provided by using the geomechanical properties for the various horizons occurring at the DGR. Young’s moduli and Poisson’s ratios, obtained from geomechanical tests, were used to estimate storage coefficients and the one-dimensional loading efficiency that is used to simulate the hydromechanical effect on glacial loading on fluid migration.

Tortuosity is an important parameter in the estimation of solu-diffusion. Data from the University of New Brunswick diffusion experiments were used to estimate tortuosities and effective porosities of the rock.

The observed formation pressures in the DGR boreholes, shown in slide number 22, on the right, was used to estimate vertical hydraulic conductivities for the Ordovician sediments.

The vertical line in the figure is the head expected based on the surface elevation at the DGR site. Heads greater than this expected value, as occur in the Cambrian sandstone, indicate over-pressurization. Heads less than the expected value, as occur in the Ordovician sediments that are host rock for the DGR, indicate underpressurization.

All scenarios of the study design investigated (Inaudible) migration within the Ordovician sediments. Pecklet numbers for each scenario support the conclusion that solu-transport in the Ordovician sediments is diffusion-dominant.

Mean life expectancies, which is a measure of the time that it will take a solu to migrate to a discharge point, were greater than 100 million years.

The MLE for the regional scale model are illustrated on slide number 23.

Confidence in the assessment that solu-transport and the Ordovician sediments is diffusion-dominant, is provided by the sensitivity analysis developed in the study design.

Confidence in the study results is provided in calibration, whereby model results are compared to observe data, such as the formation pressures in the DGR boreholes and environmental tracer concentrations from core analyses.

An upward gradient is observed in the Shadow Lake, Gull River, and Coboconk units, at the bottom of the Ordovician. This gradient cannot be preserved for more than 10,000 years unless the vertical hydraulic conductivity for the units is less than 10 to the minus 14 metres per second. Solu-transport for such values is diffusion-dominant.

The preservation of the observed underpressures also requires very low vertical hydraulic conductivities. The dissipation of the underpressures, with time, is shown on slide number 24, for an analysis that assumed saturated flow. It will take millions of years for full dissipation to occur. Solu-transport remains diffusion-dominant throughout the Ordovician sediments.

The results for the 10 paleo-hydrogeologic simulations included in the study design are shown on the right-hand side of slide number 25. Also included in the slide are the observed pressures in the DGR boreholes. Those are the points shown on those figures.

The left-hand side figure is the 120,000 year glaciacion realization from the University of Toronto glacial systems model that includes the variation of ice thickness and the depth of permafrost formation. The three-dimensional paleo-hydrogeologic model was unable to generate the observed formation, under pressures, within the Ordovician sediments.

Confidence in this conclusion is provided by the ten simulations developed in the study design. The hydrogeologic modelling study calibration investigation showed that the underpressures could be described by the presence of a gas phase, referring to slide 26.

The simulated environmental and freshwater heads, at the location of the DGR-2 borehole from the cross-section analysis of saturated flow in the Michigan basin are shown at slide number 26.

The physics represented in the model does not permit assimilation of the under pressures. Confidence in the conclusion that the over pressures in the Niagaran and Cambrian or related typography, geometry and fluid density variation in the basin is provided by the fit of the model to the measured heads. The Niagaran is point A in the figure on the right, the Cambrian is point B.

Hypothetical vertical fractures proximal to the DGR that connect the Cambrian sandstone and the Niagaran sediments were found to be inconsistent with the pressures observed in the DGR boreholes. As shown on slide number 27, the observed upward gradient between the Cambrian and the Niagaran would result in flow to the Niagaran, point A, from the Cambrian in the hypothetical fracture and the prediction of higher pressures in the Niagaran than those observed at the site. Consistent with the literature, the anomalous pressures require low vertical hydraulic conductivities. The presence of transmissive fractures is inconsistent with this observation. The comparison of the model results with observed data provides calibration.

The confidence assessment for the design of the hydrogeological modelling study that used FRAC3DVS is listed on slide 28 and 29. Model uncertainty was investigated using two different computational models, FRAC3DVS-OPG was used for the simulation of saturated dense-dependent flow with and without mechanical coupling, TOUGH2-MP was used to investigate water and gas flow.

The impact of parameter uncertainty on performance measures such as advective velocity, mean life expectancy and peckling number was investigated by sampling the parameter space and by the investigation of alternate conception models and alternate descriptions of the model boundary conditions.

The hydrogeologic modelling study was designed using an issues-based approach that addressed hypotheses and 'what if' scenarios. At all stages of the work, the study outcomes were compared to the field and laboratory derived data for the DGR site to establish confidence in the interpretation of groundwater system understanding and behaviour.

Finally, confidence in the overall modelling study outcome is provided by independent multiple lines of evidence that include a geology, hydrogeochemistry and geomechanics as described in the DGR geosynthesis document. And these are directly used to constrain, check and assess the reliability of the model scenarios and their contribution to groundwater system understanding.

The final slide, number 29, presents a table that summarizes evidence from the approach and design of the modelling study that has contributed confidence to an understanding of groundwater system properties and behaviour relevant to the DGR safety. A key finding is that mass transport within the Ordovician sediments that host the DGR has remained diffusion dominated. That ends my presentation.

THE CHAIRPERSON: Thank you very much, Dr.

Sykes. Dr. Muecke, if you could begin the questioning please.

MEMBER MUECKE: Could we go back to slide number 21 please? Thank you. You were talking about density-dependant flow in the system. And given that there were few opportunistic groundwater samples obtained and that most of the total dissolved solids data is derived from leachate tests, which are associated with a number of problems, how confident are you that the -- that data is reliable in terms of the models that they are developing?

MR. JENSEN: Marc Jensen, for the record. I'd like to ask Professor Sykes to answer.

DR. SYKES: For the record, Jon Sykes. The TDS distribution vertical -- vertically is shown on slide number 21. Where there were opportunistic samples of the groundwater such as occur in the Cambrian and in the Guelph formation in the A1 upper carbonate, that data fit very, very well with the core data from the crush and leach experiments.

Throughout the horizon between the Guelph formation, which is shown virtually about 40 percent from the down from the top of slide number 21 through to the Cambrian at the bottom of the figure, the TDS distribution is very, very consistent and in fact fit other parameters, environmental tracers and the like. And in fact -- so we believe that there -- and there was also repeatability in this curve from the multiple tests on the different DGR cores. And that's shown in fact in the figure. You'll see the scatter plot includes DGR 2, 3, 4, 5 and 6 boreholes. So there was replication in there which added confidence to those numbers.

We use in our analysis this data to populate a regional scale model, but then allow the hydraulic characteristics of the regional domain to start flushing out units and TDS where that would be expected to occur so that in the end, we end up with a regional scale total dissolved solids distribution that we feel honours both the DGR data and the processes that we expect to see occurring throughout the province.

But in the end, the important thing for us was how important is this information on the determination that within the Ordovician sediments, that solute transport is diffusion dominant. And with that measure, we're very, very confident in the end that in fact there is little impact of any uncertainty in this distribution of TDS on that measure.

MEMBER MUECKE: Thank you, Dr. Sykes.

THE CHAIRPERSON: Dr. Muecke, pardon me for the interruption, but I think it would be more efficient if we proceed in order of the slides. So members of the Panel will have questions depending on which slide. So I think that the next slide that we have questions on is question -- or, slide number 23. And I think we're pausing on this slide just as a visual to prompt -- and this is a question that I have -- and this is again in the interests of transparency and clarity and some accessible language.

The Panel understands, of course, that fundamental to the safety case is that this system is indeed dominated by diffusion. However, if you would please provide a simple lay language explanation of diffusion versus dispersion versus advection and explain why the dominance of diffusion as the primary transport mechanism is fundamental to the safety case.

MR. JENSEN: Marc Jensen, for the record. I will ask Professor Jon Sykes to discuss and describe and the advection, dispersion, diffusion question. But the overall safety case is in part relies on the long-term stability of the geologic environment in which we're going to place the repository and the evidence that we have been able to confine or to collect to test the notion or hypothesis that it is diffusion-dominated.

And clearly, through the hydraulic testing, through -- which determines the permeability of the rock, through the natural analog studies that we've done using, as Professor Sykes has described, the under pressure conditions that we see within these Ordovician rocks and, as Professor Tom Al will describe, the environmental tracers that we see within the rocks, that a strong case can be made that the system is diffusion-dominated and has remained so for geologic periods of time.

I'd like to ask Professor Sykes to describe the advection, dispersion, diffusion. Thank you.

DR. SYKES: Jon Sykes, for the record. I'll start for advection. Advection is the movement of water within porous media or under a pressure gradient or a head gradient. In other words you’d have to have a higher head at location X and down gradient a lower head and so water will move from the high point to the lower point under this gradient and that is called advection and the important property for that is the hydraulic conductivity which is the resistance of the rock to the flow. And that advection would then be possible if it were to occur to carry a solute with it.

Diffusion and dispersion relate to the spreading of a solute plume or of a solute in the porous media. The diffusion happens because of the concentration gradient whereby the solute will move from the point of higher concentration to a lower concentration just by that concentration gradient alone.

Mechanical dispersion is the other spreading mechanism. That is occurring in porous media because of the difference in velocities going from say -- through this porous media. You can think of little grains and not all water, not all solute follows exactly the same path. It starts to meander into the left lane, it goes to the right lane and it results in the spreading and that spreading is now then as mechanical dispersion and it's a result of the characteristics and the grain size of the rock. And again, it moves too, in part, on -- on a concentration gradient, but the driving force is this meandering around the grains of the water.

Within the Ordovician sediments, though, while I've described three mechanisms, only one of them pertains to the movement of solute and that is diffusion. The velocities in the rock are too small, too low to have any advective component whatsoever. The dispersion piece that I talked about, the meandering, that's also related more to the velocities and those again, the velocities caused by gradients of pressure in head are too low to be effective so that in the end, within the Ordovician sediments, the shales, the carbonates; the only mechanism that will move the contaminants is diffusion. And in all of our analyses and our study, that's a very robust conclusion. Every scenario, every ‘what if’ came to the same endpoint.

THE CHAIRPERSON: Thank you very much. That was very helpful.

I think, Dr. Archibald, you have the next question in sequence.

MEMBER ARCHIBALD: Thank you. This is concerning slide 26 in which it’s apparent that low pressures, that is, under pressures, as you have stated in your presentation, in formations such as the Ordovician sediments, will inhibit vertical transportation of contaminants. The reasons for the presence of under pressures are fundamental to the understanding of the hydrogeological formations and in light of this, one of the consequences of the statement that you have given in your presentation that the physics represented in the model does not permit the simulation of under pressures. By that, does the model over or under predict the potential movement of contaminants to the surface?

DR. SYKES: Jon Sykes, for the record.

The analysis shown in slide number 26 used a saturated model, FRAC3DVS-OPG. The under pressures that we see here are not a result of any state that we can observe today. In other words, they’re not a result of driving forces, boundary conditions that we see within the

Michigan Basin today. The under pressures are remnant or result of something that happened in the distant geologic time; possibly hundreds of millions, maybe tens of millions of years ago.

So when I go in and do an analysis using the today’s driving forces and boundary conditions, I cannot recreate those under pressures. I have to do a different analysis. I have to go back in time and develop some scenario, whether it’s paleohydrogeologic, in other words, looking at the impact of glaciation over the hundred -- last 120,000 years or look at exhumation or some other mechanism, but they’re long processes. We did not attempt to do that in this analysis, we just really were looking solely at can we get at the over pressures in the Cambrian and in the Niagaran or the Guelph Formation with our analysis and in fact, we -- you can see by the fit on the model that, in fact, we can describe those.

Now, the question was what is the impact of then this lack of characterization of the under pressures on our results. If there is going to be a dissipation of those under pressures, it requires the movement of water. And within the Ordovician sediments, this is a very, very slow process because of the very low hydraulic conductivity of those units. So if anything and in fact, when we go into these cores, if we -- if there was a gas phase there that will impede flow. I've not put a gas phase in this -- in this analysis so if anything, I'm probably overestimating the vertical flow, but in spite of that, under all conditions, solute transport within the Ordovician sediments remains diffusion dominant and so that if there's anything that I'm doing, it's probably erring on the side of conservatism.

MEMBER ARCHIBALD: Thank you.

THE CHAIRPERSON: The next slide, slide 28, I have a question and the question is regarding the sensitivity analyses that were conducted. So may we please have a more detailed description of the principal parameters that most influenced model outcomes when you ran your sensitivity analyses?

DR. SYKES: Jon Sykes, for the record.

Really for the Ordovician sediments, there is only one parameter that influences the outcome and that is the diffusion parameter and all of our data were taken from the work by Professor Tom Al at the University of New Brunswick and we found through our sensitivity analyses then in fact boundary-condition descriptions were -- had no impact on whether or not solute transport in the Ordovician sediments remains diffusion. The hydraulic conductivities didn't impact it either because they were always so low and at no point did we enter a point where advection or mechanical dispersion became significant.

So in summary, really, there was just one parameter; well, two really. The thickness of the unit, of the Ordovician sediments, so there’s about 200 metres of very, very tight; if not, close to impermeable sediments above the DGR and about the same 200 metres below. That’s important. And then secondly, within that 400 metres of rock, solute transport is always diffusion dominant.

THE CHAIRPERSON: Thank you.

Dr. Muecke?

MEMBER MUECKE: Could we have slide number 29 please? In -- in this slide, you indicate the confidence in -- in the model. Could you comment on how the confidence changes as one goes from the site scale to the regional scale to basin scale?

DR. SYKES: Jon Sykes, for the record.

Confidence here is relevant to the safety case for the DGR and in that -- with that as my performance measure, I’m very, very confident in the outcome. And what I always look at, then, is to what degree does basin-wide characteristics, do the attributes of the basin at distance from the DGR, how does that impact that conclusion; in other words, my performance measure of the DGR. And in all cases, we find in fact that the transport at the DGR is insensitive to the regional description, the regional boundary conditions and so there is a robustness; always a robustness in that conclusion. And that is what is being referred to here for the confidence. It's confidence in does solute transport remain diffusion dominant and the answer is yes.

MEMBER MUECKE: Thank you. Looking at that slide, there were sensitivity analyses extensively done for the Ordovician sediments. My question is, were similar analyses conducted; that is to say, sensitivity analyses for the Silurian shield-dominated cap rock?

DR. SYKES: As part of our work -- oh, sorry. Jon Sykes, for the record.

As part of our work, we did undertake large-scale parameter changes for the Silurian. We also looked at changes in the characterization for the upper Pre-Cambrian to put in a more permeable pathway as might exist. And in fact, for all of those analyses, again we come back to the same measure; solute transport, how long will it take a release, a potential or hypothetical release, from a DGR facility to reach the biosphere? And in all cases we come up with the same answer and so that in fact, that if solute transport very, very long period of time.

MEMBER MUECKE: Okay, thank you. Could you expand upon the sensitivity analysis results that show the transfer by diffusion is insensitive to the description of the boundary conditions? Could you give me examples of what boundary condition we are talking about and how they were varied?

DR. SYKES: Jon Sykes for the record. Within our work we looked at different conceptual models for the surface boundary condition, whether we have a fixed water table or whether we have recharge. For all of those analyses we again got the same results, solute transport and the deep sediments of the Ordovician are not impacted by that description of that surface boundary.

In our analysis of the regional scale domain we also were concerned about the boundary condition that we were imposing for the Cambrian, the deepest more permeable formation within the system. And so we included analyzes that connected that Cambrian right through to the Devonian to Lake Huron, and even for that analysis again, solute transport within the Ordovician system remained diffusion dominant.

In our paleohydrogeologic analysis we did the same thing. We're concerned about our characterization of the boundary condition for the Cambrian at the western side of the domain. And again, we looked at model analyzes; numerical models that connected the Cambrian right through to the surface and allowed flow of water, and again, ended up with the same robust conclusion of solute transport that's diffusion dominant.

MEMBER MUECKE: Thank you, Dr. Sykes.

THE CHAIRPERSON: Thank you very much. Looking at the clock, I would suggest we take a 10 minute break and then resume at approximately quarter to 11:00. Thank you very much.

--- Upon recessing at 10:35 a.m.

--- Upon resuming at 10:45 a.m.

THE CHAIRPERSON: Thank you very much. I think we'll resume our session. I noticed there is a bit of a lack of synchronization among the various clocks. So this one on the wall appears to be a couple of minutes slow according to my watch. It's past quarter to 11:00, so let's all agree, we'll go by the clock on the wall and hopefully we don't have people scrambling to get back in.

All right. So if we can now proceed with the next section, the part one on geo-science modelling, Mr. Jensen?

MR. JENSEN: Mark Jensen for the record. I'd like to invite Professor Sykes to provide this third section of this part one presentation. Dr. Sykes?

DR. SYKES: For the record, Professor Jon Sykes.

The purpose of this model work program was to test the hypothesis that the observed formation under-pressures in the Ordovician sediments can be described by the presence of an admissible gas phase in the low-permeability rock.

To test the hypothesis, sensitivity analyses were performed that included the investigation of alternate conception models to constrain an understanding of the gas and water phenomena and the system attributes that are necessary to generate and preserve the under-pressures in the Ordovician sediments observed in the instrumented DGR boreholes. The TOUGH2-MP computational model describes multi-phase, multi-compositional flow in porous and fractured media.

The phases that are considered are water and gas, as described in the equation of state module EOS3. Groundwater flow is considered density independent for the analyses of this study. As stated in the lower half of slide number 32, the TOUGH model, developed by Carson Pruess of Lawrence Berkley Lab, was released in 1991. TOUGH2-MP is the parallelized version of the code.

The state-of-the-art model is used extensively worldwide for the analyses of multi-phase flow. It is the model of choice for nuclear waste isolation studies that include a separate gas phase. Lawrence Berkley Lab has verified the model and continues to develop and support the TOUGH family of codes.

In the hydrogeological modelling study, TOUGH2-MP was used to evaluate water and gas flow in a one-dimensional column between the Cambrian sandstone aquifer and the Niagaran aquifer. The bedrock stratigraphy matches that observed in borehole DGR2. The permeability for the sedimentary rock was defined using the DGR Straddle-Packer Hydraulic Conductivity estimates, and the fluid densities estimated using laboratory derived pour fluid total dissolved solids concentrations in the Ordovician and Silurian rock.

The capillary pressure versus saturation relationships were developed for each rock type from the petrophysics tests of the DGR cores. The figure on slide 33 depicts these relationships. It is significant that the Ordovician sediments have high entry pressures for the drainage curves shown. The design of the study minimizes the impact of parameter uncertainty.

Other important parameters are the rock dependent diffusion coefficients and tortuosities. These were developed from the University of New Brunswick diffusion studies. Higher values will allow the gas to dissipate more quickly, both in the gas phase and in solution. The presence of a gas phase acts as a natural analogue for the diffusion process.

In summary, the TOUGH2-MP analyses use the data for the DGR field and laboratory studies, as described in the DGR descriptive geosphere site model. As stated in slide 34, the single hypothesis tested in the study is that the under-pressures observed in the Ordovician sediments are the result of the presence of an admissible gas phase in the low-permeability, low-porosity rock matrix.

Supporting the presence of a gas phase are the geochemical data indicating that solution methane concentrations are either at or near saturation concentrations in some horizons in the Ordovician sediments. Four scenarios were developed to explore and test the hypothesis. These scenarios involved two different mechanisms for the source of the gas.

The first is the assumption of an initial gas saturation and its redistribution in the column in geologic time. The second source model considers that the gas was slowly generated in geologic time between the Coboconk and the Queenston formations and redistributed in the column.

Each source model also investigated the

occurrence of a discontinuity of the capillary pressure versus saturation relationship in the rock. The design of the study provides a model uncertainty analysis. Confidence is provided by comparing the simulated heads with the measured values, the essence of model calibration.

The best fit results between the measured pressures of the DGR boreholes and the results for the analysis of an initial gas saturation of 17 percent that has been redistributed, as shown on slide number 35. As geologic time progresses, all of the gas would eventually diffuse from the column. The time for the complete removal of all the gas is dependent on both the gas and water phase diffusion coefficients.

Slide No. 36 presents the best refit results for the testing of the hypothesis with a gas generation source. As in the previous case, the model calibration fit between the measured pressures and the TOUGH2-MP simulated pressures supports the hypothesis that the presence of a gas phase could lead to underpressures.

As in the previous case, the dissipation of the gas is sensitive to both the rock mass permeability and the gas diffusion case coefficients. As stated previously, higher values of both will lead to quicker dissipation of the gas to the Cambrian and the Niagaran.

A gas phase can only occur for long periods of time if transport processes are minimized.

In the final case, shown in Slide No. 37, the observed pressures are compared in model calibration to the case where there is a discontinuity in the rock of the capillary pressure versus water saturation relationships. That is, different relationships are assumed for adjacent layers of the rock.

A gas phase will more readily enter the rock if the air entry pressure is lower. This results in the accumulation of -- and trapping of gas in pockets that would have a lower capillary pressure, enhance higher water pressure as shown by the spike to the right in the figure. The currents of pockets of trapped gas is important, as they would lead to further impede the vertical migration of solutes.

A confidence assessment for the TOUGH2-MP groundwater system analysis is provided in Slide 38. The model outcome is a comparison of the model results to observe underpressures in the Ordovician sediments. Confidence is provided by the study design and in model calibration by comparing the model results to the measured pressures in the DGR boreholes.

The four scenarios investigated using the state of the art computational model TOUGH2-MP support the hypothesis that the presence of a gas phase can provide an explanation of the underpressures observed in the Ordovician sediments.

It is important to note that a gas phase of only a few percent saturation is sufficient to preclude glaciation as an explanation of the underpressures. The FRAC3DVS-OPG study design and published literature supports this conclusion.

Slide 39 presents a table that summarizes the contribution to confidence that is provided by the multiple lines of evidence. That ends my presentation.

THE CHAIRPERSON: Thank you very much. Dr. Muecke, would you begin the questions, please?

MEMBER MUECKE: Yes, could we have Slide 32, please? One of the fundamental aspects of the model, as it has been run, is that it does not include brines in the modelling when considering groundwater flow, and that groundwater flow, basically, is density independent.

Could you tell me whether this conforms to the precautionary approach? Is this -- why is this a conservative assumption?

DR. SYKES: The TOUGH2 model can in fact include density dependent flow for the water phase. In our analysis, though, we excluded that in that we were modelling the flow and the behaviour of the rock between the Cambrian and the Guelph, and within that column the total dissolved solids is somewhat constant and the densities of the fluid are approximately the same throughout the column.

Further, the impact of density only affects the velocities within the analysis. The velocities, as I previously have stated, are very, very low, so that we feel very comfortable in excluding density for this particular analysis.

MEMBER MUECKE: The -- you showed us the profile for the Total Dissolved Solids, and it didn't look terribly constant to me. So is this justifiable and conservative?

DR. SYKES: John Sykes, for the record. Again, the -- within the mechanisms governing flow of a water phase, the density will only impact the advective velocities, and the advective velocities, in fact, in this analysis, are very, very small and not the mechanism that's there to move either the water phase significantly or the gas phase.

What's moving the water is in fact diffusion of the water, and the slow of the gas, it certainly is diffusion, because there is a gas gradient that I'm putting into the system. And again, the density component is very, very small.

And even if I were to put density into the analysis, it would not change the outcome of the results, first of all, that I can predict the underpressures with the presence of a gas phase, and then secondly, that solute transport within that column -- rock column is diffusion dominant. Those two are completely independent of the description of the TDS within and the fluid density within that column.

MEMBER MUECKE: Thank you.

THE CHAIRPERSON: Thank you. I have a question based upon Slide No. 38, which is a sum up of your overall confidence assessment. On that slide, you provide the confidence that you can accept the hypothesis regarding the presence of gas as an explanation for underpressures.

Again, continuing with my theme of helping people understand this in plain language, what is the significance of being able to accept that hypothesis with a high degree of confidence to the strength of the safety case?

DR. SYKES: John Sykes, for the record. Within our hydrogeologic modelling study, we also looked at other hypotheses for describing or explaining the underpressures. We looked at osmosis, and there are studies in the United States that show osmosis can in fact lead to underpressures. It's work by Chris Nozel on Pierre Shale.

We did talk to him about that particular hypothesis, and there is within our document, our report, there is a section describing the fact that we felt that because we're seeing the underpressures both within the carbonate rock and in the shale that it -- that wouldn't explain osmosis as an explanation. You would not expect to see the same thing in both those rocks. You might see it in the shales, but not the carbonates. So we really rejected that hypothesis as an explanation.

We also looked at the hypothesis that glaciation and paleohydrogeologic scenarios could be an explanation for the underpressures. And for some of our analyses we got a slight underpressure in parts of the Ordovician but not throughout the Ordovician, and so that work would lead you at, for what we did, ten different scenarios, to a rejection of the hypothesis, but there are other hypothesis that could cause the -- be put forth that it would explain the underpressures. These would include exhumation, crustal flexure and so on.

But the one that it is within literature, and it is solid, is the fact for these underpressures to exist you must, absolutely must have exceptionally low hydrologic conductivities, and once you put that low hydrologic conductivity in there, then it automatically pushes you into the domain where solute transport is diffusion dominant.

So there is very, very high confidence in the outcome, related to all of this, that in fact solute transport is diffusion dominant. It has to be for these underpressures to exist.

THE CHAIRPERSON: So in summary, because it adds confidence to the diffusion dominance, it adds strength to the safety case?

DR. SYKES: That is correct.

THE CHAIRPERSON: Thank you. I now have another question, moving to the final slide, Slide 39, please. You note on a couple of the lines of evidence, verification of the model to other codes and verification that model results are consistent with the conceptual model. What other codes were used for verification, and where is this documented?

DR. SYKES: Jon Sykes for the record. We did not ourselves verify TOUGH2, but that has been done by Karsten Pruess at Lawrence Berkeley Laboratories. The United States State Department uses this code extensively, and in their work they have undertaken verifications. I had a PhD student who looked at multiphase flow modelling, now on faculty at the University of Toronto.

And certainly his code would compare and verify to the TOUGH2-MP. But in summary I did not do that, that exists within the literature. And verification that model results are consistent with the conceptual model, again, this comes from the literature. The fact that that code does describe two-phase flow adequately, there have been a lot of box experiments in throughout the world where people have looked at two-phase flow analyses and then compared the models to those. And again, they verify that in fact you're describing the system correctly.

THE CHAIRPERSON: Further to the conceptual model, where might we find a description of that fundamental conceptual model that was the basis of your computational model?

DR. SYKES: Jon Sykes for the record.

The TOUGH2 manual and users guide can be accessed freely through the web. There are workshops continuously on the TOUGH2 family of codes. It's my understanding that there was one within the last month, 175 attendees at it. More information on that can be given to you from other panel members here if you would like. But there is a lot of very open and accessible literature on all attributes of that code.

THE CHAIRPERSON: Thank you. Again, on this slide, I'm working my way down your rows and lines of evidence. Beyond what you have presented were there any other calibration exercises performed during your hypothesis testing?

DR. SYKES: Jon Sykes for the record.

Within our analysis it was solely to find out whether the presence of a gas phase could give you under pressures. And all of our parameters that we used for the study were obtained from the straddle packer test in the case of hydraulic conductivities, from the diffusion analyses, from the University of New Brunswick, or the Petrophysics work on the course, and that provided us capillary pressure-saturation.

So we use laboratory and field derived values and in the end got a positive that we could explain the under pressures; and that was the sole purpose of our work. We did not actually then test other parameters to see if they would also explain the under pressures.

THE CHAIRPERSON: Thank you. And finally, given you refer to sensitivity analyses of the alternative conceptual models, during the runs which parameters had the most influence on the results?

DR. SYKES: The conceptual models for us was looking -- oh, I'm sorry. Jon Sykes for the record.

The conceptual models that we looked at were on the way that gas was placed within the system. But the parameter that most influenced the results was in fact the diffusion coefficient for the gas and for the water phase.

And in fact, it was a finding that we included in our report that we feel we're overestimating diffusion for this system in that the gas within that column could diffuse-out within a very short, a relatively short geologic period of time. And you could not account for the current observation of gas within that system with those diffusion coefficients.

What that means is, in spite of how low the diffusion coefficient has been from the University of New Brunswick, it would be a conclusion from this work that in fact the in situ values are even lower, which means there's less solute transport occurring within that system.

THE CHAIRPERSON: Thank you, very much. I think that concludes the panels questions on this portion of the presentation. So if we could now proceed with the MIN3P presentation.

MR. JENSEN: Mark Jensen for the record. I'd like to invite Professor Tom Al to provide the MIN3P presentation.

DR. AL: Thank you. Professor Tom Al for the record.

So this section describes numerical modelling efforts taken to develop and test an interpretation. We also refer to the interpretation as a conceptual model. And we're testing an interpretation that can explain the natural and environmental tracer profiles observed within a sedimentary sequence beneath the Bruce Nuclear site; and some examples are shown on slide 41.

Studying the distributions of these tracers in the groundwater and pore water provides a site-specific natural analog for solute transport processes that have been operative in the system over geologic time.

The natural tracers examined here include the chloride and bromide ions, and the oxygen and hydrogen isotopes that form part of the water molecule.

The assessment of the geologic, hydrologic and geochemical data indicates that solute transport in the Ordovician stratigraphic units enclosing the repository level has been controlled by diffusion.

The purpose of a MIN3P modelling was to provide a quantitative assessment of this hypothesis. The principal objective of the modelling was to develop an understanding of the time scale required to generate the natural tracer profiles by diffusion.

Moving now to slide 42. I just want to describe some of the fundamental aspects of the model. The MIN3P model was developed by Professor Ulrich Mayer during his PhD research program at the University of Waterloo. Dr. Mayer is now a professor at the University of British Columbia Department of Earth, Ocean and Atmospheric Sciences.

The model is a numeric finite volume model for simulating transport and reaction processes in groundwater. It can solve problems in one, two or three dimensions. Dr. Mayer first published details of the model development in 2000 and it's been under continuous development since that time.

The current version is MIN3P version NWMO. The model has a broad list of capabilities and those are referred to on slide 42 in the lower half. They can be broadly -- these capabilities can be broadly categorized into physical and chemical processes.

The integration of physical and chemical processes allows simulation of solute transport coupled with geochemical reaction processes. This integration is generally known as reactive transport.

The present use of MIN3P for simulating nonreactive tracer diffusion is a relatively simple application and does not require the full model capabilities.

Moving now to slide 43. The academic community requiring the use of high-end reactive transport modelling is small. But since the year 2000 over 50 peer-reviewed journal papers have been published with MIN3P. In addition, there are many peer-reviewed conference papers, book chapters, and graduate theses, and worldwide there are now approximately 20 research groups using MIN3P.

Slide 44, just referring to model verification. Verification is conducted for MIN3P with a set of standard problems for which output from the model is compared to published results from the literature, or comparison is made to output from established analytical or numerical models.

For each MIN3P code enhancement new verification examples are added, and after each enhancement the complete set of verification problems is retested to confirm code behaviour.

At several stages during the MIN3P code development Dr. Mayer has participated in international benchmarking exercises; and these are described on slide number 45. During the initial stages of development Dr. Mayer participated in an international workshop at Pacific

Northwest National Labs. In 2008 with the support of the NWMO he participated in a reactive transport workshop in Strasbourg, France.

And he is planning to participate in the second sub-surface environmental simulation benchmarking workshop in Taiwan later this year.

MIN3P has been successful at all of these events and it's worth noting that MIN3P was the only model to successfully complete the benchmarking exercises in Strasberg. I just want to talk about the modeling approach here, in the DGR context, MIN3P has been used for testing conceptual models by exploring the fit between the natural tracer data and the model output for variable diffusion times. So there is no effort in this case to calibrate the model by adjusting parameters to achieve a fit to the measured data. The diffusion coefficients are included as measured. They come straight from the lab measurements.

Also it should be noted that the model has not been used for prediction of future system behaviour. As is illustrated on slide 46, the scientific method is at work here in that a hypothesis is developed based on consistency with prior information and the site characterization data. A hypothesis as it relates to the diffusion time scale must then be tested. And one way to do that quantitatively is to use a numerical model, so that’s what we’re doing.

After repeated testing, a hypothesis is refined with -- with a goal of arriving at a robust interpretation or conceptual model to explain the natural tracer data.

Moving to slide 47, the layered stratigraphy has significant lateral continuity as -- as we’ve seen at the – at the Bruce site. And there are large distances within the sedimentary basin from this – what we’ll call the side boundaries. So as a result of that physical condition, the diffusion simulations are conducted with a vertical one-dimensional domain.

Numerical simulations of diffusive transport require a discretized or gridded domain with specific -- with specified spacing and in this case five meter spacing was used. And that’s a value chosen to be small relative to formation thicknesses. The model domain must be assigned one of more diffusion coefficients and in this case the diffusion coefficients were assigned based on the laboratory measurements and their distribution versus depth is as shown on the left side here, slide 47.

And these capture the stratigraphic variability manifest in the laboratory measured data set. These diffusion coefficients are very low in the international context for sedimentary rocks and other radioactive waste programs; yet they are conservative in the sense that they are measured under ambient laboratory pressures and they do not account for the in situ confining pressure. Some recent research that we've done indicates that confining pressure would cause a further 20 to 40 percent decrease in these -- in these diffusion coefficient values.

Now on the slide 48, the numerical model also requires the assignment of boundary and initial conditions for the natural tracers. On this slide, examples are provided for -- for the chloride ion on the graph on the left, and for the oxygen 18 isotope, the graph on the right. The description that follows provides an explanation of the approach to assigning boundary and initial conditions for the chloride tracer only. So knowledge of the geologic evolution of the basin tells us that halite or rock salt containing evaporitic rocks had been present in the Salina formation since the Silurian.

So the Salina formation is a between 200 and maybe 350 meters depth. So accordingly, when we're looking to assign boundary conditions, in the Silurian the initial and the boundary conditions were established with poor water chloride concentrations at saturation with respect to halite because we know halite is present. Similarly, there is geological knowledge suggesting that the Ordovician sediments accumulated under conditions with normal marine salinity, so much lower salinity than in the Salina. This knowledge constrains the initial concentrate – the initial chloride concentration as shown for the Ordovician portion of the stratigraphy, say from 450 meters down to about 850 meters. There is no knowledge of the initial chloride concentration in the underlying Precambrian, but it’s assumed that the dense brine from the basin invaded to some depth into the crystal and rocks. A zero flux boundary condition is established 750 meters deep in the shield and that’s a depth that we feel is sufficient to prevent an influence form the boundary condition on the simulation results.

Moving on to slide 49 - just some words about uncertainty. The time scale for diffusion as indicated by the modeling is obtained by running the model within a parameter estimation code which is called pest. Pest runs -- it takes and runs MIN3P numerous times while systematically changing the diffusion time scale. And then a least squares approach is used within Pest (phonetic) to obtain the diffusion time that provides the best fit to the measured data profiles. This best fit is indicated by the solid red lines on the three graphs shown here on slide 49. So the solid red line in the middle is the best fit. There is some uncertainty in the measurement of diffusion coefficients and the choice of initial and boundary conditions. And this uncertainty is addressed in part by conducting sensitivity analyses which allows us to investigate the range of possible or reasonable values for each parameter. And examples of the results from analysis of sensitivity to the initial conditions and lower boundary condition for oxygen 18 are indicated here by the dash lines. So the dash lines really represent simulation outcomes as we systematically vary these parameters.

Finally, slide 50. With regard to the influence of uncertainty on confidence in the results, it’s important to make a distinction between confidence in the model results and confidence in the overall system interpretation. So, accordingly, the confidence table on slide 50 provides one column for each of those. With regard to confidence in the numerical model results, the principle sources of uncertainty are the initial and boundary conditions and the diffusion coefficients. An attempt is made to minimize these uncertainties in the case of diffusion coefficients by constraining the values with many laboratory measurements. There’s over a hundred measurements throughout the stratigraphic column. And in the case of boundary and initial conditions by consideration of multiple lines of evidence, geochemical, hydrological evidence that also points in a direction of specific initial and boundary conditions. The overall interpretation of the system is not based solely on numerical model results. The model results are considered to carry less weight in fact than other lines of evidence such as hydraulic and geochemical properties of the system. However, consistency between the model output and all other contributing data is considered an important factor leading to confidence in the conceptual model. And this concludes my presentation.

THE CHAIRPERSON: Thank you very much, Dr. Muecke I believe you have a question.

MR. MUECKE: Dr. Al, in terms of the boundary conditions that you have imposed on -- the one that I'm interested in is the one concerning chloride concentrations in the Precambrian and the assumption is made that basically, the chloride concentrations are equivalent to those of the brines of the basic. If -- if this -- I wonder about the validity of this assumption and what the consequences would be if the concentrations of chloride were more typical of average Canadian Shield ground water for example. How would that influence the outcome of the model?

DR. AL: Tom Al for the record. If the chloride concentrations were significantly higher, the Canadian Shield concentrations are quite variable as I’m sure you know. If we take concentrations such as have been measured at the victor mine in Sudbury they’re relatively low salinity compared to some of those in say mines in the Northwest Territories and other locations. But if we take the high-end of the range, say from Yellowknife then the diffusion time would be lower. And I don't recall exactly how much lower. We have done simulations to look at sensitivity to these parameters.

The concentrations that are used in this particular set of model outputs are not dissimilar from those measured at the Victor Mine in Sudbury though. So the outcome would be very similar if we used those concentrations.

I should note that the whole idea of the origin of salinity in the Precambrian shield brines is a subject that's been under study for some time. And it's thought that much of that high salinity that's observed in some of these Precambrian brines throughout Canada comes from basinal brines that have migrated in during the Paleozoic.

So the initial condition for the Precambrian below the Michigan basin would predate that. So we've had a lot of discussion about this subject.

MEMBER MUECKE: So you're telling me that you have run the model with various brine concentrations, including the higher runs?

DR. AL: We have certainly looked at sensitivity to the boundary condition concentrations. Off the top of my head I don't have the absolute values for those concentrations.

MEMBER MUECKE: Could they be provided?

DR. AL: They could be provided, certainly, m'hm.

MEMBER MUECKE: Please.

DR. AL: Yeah.

MEMBER MUECKE: Thank you.

THE CHAIRPERSON: I will note that as an undertaking. This will be undertaking number 1. I believe that was all the questions that the Panel had on MIN3P. Thank you very much.

So we would like to proceed with part two of the presentation, beginning with FLAC3D modelling.

ORAL PRESENTATION PART 2: REPOSITORY EVOLUTION MODELLING

MR. GIERSZEWSKI: So for the record my name is Paul Gierszewski, I am Director of Repository Safety at NWMO.

In this second part of the presentation the repository evolution models will be described. These models assess how the site, including the repository, will evolve with time. They allow us to numerically test the robustness of the repository system. That is, they allow us to check that the repository design and the host rock provide containment and isolation under a variety of likely and unlikely conditions.

The four primary computer models used for repository evolution will be described. First, the computer code FLAC3D was used to model the mechanical behaviour of the shafts in the surrounding rock. This is important for ensuring that the backfill shafts provide effective containment.

For the record we note that modelling of the mechanical behaviour of the repository itself, that is the rooms and tunnels, was discussed in the previous technical information session on July 18th, per the JRP request, will not be repeated here.

Second, the computer code FRAC3DVS-OPG was used to model the evolution of the groundwater system around the repository, including the repository and effects in the hydraulic pressures.

Third, the computer code T2GGM was used to model gas generation and transport as well as groundwater conditions and contaminate transport.

Fourth, contaminate released within the repository, transport from the repository and released to surface was modelled with AMBER. This model assumes that people live above the repository in the future, in order to estimate potential future impacts.

We will now describe these codes. Professor Mark Diederichs will first present FLAC3D. He is a professor from the Department of Geological Sciences and Geological Engineering at Queens University. He's been involved with the DGR project since 2008 providing advice with respect to geomechanical data synthesis and numerical analysis.

Professor Diederichs.

DR. DIEDERICHS: For the record, this is Mark Diederichs. The purpose of this analysis was primarily focused on the shafts and seals looking at the EDZ through the initial operating phase to the re-excavation and installation of the seals, and then the long-term performance out to a million years.

We included perturbation such as glaciations, anticipated seismic events, over-pressures due to gas generation within the column, and combinations of these scenarios; and including time dependent strength degradation was part of the base case.

The analysis was conducted for critical sections that included the shaft seals, and the software as we've said is FLAC3D. There were 31 analysis sections done covering the spectrum of geological conditions and seal geometries.

The primary purpose was to investigate the rock mass response, both in the short-term. And as I said, through the re-excavation process, the ultimate closure, and then the long-term behaviour.

Specific shaft seal behaviour was examined. Each type of seal has a slightly different geometry and its effect was investigated using this code, with particular focus on the properties and extent of the EDZ, the excavation damage zone.

The next slide please, slide number 53. FLAC3D is a very well-known code in the geotechnical industry. It is also a coupled code, which means it can look at hydromechanical coupling as well as the mechanical processes itself. The FLAC version 3.1 was used in this analysis.

It's a finite difference three-dimensional code used in the geotechnical civil petroleum, and mining, and of course nuclear industries. It's used in almost 70 countries by nearly 3700 users, both in industry and academic users. It's a staple in the construction industry and as well as in the academic circles for geomechanical modelling. It's been commercially available since 1994.

Each version of FLAC3D is verified through a standard process. There are a large number of numerical and analytical solutions with known results that each version of the code is compared against in a very standard quality control fashion; and this process was repeated for this analysis.

The version 2.1 of this code just for reference was qualified in 2002 by the U.S. Department of Energy for use on the Echo Mountain Project, the U.S. program for disposal of high-level nuclear waste. It's also been used and is being used in nuclear waste programs in France, Sweden, Finland, Switzerland, Germany and Belgium.

The modelling approach was to take the various horizons within the shaft column, and break them out into representative volumes. The typical size was 60 by 60 by 80 metres which would be a quarter symmetry model. In other words, a quarter of the shaft is modelled. This allows us to look at non-isotropic stress fields, but capture all of the other mechanical behaviour with modelling efficiency.

Accredited laboratory data was used to

develop the rock mass, and rock strength, rock behavioural properties. We've used conservative assumptions throughout for both the rock mass properties themselves in the short-term and for long-term degradation and ultimate strength properties.

The mechanical contributions of backfill, and the seal material, and the concrete are assumed conservatively to essentially disappear over a period of a hundred thousand years. Not that the seals themselves disappear, but the stabilizing influence that the presence of those seals and backfill would provide.

There's also conservative assumptions with respect to internal swelling pressure within the units, which would serve to stabilize the material. Those types of stabilizing influences are neglected in this analysis.

Slide number 55.

There are a number of different ways of simulating the process of yield failure and deformation within a rock mass. There is purely plastic ductile approach that one can use, where the material yields and begins to deform at a certain stress level and continues to do so. There’s a strain weakening approach where the strength -- as the material deforms, the material gets progressively weaker.

And then, there’s a somewhat different

approach where we assume a fracture behaviour. This is called the DISL approach, for damage initiation and spalling limit. And this produces a somewhat different response, with failure zones typically less than the other two approaches.

The rock mass itself can be quantified with a process known as the geological strength index, and it was this was approach that yielded the larger deformation in yield zones, and the larger EDZs in our study, to look at the sensitivity of that actual constitutive model itself. So throughout the rest of this model, this analysis, we're using a strain weakening approach with the parameters governed by this GSI approach.

The long-term strength degradation is based on literature and also on tests on the Cobourg, which trended along the same lines, and we have a minimum strength over the long term, governed by test data, and by the physics of fracture which states that, below about 40 percent of the initial strength, the rock is inherently stable.

Slide 56, please? The next issue to deal with was the boundary conditions imposed. This is a sedimentary stratographic sequence, so the stresses in each layer can be different in the horizontal direction. Physics dictates that the vertical stress is governed by gravity, but the horizontal stresses in the two directions is a function of the stratigraphy itself, as well as the tectonic history.

There are some measurements at similar depths and similar units elsewhere in the Michigan basin. There were studies done on the boreholes that were drilled on-site, to look at bounding conditions for the stress state. So the horizontal in-situ stress state is deduced from tectonic modelling with conservative assumptions calibrated to the measurements in the observations that we have. As I said, the first physical stress measurement was in Barberton, Ohio, in a unit similar to the Cobourg at similar depth.

The overall profile that you can see in green for the maximum stresses are in line with bounding conditions set by the borehole observations -- that is, known strengths, known observations of borehole breakout, of which there was very little in the drilling, so we know that the strength -- that sets an upward bound for the stresses, because we have good data on the strength.

Throughout this though we used maximum and conservative estimates of the magnitudes. The orientations and directions are set quite nicely by the borehole observations themselves.

There is a potential for non-uniqueness in this particular model, if one was just to use a random approach to try to calibrate this model. However, the tectonic history of this numerical model is set by our known understanding of the forces and the strains that led to the stress state, and so the history and the directionality of the compression of the model over geological time is set by our understanding of geological history.

Slide 57, please? Core pressures were included in the model. Within the base case, the expected case for core pressure generation was considered throughout this analysis. This data came from other studies and was used as input to the flac 3D model.

Not shown in this slide is an extreme case of core pressure evolution in the short term, the short term being the first 10,000 years or so. That was included as one of our cases, but not as part of the base case.

Fifty-eight (58), please? The boundary conditions are set initially by the stress state that I've described previously. We do include an anticipated sequence of glacial events, maxing out at about 30 megapascals of additional vertical stress, which is equivalent to three kilometres of ice, and this was selected from the glacial ice sheet histories generated by the glacial systems models by Pelletier.

This represents conservative maximum likely loading, and this effect is included horizontally through the material properties themselves, including Poisson (phonetic) effect, and then the effect of crustal bending is included by the addition of mechanical equivalent horizontal stress.

Over the course of the repository life of a million years, we anticipate a hazard spectra, as you can see in the figure. This includes acceleration and frequency content of the most likely scenario at that probability.

Most of the modelling was done accepting the 10 to the minus 6 probability case, which is the highest hazard spectra, to the highest acceleration. But in order to get there, you need to analyze different frequencies spectra, and those frequencies come from having that event at different distances. An event closer to the repository will have a higher frequency content that one farther away, and the mechanical response is a function of that frequency.

Flac 3D is a dynamic code, so we can introduce these -- the wave forms you see at the left are measured wave forms within seismic records elsewhere, and these are input into the flac model to look at the effect on stability of the shaft.

Slide 60, please? So though the column you can see on the right figure, we have a lot of red dots there indicating the various combinations of loadings and boundary conditions that were used to analyze difference sections. Each red dot represents a flac 3D analysis.

The base case is a time-dependent strength degradation model, with the anticipated core pressures. We add to that glacial loading, and we subsequently add to that this elevated extreme case of water pressure and gas pressure, which is considered unlikely but considered here to see its impact, and the base case with glacial loading and seismic loading, as discussed.

Now, in this case, the potential for non-uniqueness is not a problem for forward modelling, because if you get the same answer with a different parameter set, in our case that is a real situation and, in fact, serves to increase confidence as it demonstrates a lack of sensitivity to those combinations.

May I have slide 61, please? Other aspects that increase our confidence in the flac 3D mechanical modelling, in the category of validation and calibration we’ve used the borehole behaviour from the six boreholes and we’ve used base case data and measurements to constrain the in-situ stresses, and then within that dataset we've used the most conservative magnitudes and ratios for our modelling.

We've used high glacial and seismic loading, on the conservative side, and conservative constitutive models, in other words, the behaviourial models that give us the worst case result. And then, within that we've used lower-bound strength values to increase the amount of failure that we induce in the models. We've also increased a weakening behaviour with time and with strain, and that would be an extreme case based on the literature.

As I've already discussed, flac 3D is an extensive verification suite, so that we know the code has been thoroughly verified. We also verified this particular set of modelling with a second code. This is a two-dimensional code, a finite element code, called Phase Two, which I will discuss that presently.

In terms of our management of uncertainty, we've chosen the approach -- rather than to test all combinations within the parameters set, we've chosen to go with a conservative approach throughout. We understand the impact of our parameters through experience, to the point where we can assume -- we understand which parameters lead to a conservative result, and so that's what we've done here.

The concrete -- for example, the effect of the concrete is neglected over 100,000 years. The backfill stabilization effects, which are obviously there, are ignored. We've considered extreme combination loading cases. We've ignored the stabilizing effect due to the swelling within some of these units.

And, at the end of all of this, we've taken the maximum excavation damage zone from any unit within the system and applied it to the entire vertical column and it's a serial system so that is -- is extremely conservative because any -- any pathway must pass through each and every unit in succession. And so, when we pick the most conservative estimate for the entire column, that is -- that's a very major assumption on the conservative side.

Slide 62 please. This slide shows us some comparisons with other techniques and other models, other strength -- sorry, other strength models and other numerical codes. The results were compared with Phase 2, as I said, another numerical code. The results were compared with a brittle strength model - some of these rock units will exhibit that sort of behaviour - and the results were compared with accepted empirical estimators for breakout or EDZ development.

The black circular dots that you can see in the figure represent the FLAC3D modelling and in virtually every case, they -- the 3D model with FLAC3D with the rock mass constitutive model that we used, ends in the largest excavation damage zone. The brittle codes and the two-dimensional codes all result in smaller, measurable EDZs. And as you can see in the figure, the dash line across the top, which is the EDZ extent used for the safety case, corresponds to only one unit; the Cabot Head where the -- which is a -- which has a maximum EDZ far in excess of all of the other units.

These results were continuously verified by an expert team. Dr. Derek Martin is a Professor at University of Alberta. Dr. Dougal McCreath is an Emeritus Professor from Laurentian. Tom Lam from NWMO. Drs. Martin and McCreath have a long history of experience in nuclear waste geomechanics as well.

And then, in summary, relative contribution to our confidence and our management of uncertainty is an extremely widely-used and heavily-reviewed code. The calibration used conservative estimates from the DGR site. We -- we used regional data and regional trends for the stress model. The model behaviour is consistent with our understanding of -- of how a shaft behaves in this sort of environment and we’ve compared this model with other codes.

Now, the sensitivity analysis is -- was more done on a conceptual basis to understand some of the -- some of the issues like stress -- the stress state and the stress ratio. For the most part, though, our understanding of the parameter space for this type of analysis is very -- is very good. A shaft being excavated down through these types of rock units, we understand what conservative values are in each -- in each case and so the approach in this case, for forward modelling was to use conservative values in every case. And so, input and governing criterion were used that were known to be conservative. And the overall confidence, I think, the management were satisfied with the -- with the overall contribution of these. Thank you.

QUESTIONS BY THE PANEL

THE CHAIRPERSON: Thank you very much.

As before, we'll proceed through the slides in -- in numeric order beginning with Dr. Archibald.

MEMBER ARCHIBALD: Thank you very much. I'd like to bring your attention to slide 54 please, where we have a -- a descriptive image of the shaft EDZ analysis. Given that the uppermost 180 metres of the shafts will be subject to advective water flows, is this considered to be a critical section or key horizon in the analysis, and based on that, why was the upper 180-metre long section planned to be backfilled using crushed rock fill, not also subjected to modelling analysis?

MR. GIERSZEWSKI: Paul Gierszewski, for the record.

So I'll take a first response at that and then see if any colleagues wish to add to that. So, the primary shaft seal is in the lower rock formations, the low permeability Ordovician and Silurian units. The upper region, as you noted, is very permeable, so therefore, it wasn't relied on in terms of the shaft sealant properties and engineered fill was just used there just for mechanical support.

I don't know whether any colleagues would like to comment further on that. Marc?

MR. JENSEN: Marc Jensen, for the record.

The upper 180 metres is a -- is a -- as you've noted, a freshwater aquifer; dolostones, extremely permeable, hydraulic conductivities on the order of ten to the minus 6, ten to the minus seven. Establishing seals in that part of the groundwater system would not be effective and the design was to put a permeable backfill into that place to allow the aquifer to naturally do what it does best.

MEMBER ARCHIBALD: Thank you very much.

If we can proceed to slide 56 then, please. This is where we look at the initial conditions of in situ stress. Now, could you explain how confidence can be provided when using conditions of in situ stress for your modelling that were not actually derived from measurements; that is, where the information available is inferred only from borehole breakouts and not from in situ testing?

DR. DIEDERICHS: The measurement, if one can use the word, of in situ stress is -- is one of the areas of geomechanics where measurements are often less reliable than any other approach. The stress measurement that's used in this case is actually from a mine so the access is close, the reliability is high.

Other types of stress measurements at these depths, as other nuclear waste programs around the world are finding, are very problematic and -- and is in many cases, the uncertainties within the measurements, themselves, are less than -- than the type of certainty you can get from an analysis such as this.

The -- the measured data that we use primarily came from the boreholes so this is an analysis of borehole deformations and borehole breakouts. Very extensive acoustic logs were done of all the boreholes.

We have very detailed records of breakouts and deformation profiles through -- through the boreholes and those can be used to constrain the ratios and magnitudes of in situ stress based on the strengths that we have also from the data.

So from -- from the borehole breakout analysis and borehole deformation analysis, we can constrain at least trends in the magnitudes and the orientations for -- for horizons. Then, the model itself is a tectonic model that -- that recreates the geological history of the -- of the strata, itself, and the idea is to allow this model to work until known points -- known points of high confidence are matched and then the strata that stresses through the rest of the model, which is primarily a function of stiffness, fall into place.

So it's a preponderance of evidence approach to building this stress model and in my experiences - I think I can stand on this one - is more reliable than physical measurements at this depth.

MEMBER ARCHIBALD: The actual physical measurements that we see on this slide are basically constrained to the measurements at the Norton Mine that shows a single point in space at -- at a particular depth near the repository horizon depth. And you have other evidence there, the Adams and Bell projection, the FLAC3D trend and so on, which basically start at zero horizontal stress at the surface and that is dissimilar to many readings on a worldwide basis where horizontal stresses, at least in the Canadian Shield, develop at a higher level than the vertical stress near the surface. And so this would tend to lead one to believe that the stresses are, in fact, possibly underestimated at this. So, how confident would you be that the in situ stress has not been underestimated for this case?

DR. DIEDERICHS: That's a good question. If -- if you actually look at some -- at the trends, for example, in the 200 to 400 metre range, if you extrapolate that to surface, if the rock at that location with its integrity continued to surface, that -- then you can estimate that you would have a surface stress of somewhere between 10 and 15 MPA.

What has happened above that because of the dissolution of the various salt units, et cetera, is the level of fracturing in the upper 200 metres precludes the high horizontal stresses that you're talking about. But this model does include -- if one was to assume that the rock was -- had the same integrity up to surface, you would end up with what you're talking -- with what you're suggesting which is a high horizontal stress. But the upper 200 metres, the lack of integrity precludes that.

I might say that -- draw your attention to the verification study that's in the submission. It's a separate report. There will be a number of different techniques used to verify the in situ stresses during shaft development.

MEMBER ARCHIBALD: Thank you.

Also on this same slide then, I think it's the conclusion in your written-report section, that the calculated horizontal in situ stress exceeds the regional stress data. Now, this again -- much of this data -- and I use the Norton as an example -- would be an example of regional stress, but in your conclusions, it is stated that the calculated or modelled horizontal in situ stress essentially overestimates relative to the regional stress.

And if you look at the database, it says database for greater than 600 metres, the dashed black line, dotted line at the bottom. And you project that up to the 600 metre depth level, it's only shown from approximately 840 metres and down, but it is stated to be for depths greater than 600 metres.

If you project that back up on the regional database modelling, the stress indicates that the in situ stress would be less. Your modelled in situ stress should in fact be less than the regional stress data. And so this is contradictory to the conclusion that you have in the (inaudible).

Given this, how confident are you that the model of stresses will always be conservative?

DR. DIEDERICHS: Mark Diederichs for the record.

The conservatism with respect to regional trends pertains primarily to the repository horizon as you can see there. The regional trends from the shield and from the lower units, the competent units, the carbonates, are not sustainable within the shale units according to our borehole records. The borehole records would be completely full of breakouts were we to project those stresses up. The borehole records show virtually no significant breakouts of any kind in the units.

Also the stresses with the Cambrian Shield are not continuous up through. So a lot of the regional database contains shield stresses, which should not be expected to continue through the sedimentary cover, because there's a discontinuity there in terms of stress, horizontal stresses.

So the statement -- which was the statement you're referring to, Dr. Archibald in the conclusion?

MEMBER ARCHIBALD: In your written text calculated horizontal in situ stress exceeds the regional stress data. That should be in your written documents.

DR. DIEDERICHS: Yeah. That is certainly true at the repository horizon. The picture up through the shaft is much more dependent on the individual stratigraphy in the rock units themselves. The stiffness is a big player. If you have stiff units next to soft units under tectonic compression the stiffer units will have a higher stress level. And those are typically the units that any regional data is taken from.

MEMBER ARCHIBALD: Thank you. I think the only confusion came from that projected from 600 metres as it said on the legend for that. If we had known your rationale for that it would have been much more easy to interpret. Thank you.

THE CHAIRPERSON: Thank you. So I think the next question is from Dr. Muecke.

MEMBER MUECKE: Yes, Dr. Diederichs. If you stay with slide number 56. And I'm so interested in the last statement that the potential for non-uniqueness, that is to say the potential that there is more than one plausible solution is managed by incorporating the most likely tectonic model for strain and loading.

Could you explain that in concrete terms how that is accomplished?

DR. DIEDERICHS: Mark Diederichs for the record. The actual physical model process of recreating the stresses?

MEMBER MUECKE: I'm referring to how you use the tectonic models.

DR. DIEDERICHS: Okay. This model is recreated including sedimentation and the known tectonic compression history, and those known directions. What is known of course is the exact extent of strains in each of those cases. And so the scenario is such that the history proceeds until the known points, or the points we have confidence in our estimations are met. And the interpolation, the different stresses and the different horizons that we don't have measurements for are a function of the stiffness, but knowing that the strains are consistent.

So the strains placed upon this sequence by tectonic shortening is consistent through the units and then the stresses that evolve are a function of the unit stiffnesses themselves. But when I say that the non-uniqueness is managed it's not just a random set of shortenings and extensions in different directions. We use a known understanding of maximum shortening directions and so on, and maximum extents in timing.

MEMBER MUECKE: So it's basically using the basin history in terms of progressive loading ---

DR. DIEDERICHS: Yes.

MEMBER MUECKE: --- during geologic time?

DR. DIEDERICHS: Yes.

MEMBER MUECKE: And you see that in horizons where it's reflected where you can calculate it and then you can extrapolate that basically to those where you can't?

DR. DIEDERICHS: That's right. If we can see units where we know -- where we can get the stresses approximately correctly to our measurements we can assume based on our knowledge of the rock mass properties that the intervening units are accurately modelled.

MEMBER MUECKE: Thank you.

THE CHAIRPERSON: Thank you very much. Can we proceed to slide 57,please?

This is a question that occurred to me. How conservative are the assumptions for pore pressure build up, and what proportion would be, of that pore pressure build up would be due to microbiological degradation of the waste?

DR. GIERSZEWSKI: Excuse me, Paul Gierszewski for the record.

So the gas generation calculations that led to the gas pressure in the repository included corrosion reactions of metals which would be a chemical reaction as well as microbial reactions within the repository which were degrading organic wastes. So both contributed to that story.

The microbial was certainly an important part. I wouldn't -- I have to reflect on the numbers to put a particular percentage, but certainly it was a significant contribution to the gas pressure within the repository, and therefore a gas pressure component to the pore pressure listed here.

THE CHAIRPERSON: Thank you. Could you also perhaps clarify how sure you are that those pore pressures were indeed conservative based on the conservative assumptions?

DR. GIERSZEWSKI: This would be to some extent discussed in the later models where we talk about the models, or use the gas -- where we -- sorry, the gas generation models. Sorry, Paul Gierszewski for the record.

But in summary there are a number of conservative assumptions we used in that. We assume that all of these materials, the metals and the organics were fully degraded. We assume that because there were energy sources here that the microbes would use that and would degrade.

We also took all these reactions down to their fundamental gas generating potential as opposed to having them stop the (inaudible) products along the way. So we did try to maximize the extent of gas generation in the models.

THE CHAIRPERSON: Thank you. Dr. Muecke, I believe you have another question?

MEMBER MUECKE: Yes. If you could go to slide 60, please. And we have a number of (inaudible) scenarios here, but there seems to be one missing. And that is to say the base case, glacial loads, plus seismic loads, plus water gas pressure. Is there a reason for the exclusion of that particular scenario, or could you explain?

DR. DIEDERICHS: The gas pressures that we discussed -- sorry, Mark Diederichs for the record.

The gas and pore pressures mentioned there as a case, an extra case, are the extreme cases not shown in the previous slide, which is essentially a doubling of the pressures as the outside extreme case. The seismic loading case on its own produced essentially no appreciable change.

It was the glacial loading combined with the seismic loading that was deemed here to be an essential combination because of the change in direction of stresses that that affords.

The extreme case of dynamically changing water pressure and gas pressure and the dynamic effects of the seismic loading is a challenge for the modelling package itself that we felt was not reliable enough to essentially include as a conclusion. But the extreme water gas pressure increased the EDZ by 20 to 40 percent, which was already well-within the -- which was well-within the safety case margin for everything by the Cabot Head. And it was deemed that the seismic loading would have no impact on that increase.

MEMBER MUECKE: Thank you. One more point. If you could go to slide number 63, please.

I would like to zero in on the sensitivity analysis here, being given a low rating. And my question is which critical parameter caused this low degree of confidence? I believe you mentioned it, but it skipped by me.

DR. DIEDERICHS: Mark Diederichs for the record.

This low rating is not meant to indicate that the sensitivity produced a low contribution on its own. It reflects our focus on conservative bounding conditionings over a case-specific sensitivity analysis.

So in other words, if you don't understand, and this happens in many analyses. If you don't understand what a conservative parameter is then you must do a sensitivity analysis.

Mechanical behaviour of a shaft system, in this type of environment with these type of stress levels is a very well-understood system. So in virtually every case we know in advance what a conservative value is.

So in most cases you have to look at those two lines together, the conservative inputs and the sensitivity together. And the single star versus the three represents our focus in this particular analysis.

There were sensitivity analyses done for example on the stress ratios to understand what a conservative stress ratio was in the two directions of the shaft. It's well understood that a weaker rock mass will produce a more conservative result. A higher stress magnitude will produce a conservative result and so on.

So our focus was more on choosing the conservative value in every case rather than a sensitivity study; that's what those two lines together reflect.

MEMBER MUECKE: Well, thank you for that clarification, it certainly helped.

THE CHAIRPERSON: Okay. We have one final question, again, arising from slide 63.

So Dr. Diederichs, as you've just explained, you relied upon uniformly conservative assumptions and therefore you place less emphasis on the sensitivity analysis.

So if you could assist us a bit more in giving perhaps more explicit examples of conservative bounding conditions, particularly spatially and temporally.

DR. DIEDERICHS: Mark Diederichs for the record.

Temporally, sort of the extreme rates of strength degradation are used. In fact, the strengths reach their minimum I believe within the first 2,000 years. The lower bound is the -- the lower bound for the strength of these units is understood to be an absolute conservative lower bound for how low strength can drop without any other further disturbance.

So this is not the strength of the rocks that are already yielding. This is long-term degradation of the unyielded rock. And of course, if that process was to go on forever we wouldn't be standing here today. And so there's an absolute lower bound if you have a piece of rock under a certain stress that the strength will degrade. And so temporally speaking we take that out to its absolute plausible minimum.

Spatially the data is of course based on vertical boreholes and in the six boreholes. And so when we take a distribution of the strengths, and the rock mass qualifies, and the rock mass strengths for example, we take the lower bound for that entire distribution and assume it's active throughout the entire footprint.

Does that answer the question?

THE CHAIRPERSON: Yes, that's helpful. Thank you. That concludes questions from the Panel on this section. And it just so happens to also be lunch time. So let us convene please promptly at 1:00 p.m.

---Upon recessing at 12:07pm

---Upon resuming at 1:00pm

THE CHAIRPERSON: So good afternoon, everyone. We are now going to proceed with the second section under Part 2, repository evolution modelling. And this will be a presentation regarding the FRAC3D.

DR. GIERSZEWSKI: Good afternoon. Paul Gierszewski for the record.

So John Avis will present the FRAC3DVS-OPG and the T2GGM models. He is a principal at Geofirma Engineering Limited in Ottawa, and has been providing detailed groundwater, gas and contaminate modelling support to the DGR project since 2006.

John.

MR. AVIS: For the record my name is John

Avis. As Paul said, I'm a principal with Geofirma Engineering here in Ottawa.

FRAC3DVS-OPG version 1.3 simulates the groundwater flow and the transport of contaminates, in this case radionuclides through geologic media.

In the post-closure safety assessment FRAC3DVS-OPG has been used to support the development of AMBER and T2GGM assessment models.

The numerical approach we use for the post-closure safety assessment, it was used with both triangular and --

THE CHAIRPERSON: Excuse me, Mr. Avis, sorry to bother you, but could you actually put the microphone closer to you? Thank you.

MR. AVIS: Okay. Is that better?

For the post-closure safety assessment we used FRAC3DVS-OPG with both triangular and brick-shaped finite elements. Adaptive time stepping was used to reduce computation time.

FRAC3DVS-OPG is an OPGQA controlled code version of the FRAC3DVS code. The development, and history, and status of the model have been previously covered in Professor Sykes' presentation this morning, so I'm not going to go over it here in any great detail.

Next slide please. Slide 66 shows the main processes used in the FRAC3DVS-OPG model code inside the in the safety assessment usage. The model domain extends from the bottom of the Ordovician system, at the top of the Cambrian up through the Ordovician, Silurian system through the Devonian up until the water table is shown.

The model simulate all the significant groundwater transport pathways for dissolved radionuclides from the repository. These include diffusive transport in the low permeability deep and intermediate bedrock and in the sealed shaft, as well as infective and dispersive transport in the higher permeability shallow bedrock.

Next slide, please. In implementing this we use two different model discretizations as shown in slide 67. The primary model is a detailed 3D model that includes a representation of the repository consistent with the preliminary repository design. We refer to this as the 3DD model.

This model extends vertically from the top of the Cambrian formation to the top of the Salina G and thus includes all the Ordovician and Silurian units at the site.

Hydraulic gradients are predominantly vertical within this domain with horizontal gradients indicated only within three thin permeable units, the Cambrian, The Guelph and the upper Salina A1.

The second model we use is a 3D model of the surface units, and we refer to this as the 3DSU model where flow is horizontal driven by hydraulic gradients towards Lake Huron. The model includes Devonian bedrock units, but not the surface till.

It includes a water supply well located down gradient from the shaft. This model is used to determine the well capture percentage for any radionuclides transmitted through the shaft to the surface system.

Next slide please. The 3DD model is shown in slide 68. It contains several simplifications of the preliminary or repository design. The ventilation and main shaft have been combined to form a single shaft of equal cross-sectional area. The emplacement rooms have been combined to form connected panels of equivalent volume. The ventilation and access tunnels have been schematically straightened to be generally orthogonal. Details around the shaft station have not been included.

These changes simplify the numeric modelling, but are not expected to have any influence on the results.

The access tunnels and waste panels are vertically extended 10 meters to include rock fall. Conservatively, we have assumed that rock fall occurs instantaneously at closure of the repository rather than coincident with some future glacial event. Rock fall does not occur over the area supported by the concrete monolith extending around from the shaft; there is however a higher permeability damaged rock zone presence surrounding this monolith. The 3DSU model is shown in figure -- excuse me, in slide 69, and is the model domain for the shallow ground water system. The horizontal extent in the x direction approximately 500 meters up gradient form the shaft and it extends two kilometres to Lake Huron, approximately Lake Huron shoreline, covering the shallow flow system that would be impacted from any radio nuclide release from the shaft. The water supply well extends to a depth of 100 meters and is located 500 meters down gradient from the nominal shaft location. At greater depths, the water becomes brackish and not potable and this restricts the depth of the well we’ve implemented. The downstream distance from the shaft was selected to capture contaminants that from the expanding plume, as it moves downstream, should there be a release from the shaft. The upper shaft itself has not been explicitly incorporated in the model as it is a high -- has a hydraulic conductivity similar to that of the rock formation. Boundary head conditions are specified to force a ground water flow direction parallel to the x axis and towards Lake Huron. Hydraulic and transport properties of each formation and head gradients were as specified in the descriptive site GSTR model (phonetic) which is primary site characterization report.

Slide 70 shows the key initial conditions for the 3DD model, in particular the rock formation hydraulic conductivities and the initial head conditions. These data are derived directly from the site characterization program especially as described in the DGSM. The figure shows that all the rock formations within the model domain are explicitly included in the model. Hydraulic pressures measured at the site have been converted into environmental head to account for the effect of fluid column density variations. This allows us to simulate a primarily vertical flow regime with a variable density as a constant density system. And under pressure in the middle of the formation – of the Ordovician rock formations is apparent, as is the formation overpressure at the bottom of the model. Fixed pressure boundary conditions at the top and bottom of the model were specified based on measured pressed as the Cambrian and Salina G. These are shown as the small purple dots on the – on the central panel of the figure. The side boundary conditions were set to no flow, these boundary conditions support a vertical gradient in the system which would maximize the potential impacts at the site, and this is a conservative assumption. Next slide please. Dress model calibration - there were no model calibration parameters. In this case we are not fitting to any existing model, we are basically – all of the variables affecting flow and transport within the rock mass are derived directly from the site data. In particular, the formation hydraulic conductivity values were from formation averages calculated from straddle packer testing in boreholes DGR1 through DGR6. Porosity and diffusion measurements are also formation averages of testing on rock cores from DGR boreholes. Storage coefficients were calculated from formation average porosities and rock compressibility's calculated from measured geo-mechanic parameters. And as mentioned previously, the initial heads or the pressures measured in the west based systems within the boreholes at site converted to environmental head.

Slide 72 shows some example results from the fractury (sic) DVS modelling; these figures portray the concentration of chlorine 36 at variable times. Chlorine 36 is a potentially important radiant nuclei, it is present in the waste stream and it is long lived and non-absorbing. It doesn't -- it's not retarded as it as it moves through the rocks by absorbing onto the rock mass. The concentration and repository air closure is calculated by assuming that all the chlorine 36 present in the waste are instantaneously dissolved into the -- into a fully saturated repository. The 3D figure on the left hand side shows the extent of transport at one million years. The isovolume – the boundary of the isovolume, the concentration is approximately equivalent to an annual one microsievert dose if it was used for drinking water. However the water here is far to salient to be used as drinking water. The figures on the right show a vertical cross section through the repository and shaft and the associated concentrations at 50 thousand years, a 100 thousand years, 500 thousand years, and a million years. You can see by the shapes of the concentration plume that we have a primarily diffusive transport system. There is no evidence of a defection in the system; the plume is essentially equidistance from the repository up above and below. Deal with -- verification and confidence in the fractured UVS code have been previously described in the presentation by professor Sikes, and we won’t go into great deal of details again.

Slide 73 describes the confidence in how we apply the code in modelling of the DGR. We performed new inert testing on -- on our simulation results to ensure that we had a good mass balance with our simulations. We evaluated that we are using appropriate convergence criteria and that all numeric criteria were met. We applied QA procedures to the model input data, parameter values that are entered into the models were compared to source values by checkers who are not involved in the creation of input files. Report and approaches were peer reviewed. Finally, simulation results were compared to spread sheet calculations for some simple cases. We have an example on the next slide of the comparison – the model comparison between fractury DVS and T2GGM or tough two results. For what we are comparing here is hydraulic head profiles, two different modelling cases where we have a steady state pressure profile, we see that the results from the T2GGM model and the fractury DVS model are entirely coincident. The lines fall on top of each other, there is a transient comparison which incorporates the under pressures within the system. These results at a hundred thousand years post closure are vary similar up through the middle, from the bottom of the system up through the middle of the Ordovician and tend to diverge only slightly at the top. And that's due to differences in the model domain between the fractury DVS and the T2GGM model.

Okay, next slide, looking at sources of uncertainty within the modelling and we can characterize it in basically three categories, there's parameterization of the model, the repository conceptual model, and the geosphere conceptual model. For the most part, we address all the uncertainties by using conservative assumptions and sensitivity cases. The categories are dealt with on the following two slides. Parameter uncertainties are largely addressed by sensitivity cases; these are summarized in figure 3-1 of the post closure safety assessment report, Ground water modelling report. Key parameter uncertainties are addressed as follows: first, the geosphere formation permeability's are derived directly from the borehole measured temperatures measured or hole conductivities. We have a sensitivity case where we increased the impact or increased the permeability by a factor of 10. Second, the permeability of the excavation damage zone, or the EDZ; we've increased the permeability over the assumed permeability from the flack modelling by again, by a factor of 10. Okay, radio nuclei transports dominated by diffusion in the system, we have increased permea (phonetic) one of the sensitivity cases increases the diffusion coefficient used in the geosphere by a factor of 10. The characteristics of the shaft seal and the shaft seal construction materials have been selected from the lower end of the expected performance range, i.e. the upper range permeability's. We have additional test cases where we have increased those permeability's further, increased sensitivity cases and there is also disruptive scenarios with much, much higher scenario, with much, much higher permeability than would be expected. Uncertainty within the repository conceptual model refers the kind of the imprecise knowledge of the conditions within the repository. These are addressed through conservative assumptions as follows. Rock fall seismicity we’ve assumed that this happens immediately upon closure and we get 10 meters of rock fall that sealing hide increase by 10 meters. This is -- if this does occur, it would be expected to occur at much later times. This is conservative in that it does reduce the thickness of the Ordovician cap rock. Within the fractured VS model, the repository evolution is really not modelled in any detail. We assume that all the -- all the contaminants dissolve immediately in water into a fully saturated repository. Although most of the waste is containerized when placed in a repository, we have given no credit for container for isolation. And this maximizes the potential for the release of new radial nuclides. And as in the -- in normal evolution cases, gas generation is expected to substantially delay the re-saturation and thus limit the opportunity for waste to dissolve in liquids and be made available for contaminate transport. As is stated we will -- we take a conservative assumption here and say that the repository re-saturates immediately and all waste is dissolved at closure. Geosphere uncertain -- the geosphere conceptual model uncertainty refers to our imprecise knowledge of the conditions that may affect fluid flow and radio nuclide transport within the geosphere.

These uncertainties are discussed and evaluated within the site shield, within the site shield hence this.

The post-closure safety assessment modelling is based on the reasoned expectations described within the GeoCensus documents. The particular aspects that could impact the FRAC3DVS-OPG results include the Ordovician under pressures. These are the pressures we've discussed previously and measured in DGR boreholes and indicate that the Ordovician system is under-pressured relative to hydrostatic.

Within the post-closure safety assessment we've addressed this in two respects. We have a reference case that assumes that the under pressures are present and will dissipate toward steady state with time.

And then there's a simplified base case which conservatively assumes that the under-pressures will be fully dissipated at the repository closure and the system will be steady state with a primarily an upward-pressure gradient.

The Cambrian overpressure, this is a bottom boundary condition for the system. This is specified as constant on the basis of the Michigan basin-wide modelling results from the GeoCensus program.

Gas saturations within the Ordovician rocks testing on DGR course has indicated that the Ordovician formations may include free-phase gas and saturations close to 20 percent.

We have not included gas saturations within the fully liquid saturated FRAC3DVS model, they are included in the T2GGM simulations that we've described in the subsequent presentation.

If they had been included they will have the effect of reducing the permeability further to the flow of liquid.

Regional flow in the permeable units, we have hydraulic heads measured within the permeable units at site. These are the Cambrian, the Guelph and the Salina A1 formations which show very low regional horizontal gradients.

These flows would serve to divert any radionuclides transported up the shaft and prevent them from reaching the biosphere.

We have conservatively ignored those flows in most of our cases. We have a single sensitivity case where we've included the horizontal gradients and to evaluate the effect of these horizontal flows.

Slide 77 shows results, compares results of all sensitivity cases. The sensitivity cases are labeled on the bottom axis.

And in these cases chlorine 36 again was modelled as potentially important radionuclide, and we have compared here on the figure here the sensitivity case results to the chlorine natural deposition rate of atmospheric chlorine 36, at the site, as providing a natural background level.

Most of the sensitivity cases do not show up on the axis at all. They are at least five orders of magnitude lower than the deposition rate.

The ones that do show for all the sensitivity cases are mostly below natural background with the exception of a single disruptive event.

The disruptive event scenario would be the drilling of an exploration borehole through the repository connecting to the Cambrian, and thus serving as a conduit for pressurized Cambrian flow through the repository and then to the surface system.

Generally the sensitivity case results show that the transport is diffusion dominated in the deep rock formations and this is consistent with the evidence from site characterization.

Release to the surface does require an enhanced permeability pathway.

In summary, FRAC3DVS has been used to model groundwater contaminate transport and the repository shaft and geosphere. The model does not include gas transport, gas generation or transport, and so it's not a primary safety assessment code, but it does provide support to the primary T2GGM and AMBER codes.

Confidence in the model is provided by, we have a number of factors here, use of the widely accepted FRAC3DVS code, use of input data derived from the site characterization program, development of the modelling under a formal QA program with peer review at increment final stages.

We've looked at comparing the model results with other codes, and we've addressed all the uncertainties -- we've addressed uncertainties using very conservative assumptions on over 16 sensitivity case calculations.

Overall we have a high-level of confidence that the FRAC3DVS-OPG model has been developed and highly appropriately for assessment of the DGR system.

Thank you.

THE CHAIRPERSON: Thank you, very much. As before the panel will proceed through our questions in the order that the slides represented.

So Dr. Muecke, would you please begin?

MEMBER MUECKE: Thank you. Mr. Avis, could we look at slide 66, please? And you have the bounding scenarios here, and it includes a water well which is located 500 metres from the shaft.

How does this constitute a conservative approach? A water well located closer to the shaft I assume will be impact more than one 500 metres away.

DR. GIERSZEWSKI: Paul Gierszewski for the record. So I'll respond and then see whether Mr. Avis wishes to respond further.

So the shaft seals the low permeable system, approaches the shallow groundwater system about 180 metres depth. And so then at that point it would be exposed to the flowing waters in the aquifer and there would be a sweeping sideways.

So in fact if you were to put the well at a hundred metres you actually wouldn't be the most conservative location.

So some distance downstream would be a maximum and it would be -- and that was the basis for selecting this, and it would be on the order of a few hundred metres downstream you would capture the maximum.

MEMBER MUECKE: Is this based on actual modelling of that flow or is this an assumption?

DR. GIERSZEWSKI: One of the models that was described earlier, the 3DSU model is a model of the surface system. So that was used then to determine the well capture fractions given a release at the shaft location. Paul Gierszewski for the record.

MEMBER MUECKE: And that is documented in the GeoCensus or ---

DR. GIERSZEWSKI: Paul Gierszewski for the record. So the details of the ground water modeling that were described here, these are part of the post closure safety assessment work, and these particular results are described in the post-closure safety assessment ground water modeling report.

And I'll just check whether Mr. Avis wishes to add anything to the points we've just recently discussed.

MR. AVIS: John Avis for the record. I don't have much to add to what Paul said, and flow is predominately in the bottom of the system. And we have subsequent to the report conducted sensitivity assessments on well location and the 500 metres was conservative.

Thank you.

MEMBER MUECKE: Okay, thank you. In

looking at slide number 67, showing the two different domains for which the modelling has been applied, why is the Cambrian not included in the modelling?

MR. AVIS: John Avis for the record. The Cambrian forms a high-pressure system which forms a bottom boundary condition for the model.

So its effect on the model is included, there's no actual flow within the system, within the Cambrian unit, but it does form the lower boundary condition for the 3DD model.

MEMBER MUECKE: Although there is no flow, there's no other possible interaction other than flow?

DR. GIERSZEWSKI: Paul Gierszewski for the record.

So again it's important for us in the modeling here because it's a high-pressure system so it imposes that vertical gradient on the system that could lead to transport.

So that is the key aspect from the safety assessment perspective, and that is included. We do calculate in our modelling the safety assessment modelling, the AMBER model described later, the concentrations of contaminates that would reach the Cambrian formation.

And so we do have that information, it is described in the post-closure safety assessment report that concentrations that reached down there are in fact very low. But from a groundwater transport to a surface in the system, its primary function is that it gives you that boundary condition of high-pressure creating vertical gradient upwards.

MEMBER MUECKE: Thank you. And coming back to this slide number 67 and the two domains. At what stage or how is the interaction of those two domains captured, or are they totally isolated from each other?

MR. AVIS: John Avis for the record.

As nearly all our cases showed that there was no transport up the shaft into the top of the system, the 3DSU model was used in more of a -- a sense to determine capture ratios if a contaminant was followed. So what we had done is we take a mass flux that is in theory from the shaft under some sort of a release scenario and we put that as the source term for the bottom of the 3DSU model and from that point, we calculate contaminant transport within the 3D, within the upper domains and uptake through the well. But I -- I really have to reinforce that none of the scenarios showed any transport up the shaft at any appreciable level.

MR. GIERSZEWSKI: Sorry, Paul Gierszewski, for the record.

So I just want to -- to bring out a couple of other points. So the 3DD model, that's the low permeable system and that's where the bulk of the containment and isolation is being done and it is -- is isolated, in effect, from the fast-flowing system in the top. Both of these models were used to support the more detailed safety assessment which was an integrated model, the AMBER model, was the integrated model which will be described later. So these were pieces of information that supported the construction and the parameters in that AMBER model.

MEMBER MUECKE: Thank you.

THE CHAIRPERSON: If we could move to the next slide, 68 please. The question here is since simplification may not necessarily mean conservatism, could you provide some justification regarding why the assumptions used for the model; i.e., combining shafts and rooms are the most conservative?

MR. JOHN AVIS: John Avis, for the record.

We looked at the -- the flow dynamics for the system and determined that if we're -- the flows that were concerned would be vertical flows up through the shaft system and the -- and its combined radius of the shaft which effectively governs the transport through that system under -- if there are advective conditions occurring. So the single shaft has the same equivalent area as the main and vent shafts and I guess I can also say subsequent to this work, we performed additional test cases with the dual-shaft system which show that that is, in fact, the case.

THE CHAIRPERSON: Thank you.

Dr. Muecke, I think you're -- have next question?

MEMBER MUECKE: Thank you.

Could we move on to number 69 then? And this is the mere service portion of the model and what is excluded from it is the service till cover. How does that -- how does that impact and in terms of the conservative approach, how does that reinforce the conservative approach?

MR. AVIS: John Avis, for the record.

The till at site has been shown to be quite low permeability. I think on the order of 10^{-7} metres per second. The boundary conditions we use to drive this model are a horizontal gradient through the more permeable -- some of the units are 10^{-4}-10^{-5} metres per second and we feel this will be the predominant driving force at depth and that recharge through the till would not really provide much in terms of additional gradients to the system.

MEMBER MUECKE: I recall that in the tills there are sand horizons which have considerable permeability so that if one takes the conservative approach, should one not consider that as a possibility?

MR. AVIS: John Avis, for the record.

The other thing is the gradients at site will be governed by the topography if, in fact, infiltration is driving and it is predominantly flat through that system, but I believe we probably have other comments from Marc Jensen.

MR. JENSEN: Marc Jensen, for the record.

The till sheet that exists at the -- at the Bruce Nuclear Site is a basal till sheet. It’s extremely dense. It’s a silt clay. It’s got a very low permeability through which recharge is measured on the order of millimetres per year. Certainly, with respect to sand lenses or intervening sand horizons within that, they tend to be very localized in extent and -- and do not create significant pathways for recharge that would significantly influence the hydraulic gradients that Jon has spoken about within that upper bedrock zone. This simply is because of the hydraulic conductivity of the bedrock that underlies the till and the potential sand units is -- is at least a thousand times higher in hydraulic conductivity. So Jon’s realization seems to be correct.

MEMBER MUECKE: Okay, thank you.

Going on to slide number 70 and one thing that -- if you -- if you look at the hydraulic conductivities I used for individual horizons here, I -- I assume these are a means of measured values. And how -- in -- in the modelling -- so each of -- each of these values has a -- associated variability and my question is how is that variability incorporated, the data variability for individual horizons? How is that incorporated into -- into the modeling to derive the most conservative estimates?

MR. GIERSZEWSKI: So, Paul Gierszewski, for the record. I think there's two parts to the answer again. First, I'll ask -- I think Marc Jensen could just comment on the -- on the variability in -- in the measurements. The actual parameters we used were -- were based on the geosynthesis document and they're described there and in the supporting descriptive site geosphere model so I'll first ask Marc to comment on that and then I'll come back to the second point about the -- the handling of the uncertainty and the safety assessment.

MR. JENSEN: Marc Jensen, for the record.

The hydraulic conductivities for the individual bedrock formations are described and derived in the descriptive geosphere site model. And in there, the -- the uncertainties with respect to the hydraulic conductivities at the site scale are described. We believe that there is a fair consistency within each formation at the scale of the repository at which the simulations were performed so that the values assigned in the descriptive hydrogeologic model in the descriptive geosphere site model report are considered to be average and reasonable values for the assessment that was performed.

MR. GIERSZEWSKI: So, Paul Gierszewski, for the record. So then to follow on that so the -- the reference case inputs to our models are those main values as Marc Jensen just described. We also did a sensitivity case where we increased all of the permeabilities in the vertical direction which is, of course, the one that matters in this case by a factor of 10.

MEMBER MUECKE: Thank you. That clarifies it.

THE CHAIRPERSON: If we could bring up slide number 75, please. So now we’re getting into the summary of how uncertainty was dealt with and my question is actually a direct follow on from the discussion we just had based on Dr. Muecke’s question.

So I understood from you, Mr. Avis, that you decided to use values that were 10 times higher for the permeability and diffusion. How or why was a factor of 10 selected and does this factor of 10, indeed, represent a defensible upper bound that is adequately conservative so that we can be confident that we have a measure of migration to the surface that is always overestimated?

MR. AVIS: John Avis, for the record.

Yeah, we -- these we believe were conservative assumptions. Mr. Jensen can speak to the actual variability of the diffusion coefficients, but for example, for the EDZ permeability where you increase the factor of 10. This would be our prominent --our most likely pathway through -- from the repository to the upper units. As Professor Deiderichs noted earlier, our EDZ parameterizaton is already extremely conservative and reflects basically the EDZ we'd see in the most permeable and most susceptible to damage zone. And we have taken that we have propagated those particular parameters down through the entire system.

So we've started off with an extremely conservative base for the excavation damage zone permeabilities, and then we've increased that by a factor of ten. So we believe this does certainly bound the conditions we'd expect, so...

MR. GIERSZEWSKI: Paul Gierszewski, for the record.

So, again, I think more specific information on that -- if you looked at the information in the descriptive site geosphere model, and also in the post-closure safety assessment date reports, you can see the range of numbers, and then where we -- reference numbers where we get a sense of the range of those parameters.

The factor of ten was selected with a sense of the actual range in mind. Or, in other cases, there wasn't always a factor of ten, that was just those two particular examples.

THE CHAIRPERSON: So as a follow-up clarification question then, what I gather from your response is that you are confident that a factor of ten adequately represents an upper bound, let's say, the 95^{th} or 99^{th} confidence interval?

MR. GIERSZEWSKI: So I haven't quantified it to that particular number, but I do believe it represents an appropriate upper bound for these modelling purposes, perceived assessment purposes.

MR. AVIS: John Avis, for the record.

I have just one thing to add, just a correction. The EDZ parameterization was actually increased by a factor of 100 on the inner EDZ and 10 on the outer EDZ. We had our EDZ in two concentric rings, so it was a more extreme case. Thanks.

THE CHAIRPERSON: Thank you, that helps.

MR. JENSEN: Marc Jensen, for the record.

I'd just like to point out that the factor of 10 considered for the geosphere would have represented numbers that were significantly higher than what was measured, so that they would be conservative. And yet, even still, the system is diffusion-dominated and governed, really, by the effective diffusion coefficients that occur within those sediments.

THE CHAIRPERSON: Thank you.

So what I'm hearing is the factor of 10 actually gets you into the realm of never actually even being observed in any of the data collected from the site?

MR. JENSEN: Marc Jensen, for the record.

The factor of 10 gets us into the higher values than were observed in the site -- at the site, yes.

THE CHAIRPERSON: Thank you.

It appears that we've come to the end of our questions on this section of the presentation. So if we could please -- oh, I apologize. Dr. Muecke has just pointed out he does, indeed, have a question, on slide number 79.

MEMBER MUECKE: Slide number 79, it is.

This is more a clarification than a question, because, if you look at the last line there, it says, “Uncertainties addressed using conservative assumptions and sensitivity analyses,” and then you mention 16 calculation cases.

When you say 16 calculation cases here, are these 16 cases where sensitivity analyses were done or the 16 cases represent the sensitivity analysis? Am I making myself understood?

MR. AVIS: Yes. We have a total of 18 cases for fractory EVS (phonetic) that include our standard -- our reference case and our standard base case, so the 16 additional cases are sensitivity cases.

MEMBER MUECKE: But each case -- I’m sorry -- When you talk about sensitivity analyses, it’s the sensitivity -- it’s constituted off the 16 cases? You don’t take each case and do a sensitivity analysis on it?

MR. AVIS: John Avis, for the record.

The sensitivity cases, what we refer to as the sensitivity cases, is usually where we address sensitivity to a single parameter. So, for example, the EDZ sensitivity case had the factor of 100 and a factor of 10 increase of the EDZ. Other sensitivity cases, such as the increased vertical hydraulic permeability, that would be a separate case as well.

So we start off with our standard base case and we vary one parameter, and each of those constitutes a single sensitivity case.

MEMBER MUECKE: So just to make sure that I've got this right, okay, so you take, let's say, the base case, okay, and start -- you vary one parameter, then another and another, and then you take your next scenario that you have and go through the same process? Or do you only do it for the base case?

MR. AVIS: John Avis, for the record.

Most of the sensitivity cases were primarily conducted on the base case; it was the variant, so...

MEMBER MUECKE: Thank you.

THE CHAIRPERSON: One final question on slide 79, the row where you say the use of input data derived from site characterization had a high relative contribution to confidence, I just want to dive into that a little more deeply. Perhaps, Mr. Jensen, you can help, in particular?

As you know, the level of confidence in data is directly proportional to how well and how confident you are that you have, indeed, captured the natural variability across your study area. So what I think I've heard from you and your team is that you are, indeed, very confident that the data that you have available for the site adequately captures the natural variability of important parameters, such as hydraulic conductivity, such that that in turn leads you to being confident that you are being very conservative.

Can you just confirm my understanding of that, please?

MR. JENSEN: Marc Jensen, for the record.

You are correct. It's the multiple lines of reasoning that we bring to bear on this. It's the borehole testing, it's the natural analog work that has been done, that Pr. Al discussed, it's the site-specific analog work that Pr. Sykes discussed about the preservation of those anomalous underpressures.

It's also looking at the environmental tracers, the methane gas concentrations, the helium isotopes with the system, as well as radio-isotopes, that lead us to believe that the system as a whole, that Ordovician system, that the hydraulic conductivities that we are proposing, and are described in the descriptive geosphere site model, are very representative of the conditions at the site described by Mr. Avis.

THE CHAIRPERSON: So, in other words, all of your lines of evidence are adding up to a consistent story? There haven't been any surprises?

MR. JENSEN: All of the lines of evidence that we've had are lining up on a story that the system is diffusion-dominated and stable over geologic periods of time, yes.

THE CHAIRPERSON: Thank you, that's very helpful.

I think we actually are now ready to proceed with the next section, which will be on the T2GGM modelling.

MR. GIERSZEWSKI: Paul Gierszewski, for the record.

So, again, I'll ask Mr. John Avis to give that presentation.

MR. AVIS: John Avis, for the record.

The T2GGM code has been developed to provide an integrated approach to modelling gas generation and consumption reactions in the repository, and the flow of gas and groundwater in the geosphere and the engineered barrier system. Results include repository and shaft pressures and saturations.

T2GGM combines TOUGH2 and GGM. TOUGH2 is an industry standard numeric code for two-phase, in which gas and liquid flow, while GGM is a DGR-specific code developed specific for this application.

TOUGH2 uses an integrated, finite difference method approach to spatial discretization of the domain. GGM, by contrast, treats the repository as a single compartment model. GGM is a code module that is linked into and runs under TOUGH2.

THE CHAIRPERSON: Mr. Avis, may I interrupt you a bit?

MR. AVIS: Yes.

THE CHAIRPERSON: We're still having a little bit of trouble hearing you.

MR. AVIS: Okay.

THE CHAIRPERSON: So if you could maybe increase the volume, and perhaps speak just a bit more slowly? That would be very helpful. Thank you.

MR. AVIS: Thank you. I've been told several time to speak more slowly, so, it's noted. Okay.

Slide 82 illustrates the linkage between the TOUGH2 and GGM code. As I said before, TOUGH2 models the entire geosphere and the repository domain. It calculates gas and groundwater movement in the shaft and in the geosphere, and it calculates pressures and saturations throughout the geosphere and repository.

The average repository pressures and saturations calculated by TOUGH2 are passed to the GGM model at the beginning of each time-step. GGM calculates gas generation and water consumption that will occur over the following time-step according to the waste inventory that's present and the reaction conditions.

The gas and water flow rates are then returned to TOUGH2 where they're incorporated into pressure and saturation calculations for the next time-step.

Next slide, Paul. TOUGH2 is a multi-phase and multi-component code. It includes advection and diffusion transport and can be isothermal or non-isothermal. It consists of a main program which is linked with an equation of state module which defines which processes are included.

With T2GGM we use the EOS3 equation of state module which includes water and air. They're a single-processor and multiple-processor solver versions of the code. The multi-processor code TOUGH2-MP that was described earlier by Professor Sykes -- was described earlier by Professor Sykes. The single-processor version we used here within T2GGM. Apart from the solver approach the single-processor and multiple processor codes are functionally identical.

EOS3 or TOUGH2 is provided in source code form and this allows modification by the user. So in addition to integrating GGM, EOS3 was extended to work with gases other than air and a 1D hydromechanical capability has been added to the code. The hydromechanical module was implemented using an approach similar to that of FRAC3DVS-OPG.

A fundamental assumption of TOUGH2 is that gas and liquid flow under Darcy flow conditions; i.e. non-turbulent flow of gas and liquids as defined by the permeability and pressure gradient that Professor Sykes explained earlier.

It also assumes a capillary pressure relationship between gas and liquid pressures, where capillary pressures are a function of the saturation. This results in a nonlinear system of equations.

I'm going to discuss the fundamental aspects of GGM. It's our repository model, and it models only conditions within the repository, and GGM models, gas generation reactions that are expected to occur subsequent to closure. The repository is modelled as a single, fully-connected void of specified volume.

We focus on the key processes that are potential sources of gas due to microbial and corrosion reactions. We also track water consumption within the repository. Microbial process include the decay and generation of biomass.

At repository closure GGM is provided with an initial inventory of waste and package materials, reactions proceed as conditions allow. For example, some reactions occur only when sufficient water or water vapour is present in the repository.

GGM tracks the amount of waste material, the corrosion products and gases within the repository to ensure a complete and consistent mass balance. It accounts for the flow of water and gas to and from the repository into either the geosphere or into the shaft system.

GGM includes over 30 reactions. The reactions and kinetics are described in detail in an available report, the T2GGM software documentation available on the NWMO website. The key processes in the DGR are exothermic, energy releasing reactions that occur under anaerobic conditions after all oxygen in a repository has been exhausted. These are noted qualitatively on the slide here, 85.

We have microbial degradation of organic wastes, primarily organics and water cellulose leading to methane and carbon-dioxide. We have methanogensis, which is a consuming reaction which takes hydrogen and carbon-dioxide and yields methane and water. We have the anaerobic corrosion of metals yielding hydrogen and enhanced corrosion of carbon steel, also yielding hydrogen.

The T2GGM model simulate all significant transport pathways for bulk and dissolve gas. By "bulk gas" we mean gas that exists as a separate phase. Bulk gas movement is limited primarily to the repository and engineered barrier system. Dissolved gas also diffuses into the low permeability deep and intermediate bedrock.

In the modelling and post-closure safety assessment T2GGM was only applied to the intermediate and deep geosphere. Gas transport in the higher permeability shallow bedrock was included in the AMBER-DGR model.

Similar to the FRAC3DVS model we use three different spatial discretizations for T2GGM. The primary model was a detailed 3D model that includes a repository representation that's consistent with the preliminary repository design.

We had a second 3D model which was a simplified representation of the repository that was used for certain of our sensitivity cases and to verify that the detailed model was correct. The 3D model extends vertically form the top of the Cambrian formation to the Guelph formation, and thus includes all of the Ordovician units at site, but not most of the upper Salina.

This range provides sufficient discretizations to model transport in the low formability formations and in the repository while avoiding computation time issues associated with including the very permeable Guelph and Salina units in our model, or the more permeable.

The lateral extent of the model was approximately five kilometres by four kilometres, so it extends well-beyond the repository boundary. Rock formations were modelled as horizontally flat, which is consistent with the low slope of the stratigraphy and the importance of vertical over horizontal transport from the repository.

The 2D shaft model encompasses the entire Ordovician and Silurian sequence up to the shallow groundwater system. This model was used to determine the fate of gas in the shaft for any of our cases that did show gas flow up the shaft. As a 2D model it was considerably smaller, had a reduced number of nodes compared to the 3D model and was therefore not subject to the same computation time limitations.

We see the next slide, slide 88 is the 3DD model. As for the FRAC3VS model it contains several simplifications to the preliminary repository design. Again, the vent and main shafts have been combined to form a single shaft. Emplacement rooms have been combined to form connected panels and the ventilation and access tunnels have been straightened out. Details around the shaft station have also been excluded.

As for the previous model these changes simplify the numeric modelling but are not expected to have any significant influence on the results. In all cases the void volume associated with these features has been incorporated to ensure that we have the correct gas pressures calculated during the simulations.

As for the previous model, access tunnels and waste panels are vertically extended ten metres to include assumed rock fall immediately upon repository closure. Rock fall is not included over the area supported by the monolith where there is a higher permeability damaged rock zone present.

Next slide. Two cross-sections here shows more details of the 3D model. The figures show a vertical cross-section through the repository. The left figure is to scale. And it shows the vertical limits of model domain extending from the Cambrian up to the Guelph. Although we only have four colours showing the different geologic units, we have in fact included all formations individually with the individually assigned rock formation parameters.

The expanded scale on the right uses the ten to one horizontal exaggeration to clarify the shaft seal and excavation damage zone. The excavation damage zone is shown as a darker and lighter shaded colours of the intact formation surrounding. And this shows the extent of the EDZ, which was derived from the FLAC modelling approach discussed by Professor Diederichs earlier.

The extent of the GDS this is conservatively modelled as equal in thickness to the shaft radius throughout the entire shaft column.

Slide 90 shows the key initial conditions within the model, in particular the rock formation hydraulic conductivities and the initial pressure conditions. This is similar to the previously shown slide. They derive from the DGSM and it shows that all rock formations within the domain are explicitly included.

The pressures measured onsite again have been converted into an environmental head to account for the effects of the fluid column density and an under pressure in the middle of the formation -- the middle of the Ordovician rock formations as apparent as is the Cambrian formation over pressure at the bottom of the model.

The fixed pressure boundary conditions applied to this model are similar to the previous model. We have a higher pressure, an over-pressure on the

Cambrian bottom formation and the pressure at the Guelph, at the top of the model, which is close to hydrostatic.

Repository and shaft were initially fixed at atmospheric pressure for the first 60 years of the simulation, and this represents the operating period when it would have been open to ventilation and atmospheric pressure. At that point the closure conditions were applied and it was allowed to evolve naturally.

Slide 91. Slide 91, there. The calibration of the T2GGM model as for the other site scale model, there are no model calibration parameters. All the data are traceable to site or literature values and they reflect all the requirements of the model.

We have permeability measurements from the straddle packer program, procity diffusion compressibility measurements for cores, and two-phase flow properties, in this case we're taking from petrophysics performed upon cores and then model parameters calibrated to the petrophysics values.

There's no free parameters have been adjusted here, all parameters align with the site data.

Slide 92 presents results for the reference case simulations. The upper figure shows the gas partial pressures within the repository and the total gas pressure.

So you can see by the different coloured lines we have pressures of different gases occurring throughout the evolution of the repository conditions.

And then total gas pressure which increases from near atmospheric at closure, I should note also it's a log X axis on the timescale, increases from near atmospheric pressure at closure, up to just slightly over the expected hydrostatic pressure at a million years.

The second figure shows the carbon mass balance in the system, and this shows basically the initial sources of carbon or all the sources of carbon and the destinations of carbon within the repository, and it shows the evolution as things go, from example, from cellulose to the end where we're in primarily a methane gas dominated-system. All the carbon is primarily in a gaseous form in methane.

Slide 93 shows some example results showing the gas flows and liquid flows within the geosphere and within the shaft system. Within the geosphere gas and liquids move according to pressure, gradients and permeabilities. This slide shows details of the gas saturation and liquid pressure and flow directions around the shaft at a thousand years.

At this time the shaft is nearly fully re-saturated. Initially upon placement there is some gas present in the shaft materials. However pore water moved in from EDZ in the formation slowly and displaces or dissolves as gas.

This liquid flow within the geosphere immediately adjacent to the shaft and repository which is driven by the very high pressure differential between the shaft, which is essentially at a low atmospheric pressure initially, and the formations which are a much higher pressure.

Within the rock mass there's really virtually no flow outside of the immediate vicinity of the shaft, again due to this extremely low permeability.

Verification of the T2GGM code and our confidence in the code implementation, T2GGM is based on the TOUGH2 code which Professor Sykes had noted it's a widely used code for modelling gas phenomena in radioactive waste disposal programs and in other programs as well.

It's a code of choice from modelling a two-phase flow and for assessing gas transporting DGRs internationally. The background of TOUGH was previously described in geoscience modelling presentation.

Our confidence in T2GGM is also based upon a process we used to implement and integrate GGM within TOUGH2. Our work was conducted under an ISO 90012008 registered quality assurance program. We have specific procedures to govern software development and numeric modelling.

There are numerous unit test cases designed to verify GGM operation and the integration with TOUGH2. QA procedures were also applied to the model input data. And finally the reports and the approaches were peer-reviewed.

The NWMO is using T2GGM, primarily the gas transport TOUGH2 component, in a number of additional projects as described in the subsequent slide, or in this slide, I'm sorry.

These comparisons with the experiments and other computer codes provides further confidence in T2GGM. We're using (inaudible) to simulate experimental results from the Swiss HGA program, and the LASGIT experiment in the Swedish repository program at ASPO.

Numeric testing has also been used to determine appropriate model convergence criteria and mass balances of fluid and gas were calculated to confirm the results were numerically correct.

We've also compared the results to simple spreadsheet calculations, and these include pressures due to gas generation and flow rates of gas through unsaturated media.

The next slide, please. This slide shows the results of a comparison of the GGM module to the Finnish gas generation experiment. This was a ten-year field study of gas generation from waste packages. The figure shows the total gas generation with time of cellulosic wastes.

The results showed that within a range of short-term cellulosic degradation rates, regional agreement was obtained with the experimental results for gas generation and composition.

So the experimental data being the purple line in the middle, and the degradation rates using T2GGM representing by the bounding lines there.

We have further confidence-building exercises including comparison of results from different implementations and from other models.

In Slide 96 we have the top figure compares T2GGM results for the detailed 3DD model, and the simplified 3D descretization I described earlier for three cases.

In this case each case is a different colour and the two different model results are shown as solid and dashed lines. Results from the two models are very, very similar in every case since the dashed lines and solid lines largely overlap.

The lower figure compares the T2GGM results with those from FRAC3DVS for the fully saturated system. Hydraulic head profiles show the hydraulic head profiles for the transient flow model, and 100,000 years are shown.

They differ at the top of the T2GGM to mean only due to the different boundary condition that's supplied at that point. Within the Ordovician and below the Manitoulin formation the results are very comparable.

I'll discuss briefly or -- discuss the source of uncertainty in the model, and we can categorize them in four separate categories; gas generation model, through repository model; gas and water transport within the geosphere; and the geosphere conceptual model.

First of all we'll deal with uncertainties in the gas generation, and for the most part these uncertainties are addressed with using conservative assumptions in sensitivity cases.

For the gas generation model we use simplifying but conservative assumptions that maximize gas generation. That is rather than representing the full complexity of all the microbial and degradation reactions that may be possible, including the interim products the model focuses on the total degradation of the waste inventory into elemental gases, because the importance of gas as potential release pathway.

An appropriate -- we assume that an appropriate microbial population is present within the repository environment at closure either indigenous or resident in the wastes. In effect it assumes that if energy sources exist; i.e. the waste, micros will be there to take advantage of them.

The impact of no microbial activity leading to methanogensis is tested with a sensitivity case. The sensitivity to the reaction rates and the waste inventory is tested by increasing and decreasing in two of our -- any GG1 and any GG2 cases.

Most analyses have been run with reaction water consumption turned off. In this case we conservatively assumed that nearly all the water required to support the reactions is available in a repository and is flowing in from the geosphere.

In actual fact we believe that the geosphere would not be able to supply insufficient water to this. We have additional cases which are water-limited which do not -- which account for this, and they show lower pressures and lower gas generation.

Simulation with all gas generation processes has also been performed as if we have nothing happening at all and just natural re-saturation of the facility. In this case the repository re-saturation will take approximately half a million years. And again this is primarily due to the very low permeability of the surrounding host rock.

With respect to model uncertainties we looked at the potential effects of seismisting glaciation loads are countered through -- or through the rock fall which we assume occurs immediately. And we have not taken any credit for containerization of the waste. We assume that degradation starts to occur immediately upon closure.

And the characteristics of the seal material have been selected from the lower-end of the expected performance range. In other words we've taken the upper-end of the possible permeabilities for the seal materials.

We have additional sensitivity cases where further reduction and performance have been simulated, and we have a disruptive event where a much higher permeability shaft has also been since tested.

We have done a class of uncertainties for the gas transport, is the parameterization of the liquid and gas flow properties. Two phase-flow properties include the choice of function describing capillary pressure and relative permeability and the parameterization of this function.

There's a standard function that's used

widely within radioactive waste disposal and we have -- which we have used the van Genuchten functions and we have varied the parameters for this function over several sensitivity cases to look at that impact.

As mentioned previously the formation permeabilities derive from the testing program. We do have a factor of ten increase on the vertical permeability in one of our sensitivity cases.

The EDZ, we also examined similarly as we did with the FRAC3DVS model in that we increase it by a factor of a hundred in the inner EDZ, and a factor of ten in the outer EDZ, the permeabilities.

Uncertainty in the geosphere conceptual model have primarily been discussed and evaluated within the site geosynthesis report. Our models are based on a reference case which is based on the best understanding of the geosphere, or on a simplified base case, which is based on some of the conservative simplifications of the reference case.

In particular the reference case includes the Ordovician under pressures, and the presence of partial gas saturations in the Ordovician, while the simplified base case says the under pressure is dissipated completely and the formation is fully saturated with water.

In all cases the Cambrian over-pressure is specified as constant at the bottom boundary condition, and regional flow in the permeable units we see that there is slight regional flow in the medium permeability units; the Cambrian, the Guelph, we've ignored these flows for these evaluations.

If there was flow up to gas it would tend to get swept away by regional flows in these units, and thus ignoring them is a conservative simplification.

And there's a vertical fault near the repository as mentioned by Professor Sykes. There's nothing in the -- the geosynthesis does not support the ability of the formation that would include a vertical fault and still show the data we see at site. However, we have examined such as a "what if" scenario within the FRAC3DVS-OPG groundwater code.

Next slide please. This slide shows the results of some of the sensitivity crisis. It shows the repository pressure results from all our non-water limited cases, which is our reference type cases are conservative assumptions.

Although the timing varies we see that the peak pressures of the repository all fall within a relatively narrow range, and which is fairly close to the formation steady state pressure of the repository horizon.

The mirroring effect of the various uncertainties is the timing of the peak pressure rather than its magnitude.

Another key result of the sensitivity is that there is -- it's not shown in these figures. There's some gas flow up the shafts at long times for certain sensitivity cases. However, this flow does not move past the permeable Guelph formation under normal evolution scenarios due to capillary pressure effects.

The impacts of this gas included in the post-closure safety assessment and conducts with AMBER, DGR, and they'll be described in the next presentation.

In summary, the T2GGM modelling has been used to couple a repository gas generation, liquid and gas flow within the geosphere and shaft to prevent a simulation of the overall system performance to support the post-closure safety assessment.

We have confidence in our model results for the reasons enumerated on the slide, we've got a widely accepted use -- we're using a widely accepted code as a base for the simulations. We have taken a gas generation modelling approach that emphasizes complete degradation of our waste.

We've used input data from the site characterization. We've developed both the software and the application of the modelling under a formal QA system.

We've included peer review of interim and final results. We've done a comparison of the model results with other codes, compared some results from different model discretizations and we've addressed uncertainties in a comprehensive manner with conservative assumptions in over 20 sensitivity case calculations.

Overall, we have a high level of confidence the T2GGM model has been developed and applied appropriately for the assessment of the DGR system.

Thank you for your attention.

THE CHAIRPERSON: Thank you very much.

I believe Dr. Archibald, you have the first question.

MEMBER ARCHIBALD: Yes. Thank you very much. On slide 92, if I could have that up, please? I would ask you to explain whether the level of confidence in the predicted gas pressures reflects conservative assumptions, particularly in the production of high methane pressures?

And a second part of the question is, was the model ever run under the condition of using backfill in the emplacement rooms as a more conservative case for pressure generation?

DR. GIERSZEWSKI: So Paul Gierszewski for the record. So the first question was with respect to the confidence in the peak pressure. And I think it's best illustrated in the slide. In the sensitivity slide at the end there you can see that over the range of cases that we had examined. The pressures all tended to collaborate around the natural system pressure.

And I think what you're seeing there in fact is as the pressure builds up to around that level the gas would push out water that was present in the system, or if it's slow the water fills in, so in effect the system is reacting with the surrounding water.

I think we're reasonably confident that that's a good representation of the gas pressures. The second question -- I'm sorry, could you remind me what the second part of that question was?

MEMBER ARCHIBALD: Sorry. Was the model ever run under the condition of using backfill in the emplacement rooms rather than the condition where you have immediate rock fall?

DR. GIERSZEWSKI: Thank you. Paul Gierszewski for the record.

It was indeed run with backfill. And the gas pressure was higher than it was shown here. It was, I don't recall offhand, but it was appreciably higher. That result is presented in the post-closure safety assessment gas modelling report. A result is available there.

MEMBER ARCHIBALD: Would not that then be one of the sensitivity cases that should be considered as being most conservative, or more conservative?

DR. GIERSZEWSKI: Paul Gierszewski for the record. Well, it'll be more conservative in that it was a higher gas pressure, yes, but it's a design basis assumption. So just to be clear, the difference between that and rock fall, if there's rock fall then that doesn't change the available void volume.

So you still have the same amount of space to hold the gas. If you backfill the repository first you don't get rock fall because you supported the roof immediately, but you have about 30 percent of the available volume for you, and so therefore you'd expect to have higher pressures.

So it's a design parameter choice. It's not a sensitivity -- it's sensitive to support the design decision, but the design decision is to not backfill. And so that particular case is never shown here are for the design basis.

MEMBER ARCHIBALD: Good. Thank you very much.

THE CHAIRPERSON: Dr. Muecke, I believe you have the next question.

MEMBER MUECKE: Thank you. Can we

backtrack a bit to number 85? Now you say that over 30 reactions were considered, okay. So I realize I'm only seeing a small subset here. But what I'm interested in is, do these reactions include any interactions with the wall rock sitting in carbonate, and were reactions considered that involve the wall rock, in other words?

DR. GIERSZEWSKI: Paul Gierszewski for the record. The answer is no.

MEMBER MUECKE: Can you give -- would you like to provide a reason?

DR. GIERSZEWSKI: Sorry. The reactions with the -- we were interested in gas generation, and so the reactions would be from the waste organics and the metals in the waste would be giving you gas-generating reactions. The wall is primarily a limestone and calcium carbonate. So it is possibly that there's be a chemical equilibrium. There would be an exchange of some of the CO2 and gas phase with the calcium carbonate.

We don't see those as being a -- if anything we think that our modelling is conservative to do it the way we did. That if we included wall reactions, that they would result in more loss of carbon-14, which is an important radionuclide to a solid phase. And so therefore it was conservative to not include those reactions in the model.

MEMBER MUECKE: And to -- and increase the gas pressure of course, right?

DR. GIERSZEWSKI: I believe Richard Little wishes to make a comment on, I'm not sure if it's a previous question or the answer to that, so ---

MR. LITTLE: Richard Little for the record.

Coming to the question with regard to reaction with the wall rock. We did do some screening or scoping calculations associated with that which are presented in the system evolution report as an appendix. And it actually shows that the reactions with the wall rock are not significant in terms of dissolution of the limestone, but the information is presented in the documentation.

MEMBER MUECKE: Okay. Thank you for that. I shall look at it. Moving onto slide 101 I believe it is. And we are looking at confidence here. The GGM portion of the T2GGM model is a custom code which has been newly developed and so I'm wondering, has it undergone sensitivity analysis and what are the critical parameters that were identified as a result of the sensitivity analysis, for the GGM portion?

DR. GIERSZEWSKI: Paul Gierszewski, for the record.

So I'll take an initial response and then see if our colleagues wish to add.

So GGM, as you noted, is a custom code that we’ve added here. The intent, appreciating that some of these gas reactions there could be quite a range of them, that there’s microbes involved, our approach has been to -- because of the importance of the gas to the safety storage, to choose an approach that maximized the generation of gas and was consistent with -- on the advice of expert modellers who have done more detailed modelling of these systems and what they say these are the key reactions.

It emphasizes the reactions that are exothermic and so we’d expect -- and maybe the rates aren’t quite right, but those reactions will occur over the time scales that are relevant here, and generates the gas.

That’s fundamentally the approach that we’ve taken to that.

From a more -- of a QA perspective on it, both from a sort of software development point of view, yes, there were a number of -- as noted earlier in the presentation -- unit verification tests done, to test the individual reactions, were being implemented properly.

Then at a higher level, we have done sensitivity cases where we varied, within the T2GGM framework, some of the sensitivity cases varied parameters that are specific to the gas generation storage.

And from a more of a verification/validation system, we've had the one case where we did compare with the -- it's a short-term, it's a several-year case -- but we did have a comparison there between the GGM and some actual field data.

And, I guess, the other broad -- from a natural analogue perspective, again, what we see in -- underground in the rock where there's been organics that have been deposited over -- and left underground, under sediments, for long periods of time, we generate methane-dominated systems. And, again, that's what our model is predicting, so at a very qualitative level again, it was a consistency.

So I think that's the general context there. I guess the other part of your question was with respect to what parameters the model is most sensitive to.

I think, generally, if you look at the sensitivity results that were on slide -- sorry, I'll go back to 100 -- I think that's kind of a good summary of the system here. The assumptions -- we're not sensitive to the assumptions, strongly sensitive to assumptions about the rates of these reactions, we're sensitive to the assumption that if -- that the reactions are -- that they occur that generates the gases. That is important from the release of radioactivity, that you've decomposed the gases.

But, broadly, the results seem to -- as you see here -- coming to the same kind of pressure storage. So we're not seeing -- I'm just struggling a bit here trying to think of something that I'm particularly sensitive to.

I think we've shown that the results have a degree of robustness, and probably the most important parameters to this system, really, is the void volume relative to the amount of waste, and that goes back to the earlier question about the backfill story.

I think that's probably the key point that I would want to make on just sort of a reflection here, and I'll see whether my colleagues wish to add.

MR. AVIS: John Avis, for the record.

The only point I'd make is the sensitivity is more to timing than absolute pressures, as Paul said. So if we increase the rates we get earlier time, but we get the same absolute pressures occurring.

MEMBER MUECKE: Now I have a more generic question which basically addresses all the models we have talked about, hydrogeological models, and it's in anticipation of what we're going to hear about AMBER.

AMBER has the ability to evaluate scenarios in a probabilistic way, and my question is, the models that we have heard about so far -- gas generation, et cetera, et cetera -- are all -- correct me, but I see them as deterministic. And I have a -- at least, in my limited knowledge, it seems that a probabilistic approach would approach reality better or more clearly than the deterministic models.

And I have seen indications that probabilistic models for hydrogeology are being developed, and I was wondering whether you could give me an indication as to whether these models are available and whether you have looked into using models which use a probabilistic approach in order to encompass some of the data variability that we see in the parameters?

DR. GIERSZEWSKI: Paul Gierszewski, for the record.

So internationally there's a range of opinions when you look at what other organizations have done on that balance deterministic and probabilistic.

In the approach that we've used here, I think as you correctly identified, for these detailed models that we've just described, the FRAC3DVS and the TOUGH2, they were run in a deterministic manner and that reflects in part that really the important code to us, the

T2GGM with the two-phase system, is a numerically challenging code to run for the kind of timescales, two-phase, the range in permeabilities that we're dealing with, so it is hard to run in a fully probabilistic manner.

So we have addressed that by looking at a wide range of probabilistic -- sorry, of deterministic cases, including some conservative "what if" scenarios.

We have done probabilistic calculations in the AMBER, as you would see I believe in the next presentation. Those were limited though to parameters related to radionuclide released in transport. They weren't related to geosphere-related parameters that would require, in effect, running TOUGH2GGM in a probabilistic manner in support of it.

So that was the approach that we have taken. We think it's reasonable for the system that we've bounded, and covered the range of likely to unlikely by this particular approach and gained appropriate insight into what matters for the safety case.

Now, as far as going forward, we certainly are interested in trying to increase our code capacities, and there's ongoing work to try to do that.

In fact, we have some work ongoing now. Of course, it's subsequent to the report that you've seen where we’ve been trying to run things on a probabilistic manner. So we’re definitely trying to do further with that, but for this report we took the deterministic approach.

MEMBER MUECKE: Thank you.

THE CHAIRPERSON: Thank you very much. That concludes the Panel’s questions on the T2GGM.

So may we now proceed with the presentation on AMBER?

DR. GIERSZEWSKI: Paul Gierszewski, for the record.

The presentation on AMBER will be given by Richard Little. He is Operations Director at Quintessa Ltd. In United Kingdom. Quintessa has provided post-closure safety assessment expertise to the DGR project since 2002.

Mr. Little?

MR. LITTLE: Thank you, Paul. For the record, my name is Richard Little, Operations Director of Quintessa Ltd.

My presentation describes the use of the AMBER code to develop a model of contaminant release, migration and impact in the post-closure phrase for the DGR system.

My presentation provides an overview,

firstly, of the AMBER code itself and then, secondly, of the DGR-specific model that has been implemented within the AMBER code.

The AMBER code is developed and maintained by Quintessa Ltd. It provides a numeric framework for the user to implement their own specific model. It does not have a pre-defined, hard-wired model. The code is typically used for the modelling of contaminant release, migration and impact in environmental systems.

The AMBER code adopts a compartmental modelling approach in which the system to be modelled can be represented using a series of user-defined compartments. Contaminants are transferred between these compartments according to user-defined algebraic expressions.

The code has two solvers; a Laplace transform solver, which is suitable for use with systems with non-time dependent transfers; and a time-step solver, for systems with time-dependent transfers.

The AMBER code is widely used and has been commercially available for over 15 years.

Slide 104 lists the key features of the code. It provides the user with the flexibility to specify the contaminants and compartments to be modelled. It allows the user to input their own algebraic expressions to represent time varying properties and transfers, contaminant concentrations and flexes, and the exposure of humans and other bio to contaminants. It also has the inbuilt ability to represent radioactive decay and in growth.

In addition the AMBER code can be used to undertake probabilistic calculations as we have just heard and to analyze the associated results. Either Latin Hypercube Sampling or Monte Carlo Sampling may be used.

Slide 105 shows that there are a number of factors that build confidence in the AMBER code itself. It has been managed, and developed under Quintessa's quality assurance system.

Secondly, each release of the code has been extensively tested against a broad set of verification tests. The code is now used by over 85 organizations in more than 30 countries. And there are more than a hundred publications describing assessments in which AMBER has been applied, including both international exercises involving code into comparison, such as ISAM and BIOPROTA, and in assessments of other geologic repositories, such as the Swedish Nuclear Regulator's review of the Forsmark facility for the disposal of low and intermediate level of radioactive waste in Sweden. Documentation for the AMBER code is available from the Quintessa website.

With slide 106 I'm now moving on to provide an overview of the specific model that has been implemented within the AMBER code to represent the post-closure contaminant release, migration and impacts from the DGR. I will refer to this model as the AMBER DGR model.

The implementation of the DGR model in AMBER has been supported by the FRAC3DVS-OPG and the T2GGM detail models. These were used to identify the contaminant transport pathways to be represented within AMBER, and to quantify saturation profiles, gas compositions, groundwater and gas flexes and the well capture fraction used in the AMBER-DGR model.

The model is documented in the normal evolution scenario and the disruptive scenario reports, which are available.

Slide 107 summarizes the main repository geosphere and surface environment processes, and the associated exposure mechanisms that have been included in the AMBER-DGR model for the normal evolution scenario. It shows the following:

The gradual re-saturation of the repository. The partitioning of contaminants between liquid and gas phases within the repository. The diffusion of contaminants into the rocks surrounding the repository. The diffusion and advection of contaminants into the shafts. The migration of the contaminants into the shallow groundwater system due to diffusion through the rocks, and potentially diffusion and advection in the shafts.

The release of the contaminants into the surface environment via well pumping, groundwater discharge to Lake Huron and gas flex, and then the subsequent exposure of humans via ingestion, inhalation and external radiation.

Slide 108 lists the key waste and repository assumptions that have been adopted in the AMBER-DGR model. As mentioned previously we use information from the T2GGM model to represent the re-saturation of the repository. No credit is given to waste packaging either as a chemical or a physical barrier.

There is instantaneous release of contaminants on contact with water for all low-level wastes. And for most of the intermediate level wastes. Tritium and carbon-14 are also released as gas due to waste degradation processes. There is also no absorption of contaminants within the repository. And there is no solubility limitation except for carbon.

Slide 109 lists the key assumptions with regard to the geosphere and the shafts. Firstly, water and gas flexes in the shafts are taken directly from the FRAC3DVS-OPG and T2GGM models. Transport is dominated by diffusion in the geosphere. There is absorption of only certain elements, there are seven listed there. And there is no solubility limitation of contaminants within the geosphere or the shaft.

In terms of the key assumptions for the surface environment, or the biosphere, they are first, contaminants are released via the pumping of well water from the shallow aquifer. The discharge of groundwater to the near shore lake bed. And in certain cases the flex of gases from the shaft into a house and surrounding soil.

The second key assumption relating to the surface environment is that a self-sufficient family farm is located on the site and is using the well water.

Slide 110 shows that within the model the DGR system has been discretized to represent its key components. Firstly, we have the wastes. A total of 21 compartments are used to represent the various low and intermediate level waste categories.

Secondly, we have the repository and its rock damage zones. Fifty compartments are used to represent the emplacement rooms, the access tunnels, the monolith and the associated rock damage zones.

Thirdly, we have the shaft seals and their associated damage zones, which are represented by a total of 69 compartments.

Fourthly, the geosphere. A total of 188 compartments are used to represent the four groundwater zones. And finally, the surface environment, or the biosphere, which is represented by seven terrestrial and eight lake compartments.

Slide 111 provides an overview of the discretizations of the waste and the repository, and the associated release and migration processes. Here we can see that contaminants are released into the DGR2 panels in either gaseous or liquid form. Once in the panels the contaminants are partitioned between gas and water. There's assumed to be free mixing of gas and water between the panels and their associated access tunnels.

Contaminants in water can migrate into the damage zone surrounding the panels and tunnels, and then into the concrete monolith and its associated damage zone, and then finally into the shafts. Gas can migrate directly from the access tunnels into the shafts.

Moving onto the geosphere and the shafts, we see that slide 112 provides an overview of the discretizations of this area of the model and summarizes the migration processes and pathways. So we have four bedrock groundwater zones. These are explicitly represented, as is the combined shaft and its inner and outer damage zones.

Contaminants can potentially migrate via the shafts and also via the geosphere. Any contaminated groundwater that actually reaches the shallow system can discharge into the surface environment via the well and the lake. Any contaminated gases can discharge into a house and to soil which is located directly above the combined shaft.

And finally, we see slide 113 which shows the surface environment, the biosphere model and its associated processes. Contaminant releases can occur to the terrestrial environment, which is on the left-hand side of this figure, and to the lake environment which is on the right-hand side of the figure.

A number of processes result in the migration of contaminants from the terrestrial environment to the lake system such as erosion, interflow, airflow and stream flow.

Moving on to slide 114. The AMBER-DGR model has not been calibrated in the strict sense of the word since no free parameters have been adjusted to calibrate the model.

However, it has been ensured that the model's input data are mainly derived from and traceable to DGR waste and site characterization programs.

The groundwater and gas transport data are imported directly from the detailed models, and many of the biosphere data are taken from the Canadian Standards Association publication for calculating impacts from liquid and airborne releases.

Slide 115. We're now moving onto the verification of the AMBER DGR model. The model has been verified using a number of approaches.

First of all the model uses the AMBER code which is numerically robust and well-verified code suited for the development of models of radioactive waste disposal systems. Second, the model has been implemented an intuitive manner under the projects quality management system.

So there has been checking of model and data implementation, mass balance checks have been undertaken to ensure that mass is not been generated or lost from the system due to numerical instabilities, and there's also been peer review of the models and results, including the review of the interim results by an international peer review team.

In addition the results from the AMBER DGR model have been compared with those from other models. First of all the key contaminants have been compared with those identified in simple scoping calculations, and they have been found to be the same.

Second, chlorine 36 fluxes, and this is showing on Slide 116, through the shafts and geospheres have been compared with those calculated by the FRAC3DVS model.

This slide shows that the AMBER DGR results are consistent with but more conservative than those calculated using the more detailed code. This is to be expected, and this is due to the course at descretization of the diffusion-dominated system within the AMBER DGR model.

Slide 117 shows that uncertainties have been addressed in the AMBER DGR model using a number of approaches.

First, future evolution scenarios have been addressed by implementing and evaluating the normal evolution scenario and four disruptive scenarios.

Second, model uncertainties have been addressed by implementing a range of sensitivity cases. For example cases with or without Ordovician under-pressures, and cases with immediate or gradual repository saturation.

Finally data uncertainties have been addressed. First using DGR specific data augmented by national and international sources as appropriate. Second, by undertaking multiple deterministic sensitivity calculations with alternative sets of parameter values. And then thirdly by undertaking probabilistic sensitivity analysis.

In addition model and data uncertainties have been addressed using conservative record case assumptions as I identified in the earlier slides on key model assumptions. These key assumptions are summarized on this slide.

Slide 119 summarizes he results from the reference and sensitivity calculations for the normal evolution scenario. The figure shows the maximum calculation effective dose on a logarithmic scale. For all cases the maximum dose is orders of magnitude below the dose criterion of .3 millisieverts per year.

In particular all cases are within the gray shaded region which corresponds to extremely low doses of less than one nanosievert per year. These sensitivity results show that the calculated dose are most sensitive to the gas generation and shaft seal parameters.

Probabilistic calculations were also undertaken to investigate the sensitivity of impacts to release and transport parameters. The effect of varying the sampled parameters on the maximum calculated concentration in the well water is shown on this slide.

The results demonstrate that the concentration of leading (inaudible) in well water may increase by up to two orders of magnitude when parameters are varied over plausible ranges. However, the very small calculated impacts indicate that the safety of the system is not sensitive to variations in these parameters.

So moving onto my last slide to summarize. Confidence in the AMBER DGR model and its evaluation that the impacts will be low, has been built using a number of factors.

Firstly by the use of the AMBER code which is quality assured and widely used.

Second, by the use of standard conceptual and mathematical models such as those of the Canadian Standards Association.

Thirdly, by the use of input data derived directly from DGR specific waste and site investigation programs, and also from detailed models.

Fourthly, by the development of the model under a quality management system with peer review at interim and final stages.

Fifthly, by the comparison of results from the AMBER DGR model with those from other codes. And finally, by the large safety margin presented in the results.

Uncertainties have been addressed by assessing five scenarios, by using conservative assumptions and by undertaking both deterministic and probabilistic sensitivity analysis.

Overall there is a high-level of confidence that the AMBER model has been developed and appropriately applied for the assessment of the DGR system.

This concludes my presentation and we would be happy to take any questions that you may have.

THE CHAIRPERSON: Thank you very much.

Again, as per our usual procedure we'll go in order of the slides, and therefore the first question will be from Dr. Muecke and it'll be Slide 108.

MEMBER MUECKE: It might actually be Slide 111, I think.

THE CHAIRPERSON: Oh.

MEMBER MUECKE: But could you just confirm for me that one of the assumptions that you make is that there is free mixing of gas and water, including contaminants, between the panels and their associated access tunnels; am I correct?

MR. LITTLE: Richard Little for the record. Yes, you are correct.

MEMBER MUECKE: Now if I develop an

alternate scenario here for you, if -- because I wonder if this is really the most conservative assumption you can make. If there was no free mixing, let's take that as a case, the intermediate level waste panels are in closest proximity to the shafts.

So if there was no complete mixing you would have a high concentration area near the shaft which would set up a high gradient. Would that not be a case that -- how would that case impact on your conservatism?

MR. GIERSZEWSKI: Paul Gierszewski for the record.

So I think first -- I don't think that the intermediate level waste is particularly located close to the shafts. There are some IOW rooms near the shaft, but I believe that they're reasonably generally distributed across the repository, or at least not so much that I'd expect that there's any close concentration.

Secondly, there's no real division within the panel except for the concrete plugs, otherwise the panels are physically open and well-connected in ability of gas and liquid to flow.

And those concrete plugs themselves they're intended for -- during the operational period, but they wouldn't provide a significant barrier on the kind of timescales that we're talking about here, they're not designed and intended to do that.

There's more information on that of course in one of the information requests that also verifies that point.

So my reaction is that that wouldn't be a more conservative -- wouldn't actually happen and therefore wouldn't be a more conservative scenario. But I'll see if my colleagues wish to comment further on that.

MR. LITTLE: Richard Little for the record.

It's an interesting question. My observation would be to draw your attention to the fact that we have got an assumption in there of instantaneous release to water for a lot of the wastes, and recognize that in fact a lot of the intermediate level wastes are in significantly more robust containers than the low-level waste, and therefore you'd expect them to be released a lot more slowly.

However we have been conservative for most of our -- for the waste streams, and assumed that there is instantaneous release. So I believe that what you would be doing is adding conservatism on conservatism, and you're pushing the problem into a physically unrealistic area.

MEMBER MUECKE: Okay. I'll accept that for the moment. Could I ask another question? Was the AMBER model run with a scenario which involved a proximal fault?

MR. GIERSZEWSKI: So one of the disruptive scenarios that we looked at in the safety case was a nearby vertical fault. That was explored with a number of tools, the detailed modeling was done with FRAC3DVS, and so it was a groundwater flow based system.

And then it was in terms of any dose impacts it was also implemented in AMBER to look at that. So, yes, we did do that case.

MEMBER MUECKE: Okay, thank you. I'm very interested in the probabilistic aspects as you have discovered by now.

And first of all in the documentation that's available to us I haven't seen that approach documented. Is that material available to us?

MR. LITTLE: Richard Little for the record.

Yes, it is available. I have in front of me the preliminary safety report. And in Chapter 8 of the preliminary safety report results are presented for the probabilistic calculations.

I'm just if you bear with me leafing my way through to actually give you a section number. Yes, so in the preliminary safety report it's in Chapter 8 and it's section 8.8.4. There is further information also provided in the post-closure safety assessment report in Chapter 7 and also in the normal evolution scenario report.

MEMBER MUECKE: Okay. Thank you for pointing that out. Somehow my search engine didn't manage to capture that.

Now in the slide number 120 if we could have that. You show the probabilistic results at various percentiles for two of the radionuclides. If that approach was applied to all the radionuclides that one would expect, would that materially change the release rates that we see in slide number 119?

MR. LITTLE: Richard Little for the record.

Slide 120 shows results for chlorine 36 and for iodine 129. We did calculations in addition for carbon 14 and zirconium 93. However, they are not presented in Slide 120 simply because the concentrations are significantly lower than you see in that figure.

For carbon 14 the reason is because it's relatively short half-life compared with iodine 129, and for the zirconium 93 it is due to its absorption within the shaft system.

MEMBER MUECKE: Thank you, Mr. Little.

MR. GIERSZEWSKI: Paul Gierszewski for the record.

I just wanted to add with respect to your previous question about finding those particular calculations. The acronym we've used in the reports is NE-PC, so you might try searching for that and see if that helps you zoom in faster on those cases.

MEMBER MUECKE: Thank you for that hint.

THE CHAIRPERSON: Thank you very much.

If we could please back up to slide 119. I note that in the various runs of the sensitivity analysis really the only parameter that was varied, that would be relevant to the surface environment if I'm correct is the, "Tundra climate state."

And I was wondering whether this indeed represents the only parameter that was varied in the sensitivity analysis relevant to the surface environment?

MR. LITTLE: Richard Little for the record.

No, it's not the only parameter that's been varied. We have also considered alternative exposure groups. So we have considered a group living downstream from the site. We have also considered a group taking water direct from the lake and having a high fish intake.

The other case that we have considered that is shown on this slide is the 100 metre surface erosion case which assumes that due to ice sheet movement over the site you actually have 100 metres of the existing shallow system removed. So that is a sort of biosphere/geosphere sensitivity case.

THE CHAIRPERSON: Thank you, Mr. Little.

Further to that I'd like to ask a question about how well in your opinion the Canadian Standards Association input data that were used represent the upper and lower bounds that are likely for biosphere characteristics at the site?

MR. GIERSZEWSKI: Paul Gierszewski for the record.

So those information are developed for use in the nuclear stations, one of which of course the Bruce nuclear station which is at that site. So it is relevant information to that. So we consider that to be a reasonable basis for these parameters.

I haven't done a specific analysis beyond that on terms of the data range, but being a standard I think that would be a reasonable representation because it is intended to cover that location.

THE CHAIRPERSON: May I ask a follow-up specific to that? I listened with interest to Mr. Little saying one of the receptor groups was a receptor group consuming fish down gradient or downstream.

Of course many of the concerns related to that particular group would be the kinds of people that eat more fish than usual; notably Aboriginal people. So I just want assurance that the range of input assumptions for consumption of fish indeed encompasses those upper bounds represented by people who are subsistence fishers, or for other reasons consume a higher than average amount of fish.

MR. GIERSZEWSKI: Paul Gierszewski for the record.

So again just for clarification we did look at two cases which had a high-fish diet. One was somebody who lived downstream. But we also did look at the possibility of someone living at the site and fishing, getting their fish from the near-shore region so therefore potentially higher contamination than further down in the lake. So we did look at those two variants on the high-fish diet.

Secondly, with respect to the parameters, there was some work done in 2003 with the Nawosh First Nations' people in the area in terms of looking at their fish diet and some other implications of that.

We looked at the parameters from that and I believe that the assumption of the amount of fish being consumed that we've used for those cases was five times the value from that study. So I think we've definitely captured a high-end fish diet.

Sorry, there’s a follow-up I believe from Mr. Little.

MR. LITTLE: Richard Little, for the record.

Information is provided in Section 4.4.2 of the Normal Evolution Scenario Report.

And just to clarify something that Paul has just mentioned, the fish consumption rate for adults is conservatively taken to be 100 grams per day. This value is five times the value for the site resident group that we took for our Normal Evolution Scenario, and it is twice the maximum value given in the survey that Paul was referring to. So it's twice the maximum value.

THE CHAIRPERSON: Thank you.

Remaining on Slide 119 and back to envisaging scenarios on the surface environment, this is related to imagining human society and ecosystems in more distant future.

And I have a question regarding whether there were any attempts at imagining major changes in ecosystems and/or in human society, and over what period, in your opinion, it would be -- we would be reasonably certain that the AMBER conceptual model does, indeed, apply?

DR. GIERSZEWSKI: Paul Gierszewski, for the record.

So a couple of points. So we're looking a long time in the future, so there’s a degree of speculation clearly involved with that.

The fundamental approach that we’ve used for that is to assume that people in the future are generally similar to us, we’re not dramatically different physically or lifestyles, we’d be as stylized as reference point, assume that they’re like us and we protect them to the same extent that we protect ourselves.

So we’re not discounting the future, as an example, we treat them as well we treat ourselves and we assume that they’d be generally similar in lifestyle to us.

In terms of considering a range of alternatives, I think again if you look on this Slide 119 that fourth case down, the tundra climate state does, I think -- is rather dramatically different climate state from where we are now, and it’s described in more detail in the report, but it is of a hunting/gathering type of lifestyle than a farming one which was our normal reference case. So we believe we’ve reasonably illustrated the sensitivity to that.

There are some other -- there’s been some other work done not described in this particular report. Just looked at some other types of scenarios that you can imagine, municipal or so on, at the site, and the general sense is that those tend to involve other factors such as food isn't locally sourced so that the kind of cases that we focussed on are going to be your higher exposure cases. And, therefore, from the safety perspective are good indicator species or -- sorry, indicator receptors to use.

I don't know if my colleagues wish to add to that?

THE CHAIRPERSON: Just as a follow-up to that - and this is a curiosity on my part.

Did your study team confer with cultural anthropologists, historians, those kinds of disciplines, from whom we might learn the range of variability in the consequences of, let's say, a dramatic breakdown in society, cycles of various levels of civil society, at least looking backward and then cast forward?

And in terms of making sure again - our theme on the Panel - making sure that we have always over-estimated the consequences of this migration to the surface even in the far-distant future?

DR. GIERSZEWSKI: Paul Gierszewski, for the record.

So we have not had that type of formal consultation on this project. Again, we have cast into the past, for example, to look at the tundra climate state again. We're informed by historical aboriginal lifestyles, so there is that bit of history there that advises us going forward, but we've not specifically done assessment like you've just described.

THE CHAIRPERSON: Thank you. One final question on AMBER.

This is for Slide 121 where the line of evidence refers to the large safety margin in results, in particular given the probabilistic runs which show that even when you're sampling from the higher range, we're getting a more than adequate safety margin.

We were interested though that because the previous slide only illustrates the two radionuclides, how confident are you that there will still be a large safety margin in the results for total dose from all plausible radionuclides reaching the surface?

DR. GIERSZEWSKI: Paul Gierszewski.

So we're very confident in the normal evolution scenario. I think as was answered in the previous one, we did look at the other radionuclides that could potentially be of importance and really the system is so diffusion-dominated, so low-permeability that it just stops things from coming to surface.

THE CHAIRPERSON: And, as you pointed, out this is for the normal evolution scenario?

DR. GIERSZEWSKI: Correct.

THE CHAIRPERSON: Thank you very much.

With that, I think we've come to the end of our questions on AMBER. I'm just confirming with my colleagues? Yes.

And, once again, we've managed to very handily also be at the end of a nice -- that represents a nice opportunity for a quick break.

So let's take a break and reconvene, promptly please, at 10 minutes past 3.

--- Upon recessing at 3:01 p.m.

--- Upon resuming at 3:12 a.m.

THE CHAIRPERSON: Welcome back, everyone.

So, let us now proceed with the Part 3 on Radiation Dose Modelling.

And, Dr. Gierszewski, I believe it is you that is making the presentation, so I'll look forward to your presentation. Thank you.

ORAL PRESENTATION PART 3:RADIATION DOSE MODELLING

MR. KING: Perhaps before we get into the next session, there's a couple of things I'd like to bring up.

Dr. Diederichs has to leave very soon and before him leaving I just wanted to give the opportunity to the Panel if there's any other questions you might have for him, just let us know, otherwise because he will be leaving very shortly.

And, secondly, we took an undertaking earlier on, Dr. Al. Dr. Al has to leave relatively soon as well, but he thinks he may be able to clear up Dr. Muecke's question and, hence, maybe avoid the need for an undertaking. And if you would like to do that, we could do this right now and before moving on to the next session?

THE CHAIRPERSON: Yes, please, that makes a lot of sense. So Dr. Al?

DR. AL: Okay, so Tom Al, for the record.

So the undertaking was requesting information on the range of initial conditions used for chloride in the simulations that were done with MIN3P, and I've been looking through some information I have with me. I don't have the chloride simulations, but I have the O18 simulations and the range of -- the relative changes were the same, and it's plus or minus 15 percent around the base case. So everything's based on that base case, which is the normal marine salinity.

Your question was alluding to an interest in whether or nor we had considered the very high salinities that are observed in the Precambrian shield, and that hasn't been done. But, I should point out that if we look at the profiles that -- the actual data profiles, as we go down through the Ordovician, we go from near-Haleite saturation, towards something just above normal marine salinity at the base of the Ordovician.

So if there was anything close to, say, the very high salinities that are observed in Yellowknife and Manitoba, and so on, in the shield, then we could never achieve those data profiles. We would never see the freshening that we see at the base of the profiles. The Precambrian -- if those concentrations were very high in the shield, what it would lead to is kind of a profile that foes straight up at very high concentrations.

So we think it's inconsistent with -- well, it is inconsistent with our conceptual model for the evolution of the site.

MEMBER MUECKE: Would it still be possible to see this in graphic form? Or it ---

DR. AL: To see a simulation ---

MEMBER MUECKE: Yes.

DR. AL: --- with high concentration at the bottom? Sure. We could ---

MEMBER MUECKE: I follow your argument, okay, but it would be interesting to see the actual magnitude of the effects ---

DR. AL: Okay.

MEMBER MUECKE: --- if it's possible.

DR. AL: Well, it is certainly possible to do it, but I can tell you in words that if we started with a very high salinity, it would be similar to what we have in the shales right now. So we would have a very high salinity in the shale, in the (inaudible) division, and then we would have a similarly -- in this simulation, we would have a similarly high salinity in the Precambrian, so that over time, as a result of diffusion, we would evolve towards a straight line up and down. So it wouldn't bear any resemblance to what we observe with the data from the pour (phonetic) water.

MEMBER MUECKE: Okay, I accept that.

DR. AL: Okay.

THE CHAIRPERSON: I would ask my fellow Panel members; do we have any further follow-up questions for Dr. Diederichs? Okay then, so I think we can then proceed with the MicroShield MicroSkyshine/MCMP presentation.

MR. GIERSZEWSKI: For the record, my name is Paul Gierszewski.

This third part of the technical information session describes computer models used to calculate dose rates during the DGR's pre-closure.

These models are used to ensure safety while the DGR project is operating and waste packages are being handled and emplaced.

The first few models listed here were used to calculate radiation dose to workers and public from gamma radiation. MicroShield is the primary radiation dose code used in this phrase of the DGR project. It is supported by MicroSkyshine and MCMP for specific analyses of gamma radiation scattering pathways. A separate radiation dose model was used for non-human biota.

I will now present the radiation dose models for workers and public, and as the work was done primarily with MicroShield, I will present these three codes in one presentation.

So, MicroShield is a photon-shielding and dose assessment program. It was used in the DGR project for gamma dose ray calculations and preliminary shielding design.

The numerical approach is called the point kernel method, where a volume source is treated as a number of point sources, as illustrated in the figure on slide 124, and the flux from each point source to the dose point is calculated analytically, including attenuation and build-up.

MicroShield uses defined -- a define source and shield geometries, and illustrations of these are shown in the two figures on the bottom of slide 125. This figure on the left shows a cylindrical source, and the cylindrical shield, and then, further away, a rectangular shield; the figure on the right shows a rectangular source and shield; two illustrations of the types of geometries that can be modelled.

As these figures illustrate, it can include multiple shield errors, of different materials. It includes shielding of the source, self-shielding within the source. The source concentration of the source radionucleides, the gamma emitting radionucleides is assumed to be uniform, and it uses build-up factors to account for the fact that there will be some degree of scattering of photons within the source or within the shield.

MicroShield, there’s no calibration. The input parameters are fully defined based on the source and shield properties.

MicroShield version 8.02 is the latest in a series of codes going back to IsoShield, from 1966. The basic algorithms have been in use for decades. It comes with a built-in library that has data that provides standard reference values for various key inputs. These include the radionucleide properties, material properties, and dose conversion factors.

It is a widely-used commercial code, including industry, OPG, regulators internationally, industry universities, and a quick Google search indicated it was cited in approximately 200 papers.

It has been used in support of regulatory and licence applications. For example, it has been used in the OPG dry storage buildings at Darlington, and the Western Waste Management Facility.

I have some examples here, and then the other ones of validation verification. In the interest of time, I’m proposing not to spend a lot of time describing them in detail, but I’d certainly be happy to take questions.

Essentially, what they are is examples from -- in this page of literature that shows “MicroShield comparison” on the top, with some experimental results, and on the bottom, MicroShield comparing with some other reference codes for an ANSI standard. These are an ANSI standard radiation-shielding problem.

More relevant to the DGR, we did do a specific comparison of MicroShield with MCMP for a DGR-specific application. MCMP is generally regarded as a more accurate model. In this particular case, we're looking at the dose to a forklift driver underground in a DGR emplacement room, as is illustrated on the slide 129, and this is a more complicated geometry. In this case, there is a difference between the two codes, but MicroShield was conservative relative to the more accurate MCMP code.

In respect to the treatment of uncertainties with MicroShield, first, MicroShield is a code that's intended for a certain class of applications, and that class was respected here in its use in the DGR. It's a gamma dose-dominated environment. This was used to calculate a direct dose in simple shielding geometries, and the source photons were all relatively standard photons.

The source term that was used, generally we use higher dose rate packages. It did depend on the specifics, the specific purpose of the calculation. We did look at a range of different low-level waste and intermediate-level waste packages, to ensure that the results were not -- that we had tested that particular sensitivity.

The shielding material was generally standard shield materials, concrete and steel. The choice of build-up material, the building-up material used to calculate the build-up factor; we used a conservative choice and maximized that factor.

And in cases where we were looking at a scenario that had multiple packages, we did not take credit for any package internal structure that might contribute to some self-shielding; we'd only take credit for the external shielding in the direction of the receptor.

With respect to the receptor itself, it was always placed at the closed position, consistent with the particular scenario that we were looking at, and we would use the anterior-posterior dose model for calculating dose, which is a person facing directly towards the source.

Now, MicroShield is not capable of doing scattering from either Skyshine or well scattering, so in order to address that we ran these additional codes, MicroSkyshine and MCMP, and I'll now briefly describe those codes.

So with respect to MicroSkyshine, the purpose of this is to calculate the dose from overhead air-scattered gamma radiation. A numerical approach is based on beam functions, which are developed from more detailed calculations. It is a commercial code.

Just to elaborate, and what I mean by “Skyshine,” is shown in the figure on slide 132. We have a source in the center that's giving off gamma photons in all directions. We have a receptor, in this case on the right side, and in order to protect that receptor we have a shielding wall put in the middle that stops the gamma radiation from source to receptor.

But in practical situations, since those photons are going in all directions, some of them will be going upwards. And it may be that the roof is not as well-shielded as the walls, so some photons may escape through the roof.

And most would be harmlessly dissipated in the air, but some could be scattered just randomly, but some could be scattered towards the receptor location. And in a design where the shielded wall, that vertical wall there is very effective in stopping the dose, it can be that the Skyshine component is actually what dominates the dose at that location.

So again, to ensure that that wasn't happening in our case we did do Skyshine calculations.

Some fundamental aspects of MicroSkyshine are listed on slide 133. It comes with standard source geometries, use standard source and shield materials. The scattering medium is restricted to air and the vertical wall is taken as a perfect shield. So it is solely for calculating Skyshine, it does not calculate the direct dose.

There's no calibration of it in the DGR application. It is a commercial code recognized by CNSC and other regulators, the U.S. Nuclear Regulatory Commission for example. The key data comes in a built-in library, and it has been used in support of licence applications. Again, it was used most recently in OPG dry storage facilities at the Darlington and Western Waste Management. And the second bullet here is an example of its use in the U.S. nuclear program.

Again, a couple of slides that illustrate some examples of validation of the code from the literature. I won't describe these in details, but happy to come back and respond if there are questions. The first is an example of an standard problem, again from the N.C. radiation standard.

Second is an experimental comparison. And again, the figures are showing good comparison of the code with the experimental data in this case.

With respect to treatment of MicroSkyshine and potential uncertainties, again, the application, it's a simple code but the application that we've used it for is appropriate for its limitations. We're looking at standard radionuclides in terms of photon energies.

We're using source to receptor distances within its range, and also the roof thickness, there's a particular numerical test here in order to be within its range; and our design right now is within that.

For our Skyshine calculations we used a conservative source term. So we're particularly interested in the case where waste packages may be stored in the waste package receipt building and then what would be the potential Skyshine dose to people at the, we call non-nuclear energy workers, non-news in the notation here, who might be at the DGR site boundary, workers on the Bruce site, but not nuclear workers part of the DGR facility, or to public at the Bruce nuclear site fence.

In those calculations, in addition to putting the receptor at the closest fence line location we also assume that the WPRB had the maximum number of packages, 24 low-level waste, or two ILWs that might be staged at a time.

And finally, the results, there's a large margin, the results. The Skyshine dose rate is a small contributor and that was expected. We just confirmed by the modelling results.

Now just to talk a little bit about MCNP. This is the code that was developed for modelling of neutron, photon and electron transport. Been used in the DGR to evaluate the importance of gamma scattering from the walls in an underground emplacement room. And the miracle approach is Monte Carlo, which is a statistical approach that simulates the random walk of individual particles. It is a widely-used commercial code.

As already noted it is applicable to gamma radiation as well as other transport cases. It allows detailed treatment of geometry, including complex source shield and surrounding structures. Allows detailed treatment of particle interaction with materials including scattering.

It is a statistical approach, so it does come with options and guidance on various reduction, getting faster convergence on tests that you have converged.

There's no calibration of this code in the in the DGR application. The code is developed and maintained by the U.S. government through Los Alamos National Laboratories under a formal software QA system. Reference is given here to that documentation.

The nuclear data is available in standard input files. It is a widely used code. Again, here just to check a Google scholar referenced in 17,000 articles as extensive verification validation and its good starting point is the MCNP home website, which is listed here.

Again, not to dwell on it. I picked an example from the literature for validation of MCNP with back scattering experiment, and the results show good agreement.

So the way it was used for the DGR was to look at the importance of wall scattering on dose rate. And that's shown in this figure here. So again, in this case here we have a forklift driver who's emplacing waste packages. So the forklift driver shown in the middle there, that's the dose point.

And on the left side of them are, in this case, resin liner shields. Through MicroShield we had calculated the direct dose from those waste packages to the forklift driver. We wanted to check whether scattering off the side walls or the back walls a significant factor in these dose rates.

It was a bounding assessment. We looked at ILW, so intermediate level waste, higher dose rates. We assumed that the room was full at the time of these calculations. So there essentially 99 rows of these packages, three packages per row. And we did do some sensitivity analyses. We looked, because we were particularly interested in the influence of scattering, we did calculations where there was no wall, just air, and then with the rocks surrounding the room.

We also looked at whether the results were dominated by the front row of packages alone, or whether when you added all the other packages in you got a significant change in the dose rate.

So if I were to kind of summarize where this puts us in terms of our confidence in the radiation dose, gamma radiation dose to the work or public as described here, our confidence -- our primary code is MicroShield, a widely used commercial code. We applied it here in simple standard geometries. Standard radionuclides and shielding.

We did independently check the results. There was some limited comparison of the model with other codes with MCNP, but we did also then the particular aspect, we did evaluate the uncertainty and the scattering contributions by using specialty codes intended for that purpose.

Thank you.

QUESTIONS BY THE PANEL

THE CHAIRPERSON: Thank you very much. So if we could back up to slide 129, please. And as usual we'll be going through the slides in order.

Just a general, more of a curiosity question. What in your opinion gamma dose still predominate -- I guess this is the wrong slide to illustrate this question, so I apologize for that, but would gamma dose still predominate for a non-news worker or a member of the public?

I'm envisioning a person who is not wearing the full PPE. Who may in fact be exposed via dust inhalation. So instead of gamma dominating you were having a lot more of the alpha beta concerns. And how and where that portion of potential doses being discussed and handled in your documentation?

DR. GIERSZEWSKI: Paul Gierszewski for the record.

So this particular case described the gamma radiation codes, and that of course was the nature of the response here. The other emissions from the facility, we have looked at as part of the normal evolution and the accident assessment during the operational phase. That's described in general in Chapter 7 of the preliminary safety report.

In that particular case we've identified tritium and carbon-14 as being part of the regular emissions, and there are some calculations in there. They're basically hand calculations on the concentrations of those in the surrounding environment and are shown to be within criteria. But that's where you'd find that information.

THE CHAIRPERSON: Thank you very much. Moving to slide 130, please.

So in terms of the uncertainty analysis, were there any model runs under operational malfunction scenarios where the receptor was unshielded?

DR. GIERSZEWSKI: Paul Gierszewski for the record.

Yes. In the pre-closure assessment we did look at accidents, and we identified a number of accidents. One of them was a package breach. And in that case part or all of the shielding, depending on the scenario, was lost and then the worker was exposed to both potentially gamma radiation or inhalation, and that was considered.

MEMBER ARCHIBALD: Yes, if we could move to slide 133, I am fairly interested in the importance of air scattering on dose effects.

My particular question, because everything on MicroSkyshine appears to focus upon surface repository and storage capabilities and exposure levels.

Does MicroSkyshine include the effects of dust and elevated aerosol -- sorry, aerosols that might be created by elevated relative humidity as sites of scattering in air. Would it, for example, be useful as a common underground environment source model?

DR. GIERSZEWSKI: So I think there's two parts to that question. I think the first really is intended, I believe, for surface application where you have large -- we have air scattering. If you're underground, I would be more interested in the scattering from the solid walls and that will be better handled with as we chose with MCNP, I believe.

The second is whether humidity is a significant factor in scattering and you could argue that it could scatter more but it also would absorb more. I don't know the net trade-off between those, but I would just fundamentally come back to the point that while we did check where the scattering was important just part of a checking for it, it really is not -- these are scattering mechanisms relative to any direct dose. They're not large doses.

MEMBER ARCHIBALD: The reason I'm asking is that in an underground work environment and including in these sites where they're repository built, there is no way in which the environment can be kept clean even if you concrete the floors as a nice staging area for all of the materials. In every underground work environment, you have a very high and dusty atmosphere and generally because you have normally higher than normal relative humidity because of the ventilation capacities, you have a lot of material in the air that may act. And I'm not sure of the program, but in your picture on 132, you're seeing the MicroSkyshine is basically affecting a receptor by scattering from some particles in the air.

So obviously the same case would have to occur underground. It's not just the wall rock. If you have the first row of waste materials in place, you would have a fairly large distance between the source on the walls to reflect back from the walls themselves. You may not have much shielding and, therefore, there could be a possible or potential contribution from something scattered in air in a very dusty environment. Would this not be the case?

DR. GIERSZEWSKI: I'll make a couple of comments. The MicroSkyshine, of course -- well, it's intended primarily for public and non-nuclear energy workers at surface, which is a different environment.

Underground, I'm not certain of the contribution of dust and humidity to the scattering. I'm inclined to think that they would act more as absorber more so than their scattering source would be but I don't actually know that.

But I would also point out that the workers will be instrumented. They will be having dosimeters with them. So they would -- they would be adequately protected by the use of the fact that they had appropriate equipment with them.

MEMBER ARCHIBALD: Just for clarification then, MicroSkyshine is not normally used for estimating dose to underground workers?

DR. GIERSZEWSKI: Certainly not the application that we've used it for, I'm not aware of it being used that way.

MEMBER ARCHIBALD: And to your knowledge then, it is not used in other underground repositories for the same purpose?

DR. GIERSZEWSKI: To my knowledge, that's correct.

MEMBER ARCHIBALD: Thank you.

THE CHAIRPERSON: I have another question, this time on slide 143, if we can skip ahead. So here we are with the summary for the Contribution to Confidence.

And in the second row down the line of evidence states, "Simple Geometries, Standard Radionuclides, and Shielding."

And you explained that that actually provided a higher relative contribution to confidence.

I would like you to expand upon that a little bit. How confident are you that the use of those standard simple geometries ensures a conservative estimate of dose, given the range of low-level and intermediate-level waste packaging that includes geometries that likely would have higher emissions versus other types of geometries?

DR. GIERSZEWSKI: Paul Gierszewski, for the record.

So, really what would matters in these cases, it's the direct dose, it’s what's the shielding between the source and the worker, and that's what MicroShield is intended for. And we -- I would add that the kind of doses that we expect at this facility here, we are handling similar waste packages now at the Western Waste Management Facility and the doses to the public and the workers are well within the criteria.

It's partly managed by the design of the packages and the design of the shielding. It's also managed operationally and I don't -- I expect that it will also apply here and that would be able to again protect the workers and the public handling the same waste packages.

THE CHAIRPERSON: And would that also apply to your MicroSkyshine level of confidence?

DR. GIERSZEWSKI: Yes. Paul Gierszewski, for the record. Skyshine, these are low and intermediate-level wastes. They're not -- I mean the dose rates are limited. They're not close to places where public are. So scattering is really a rather secondary process. We've checked to make sure it's low. We find it low in the field and these calculations also indicate it's low. So we're confident that that's not a significant dose contributor.

THE CHAIRPERSON: Thank you.

MEMBER MUECKE: Staying with the same slide, a little bit of a puzzle here.

The overall confidence is rated as high, given 3+ rating, but if I look up the column, I see that the comparison of model results with other code is only scored as 1; uncertainty and scattering contribution, 2; use of MicroShield coat, widely used, rated 2.

If I take an average, I don't come up with a 3. Could you clarify?

DR. GIERSZEWSKI: So these weren't intended to be interpreted in that kind of degree of numerical quantity. I guess there's a waiting of the various factors that's implied.

Sorry, Paul Gierszewski, for the record.

Also, what I've done here is I've tried to indicate which are more or less contributors to the overall confidence. And so, you know, again, we have high overall confidence that we will be within criteria for public and for workers, but this particular slide shows what contributes more to it than others.

And I guess I probably should have included on here another line that just reflected the fact that operational experience with these also adds to our confidence.

MEMBER MUECKE: Thank you.

THE CHAIRPERSON: Thank you very much. That concludes the Panel's questions on the MicroSkyshine MicroShield MCNP.

So if we could now please proceed to the presentation on Dose Modelling for Non-Human Biota.

DR. GIERSZEWSKI: Okay, Paul Gierszewski, for the record.

I will now ask Mark Gerchikov to present the Non-Human Biota Radiation Dose Model. He is from AMEC NSS Ltd. in Toronto, where he is Manager for Environmental and Radioactive Waste Management. AMEC NSS has been supporting the DGR project since 2006 with respect to radiation and radioactivity aspects of the environmental assessment. Mr. Gerchikov.

DR. GERCHIKOV: Thank you. Mark Gerchikov, for the record.

The assessment was conducted using Tier-Two approach, which was in compliance with EIS Guidelines. The tier-two approach is defined in the recently issued Canadian standards, CSA N38.6, as a preliminary assessment.

Tier One is a screening level assessment which is principally concerned with determining potential pathways and potential receptors.

Preliminary safety assessment is designed to look at actual long environmental concentrations and using conservative approach to evaluate doses to non-human biota in case the criteria for Tier 2 exceeded, then the assessment would go to Tier 3 which is a detailed assessment and that would involve more comprehensive evaluation using more realistic parameters.

The same approach has been used in several recent environmental assessments in Canada including Darlington Nuclear Project.

I would also like to note that this evaluation was conducted only for the pre-closure period as described in the current presentation, and that it's specifically the operational part of the pre-closure period that we're concerned with because it is associated with maximum potential releases of radioactivity.

The key features of the approach are outlined in Slide 146, and there were two types of exposure that we looked at. The first is direct exposure. And in the context of this environmental assessment it was concerned with exposure directly to the packages, external gamma exposure to the packages.

All other exposure resulting from radionuclides and to environment and then exposure is via internal intake or via external exposure that is termed indirect exposure.

And this slide presents basic equations reflecting the transfer of radioactivity of the source into the environment and then into individual non-human biota species, and then estimation of the dose resulting from concentrations and external exposure.

The scenario that we looked at for direct exposure was related to transfer of packages from neighbouring western waste management facility through the DGR, and storage in the waste processing building.

The assumption, the approximation that we used was a point source and then it was assumed that the non-human biota species would be exposed for a period of one hour per day and at the distance of ten metres.

This assumption is conservative in that we are principally concerned with populations of non-human biota with typical home range. That would be quite significant and the number of species depending on what we're looking at in a population would in the order of 500 individuals. So to place them all in the vicinity of transfer packages is a conservative assumption.

This particular scenario of direct exposure was screened out in the second screening step of the environmental assessment because the results were significantly below the criteria. So subsequent discussions primarily focused on indirect exposure scenario for normal operations.

In terms of the source term it was assumed that non-human biotas would be exposed to levels twice current conditions. That is a bounding conservative assumption because we're effectively assuming that incremental concentrations in the environment would be equal to the current levels.

Current levels are resulting from operations of two nuclear generating stations at Bruce and also from emissions from Western Waste Management Facility, which includes the incinerator. The actual estimated emissions for the DGR are significantly below those levels.

The additional conservatisms that was introduced in the assessment was that the non-human biota well was located, the whole population in points of maximum concentrations. The receptors, the exposure pathways and other parameters used in the calculations are detailed further in the presentation.

In addition we looked at the accident scenario. The accident scenario included bounding accident which was derived from the preliminary safety assessment. The scenario looked at the worst case accident involving fire within a container with moderate rays located outdoors. And the exposure period for this scenario that was considered was 24 hours reflecting that concentrations would be reduced over time.

Maximum estimated air concentrations were considered from the preliminary safety assessment. Pathways transfer effect as the symmetry and receptors were consistent with those used in the normal operations and will be discussed further.

Slide 149 represents a typical picture of southern Canadian forest and typical species of non-human biotas that are present, and how radioactivity is transferred between -- from the source term and then between various environmental components ultimately is ingested or species may be subjected to external exposure by sediments or soil.

The next Slide 150 presents the transfer of radioactivity specifically considered within our model. From the source term radioactivity is transferred from either atmosphere or water, and then it moves through the ecological system, again ultimately ending up with exponential exposure to animals or plants.

Confidence in model was achieved through several aspects. Firstly, the assessment method that we used was consistent with recent environmental assessments in Canada. It was also consistent with relevant international studies such as FASSET.

FASSET is a European study which was conducted by 15 organizations coming from several different countries. And it developed overall framework for exposure of biota to ionizing radiation. And that this study has since been extensively used in all subsequent assessments. They are currently approximately 14,000 references to this study in Google Scholar.

Concentrations, moving onto the second item, concentrations that were used in the assessment where based either on measured site concentrations and using conservative approach as described earlier, that the exposure to the same level of environmental concentrations, or they were based on preliminary safety report; and these data were derived using appropriate quality assurance pedigree.

The intake and exposure parameters were mostly based on U.S. Environmental Protection Agency data, and some additional information in terms of ingestion of soil and sediments was taken from a well-known reference in the literature.

In terms of transfer of radionuclides between different components, the Canadian Standards CSA entry 8.1 for derived release limits was used.

And finally with regards to estimating the doses, FASSET data centre was applied both for those coefficients and to – in terms of looking at biological efficiency of radio nuclides. So for example, AB03 was used for tritium, which is a conservative value. The current recommended value in the CSA standard enter 88.6 is to and it is suggested that the value of -- values of one and three would be used to analyze uncertainties. For -- in terms of confidence in model, additional degree of confidence is provided by the fact that we have used our aim make and assess quality assurance program which is accredited to ISO -- international ISO 9001 quality standard as well as to Canadian valid Canadian quality standards.

Looking at slide 153, it presents

approaches to calibration validation and verification. And calibration was achieved by using measured sites specific concentrations for the model system. Validation was not conducted specifically within our study, however the same over all model was implied in studies like Emrous (phonetic) and by other working group of this international atomic energy agency study, looked at comparing various models with available environmental data. For example, at such sites as Chernobyl and Patch lake in Canada, there -- the findings from that were that their agreement was better for terrestrial biota than for aquatic. Furthermore, for certain pathways, there was better agreement than for others. However, overall those, it was found that the agreement was very good. And this validation included bostizimitry (phonetic) and transfer of the nuclide in the environment. Verification was conducted internally using independent checking within a -- and make an asses following our quality assurance procedures. For uncertainty, there are four principle sources: first one is selection of species indicators of concern and their habits, the second one is environmental pathway and pathways that are considered, the third one is characterization of contaminants, the source (inaudible), and the final and major source -- main source of uncertainty is the dose criteria and I will talk about this – each of this in more detail.

With regards to selection of indicators, firstly valued ecosystem components were selected which grouped several species by their general behaviour. This valued ecosystem components were consistent with other studies and the purpose here was to ensure that all maximum potential exposure pathways are considered. So for example, Bentley convertibra (phonetic) was considered because it’s relatively immobile and maybe the whole population may be potentially exposed. The next step was selecting of indicators within this groups of non-human biota. And selection -- and that selection was focused on typical representative species which are present on site taking into account result of -- of the consultation conducted within the environmental assessment. While we may not have specifically focused on identifying most radio-sensitive species in that selection, these are typically covered, for example, conifers are known to be most radio-sensitive species for – for terrestrial vegetation and representatives are included. There is also a certain degree of uncertainty as to the exact species that would be most radio-sensitive due to certain limitation in the variable data. However, the criteria which I will talk about later do address the most radio-sensitive known species. Their characterization of indicators included data from US environment protection agency as mentioned earlier on intakes; we also met conservative assumptions in terms of habitation area and time – specifically time spent on site. For migrating species like birds, it was assumed that they spent 50 percent of time on site and for non-migrating species like mammals, ideally it was assumed that they would be on site full time. Their third uncertainty area is exposure pathways. It can be seen that we considered all potential exposure pathways such as external exposure to soil sediment, food water ingestion -- ingestion of soil and sediment, immersion in water and external exposure due to that. Also, direct uptake through skin, or of radio-nuclides into fish and inhalation. And one pathway hat was not considered was dermal contact, and external exposure through that. This is consistent with - as an environmental assessments. This pathway would typically become significant for very high levels of concentrations and we are only looking at environmental levels of radioactivity. So it’s not relevant for the final assessment. Their final source of uncertainty is the system and concentrations that were considered. They were for normal operations based on maximum measured values and using conservative bounding assumptions that described earlier that the current values would be effectively doubled for cumulative effect. And their maximum -- this maximum values were taken in each environmental component such as water, soil, sediment. For their accident again, maximum values were taken from preliminary safety report and this was for air, then for transfer into other media was assessed using transfer factors from the current CSA standard. Selected those criteria, this issue is developing quite fast within the radio-ecological community; there are a number of potential benchmarks out there. And their values that we use were selected conservatively, they were based on estimated no-effect values which were either the same or below the PSL to property substances in least assessment report from environment Canada in 2003 and they're also below the levels provided in the recently published CSA standard N288.6. And they were also consistent with those criteria for post closure period as accepted by CNSC. The actual ENEV's are represented in slide 160.

Moving on to slide 161, we are – I would like to summarize and their reasons for – major reasons for confidence in the results assessment was based on bounding exposure concentrations and the methodology was consistent with international and Canadian guidance. We used conservative dose criteria uncertainty in the selection of parameters and the assessment of model and in the assessment criteria is acknowledged. However, by using conservative parameters we have high confidence that the results do not underestimate the doses in the assessment.

This is also summarized in slide 162. You can see that we have knowledge and certainty in model parameters and the limitation of available validation date depending on the species.

We also acknowledge certain uncertainty in assessment concentrations that we used. However, we end up in the high overall confidence because we used very conservative parameters for this concentrations, but furthermore used accepted model assessment approaches, and we finally used low dose criteria to come up with a high overall confidence.

Thank you.

QUESTIONS BY THE PANEL

THE CHAIRPERSON: Thank you very much. So if we could return back to Slide 147 please. I have a question around the normal operations indirect exposure scenarios.

I was wondering if during your construction of your conceptual model for normal exposure you included the possibly of remobilization of current levels of radionuclides, for example; present in site soils due to construction activities?

DR. GERCHIKOV: Mark Gerchikov for the record.

The period of construction was not specifically addressed during the assessment. The overall approach is that the emissions resulting from normal operations during the actual transfer of containers to DGR site, and during the placement of containers into the repository would be higher, particularly that we added the conservatism in doubling the current levels of concentrations on site.

So that would capture all possible scenarios that may arise during construction and disturbance.

THE CHAIRPERSON: Dr. Gerchikov, I'd like to ask a follow-up question to that.

So just to clarify, so the modelling to non-human biota explicitly did not include the construction period, so it's only for operations. And your assertion is that notwithstanding that, the model for during operations is so conservative that it encompasses what might happen during construction.

I guess I would need a little more

convincing, just because the transfer factors in particular are going to be highly sensitive to the remobilization process, and therefore the bio availability of some of the radionuclides that have maybe have spent quite a few years nicely immobilized and unavailable, and they were going to be remobilized and therefore different transfer factors might in fact apply.

Secondly, I can fairly easily envisage situations where the construction activities are disturbing areas of the site for which we have no relevant data, very little, particularly sediments; I'm thinking in terms of the ditches and Stream C for example.

So I would just ask that perhaps the study team revisit this to help the Panel with our confidence that we can in fact rely on your assertion that the non-human biota doses do encompass the construction period and are reasonably conservative?

DR. GIERSZEWSKI: Paul Gierszewski for the record.

I want to make just one comment. So with respect to transfer factors I think you're making a fair point that the actual radionuclides at site as they exist now could be in a less mobile form and therefore released.

I think the transfer factors themselves are generally derived under circumstances where the radionuclides are more mobile. The nature of the experiments tends to be more of the short-term I believe.

But I think the larger point though you've raised I think we should take an undertaking to respond to give that some thought, so we'll take an undertaking on that and get back to you.

THE CHAIRPERSON: I would appreciate that. So that now will be undertaking number 2. Number 1 because we already dealt with it Good, we have a nice short list of undertakings so far.

I would like for the record though to comment that in my experience many transfer factors are derived from observational data from the field, that do not represent necessarily the more readily available forms. They in fact often represent studies from for example older uranium tailings areas, receiving environments where it's actually a realistic range of transfer factors, that truly reflect the lower availability, the immobilization processes.

And therefore I'm not sure I agree that the uptake transfer factors that are used necessarily reflect these remobilization process that I'm concerned about.

If we could please go to Slide 157. My concern is the final bullet where dermal contact was not considered. It appears that that is actually --

specifically refers to birds and mammals, because I'm assuming that certainly for amphibians and invertebrates and you already said fish, you would in fact be modelling uptake through -- direct uptake via the exoskeleto or skin in amphibians.

DR. GERCHIKOV: Mark Gerchikov for the record. Yes, your understanding is correct.

THE CHAIRPERSON: Thank you. Slide 158 please.

So we get into the sources of uncertainty and certainly around the level of confidence and assumed transfer factors. As I'm sure you know there are many data gaps out there. The transfer factors often require you to extrapolate from fairly distant relatives to the critters that you have chosen for your indicator species.

So how did you deal with uncertainty around transfer factors when -- for there are very little or no data, in particular for example transfer from sediment to let's say to the Northern Leopard Frog, some of the less understood indicator species?

DR. GERCHIKOV: Mark Gerchikov for the record.

Yes. You are absolutely correct that the quality of data varies significantly, and availability of data varies depending on the species and sometimes analogous species may have to be used.

In the majority of cases we had the advantage of the Bruce Power's REMP program, Radiological Environmental Monitoring Program. So in many cases it was not necessary to apply the transfer factors where concentrations were available in various environmental media.

However, in the cases where we did not have that and we used the values generally accepted by the scientific community consistent with FASSET program.

THE CHAIRPERSON: Thank you. Slide 159.

My question is with respect to the estimated no-effect values. As I'm sure you're aware again this is in the same problem that we have with transfer factors.

There is an extreme lack of data in many cases to be able to even derive no observed defect levels. We simply don’t have the data to allow that. So how do -- how did your study team cope with the fact that in many of your indicator species, there’s just a vacuum of -- of information out there and the extrapolations you’re making are across quite a -- from distant taxa (phonetic) that have very different life histories, very different habitat, food, habits et cetera?

DR. GERCHIKOV: Mark Gerchikov, for the record.

Yes, you are absolutely correct. This is identified as one of the areas of significant uncertainty. However, there are several levels of -- of confidence that we have in that the values that were used -- were used are conservative. There -- firstly, we looked at effects at the levels of -- at the community level, the population level; however, most of the actual numbers that are available, the actual data, are based on individual species. If potential effect on individuals may not result in -- affect the population level.

The second level of conservatism is again the data that are available. They're typically for acute doses as opposed to chronic exposure and in general, while there are gaps, our approach is consistent with the lower values that are available in the literature. They are lower than dose levels that are defined in the 2012 CSA standard and they're defined by such large groups as, for example, terrestrial and aquatic vegetation. So you're absolutely correct that there is uncertainty with regards to the dose benchmarks, but what we used was -- was very conservative.

THE CHAIRPERSON: Thank you. Further to the -- to the questions around benchmarks, was there any consideration for chemical as well as radiological toxicity component to deriving those benchmarks for exposure? As you know, some radionuclides just by virtue of the fact that they're large, heavy metals, for example, their chemical toxicity can often dwarf their radiological toxicity.

MR. GIERSZEWSKI: Paul Gierszewski, for the record.

So the criteria that were used for looking at non-radiological are described in the preliminary safety report and they were derived from the Ministry of the Environment or whatever Canadian Council of Ministry of Environment recommended values, so I think that would have been taken into account if it was -- to the extent that it was relevant.

THE CHAIRPERSON: Thank you very much.

I'm just reading the last couple of questions that I had, but I believe they've already been answered as well as anyone can; it's around the lack of data again.

I guess my final comment -- and -- and perhaps you would like to respond a bit further -- is in particular, with respect to indicator species for which we may want to protect at an individual level in a highly-valued listed species for which we know there are a couple present in -- according to the EIS in the area, just document how confident you are that those conservative benchmarks protect at the individual level when necessary.

MR. GIERSZEWSKI: Paul Gierszewski, for the record.

So we'll take an undertaking then to -- to do that as you requested.

THE CHAIRPERSON: Thank you very much. So that will be Undertaking Number 2.

All right. I think we're finally getting to air quality. So if we may have the presentation on the AERMOD modelling please.

ORAL PRESENTATION PART 4: ENVIRONMENTAL MODELLING

MS. BARKER: For the record, Diane Barker.

This fourth section of today's technical information session will focus on environmental modelling; more specifically, the modelling of atmospheric emissions of radio -- non-radionuclide -- non-radiological contaminants.

The first presentation on atmospheric emissions focuses on the AERMOD model used to predict air concentrations associated with emissions from the DGR project. The predicted air concentrations were then used in assessing the potential effects of the DGR project on air quality and human health. Air quality modelling was completed for the site preparation and construction and operations phases of the DGR project. Air quality during the decommissioning phase was assumed to be similar to air quality during the site preparations and construction phase.

Because there are no physical activities taking place on the DGR site during the abandonment or post-closure phase, there are no air emissions and thus no need to model air concentrations for this phase.

Air quality modelling for the DGR project was completed by Golder Associates who were contracted in 2006 to undertake the environmental assessment for OPG's DGR project and they have been providing support for the environmental assessment throughout this process.

I will now ask Mr. Martin Rawlings, Air Quality and Environmental Assessment Specialist with Golder Associates to discuss the air quality modelling.

Martin.

MR. RAWLINGS: Martin Rawlings, for the record.

The air dispersion modelling, completed for the DGR project, was done using the AERMOD dispersion model; specifically, version 09292. The AERMOD model was used for predicting concentrations of both indicator compounds used for assessing air quality effects and non-indicator compounds passed forward to the human health assessment presented in Appendix C of the EIS.

AERMOD is a public domain model made available by the USCPA. It is the official regulatory model in the United States and has been for the past six years. It is also currently the regulatory default model in Ontario for most dispersion modelling applications. It’s accepted in numerous Canadian jurisdictions and used widely around the world.

The model was developed jointly by the United States Environmental Protection Agency and the American Meteorological Society through the AERMIC working group. The objective of AERMIC was to incorporate state-of-the-art dispersion modelling concepts into near-field dispersion models. The model was planned to replace the Industrial Source Complex, or ISC model, which had been used as a regulatory model in the United States and in other jurisdictions since the early 1970s.

AERMOD was originally proposed for regulatory adoption in April of 2000 and was finally adopted as a regulatory model in December of 2006.

AERMOD is a public domain model, the code and executable files are readily and freely available through the United States Environmental Protection Agency.

The USEPA also provides extensive verification and calibration data sets for use by third parties. The model documentation is all available on-line and multiple third-party interfaces have been developed to ease the use of AERMOD. For the purposes of the assessment of the DGR project, we use the version of AERMOD that’s available freely from the USEPA.

The AERMOD modelling system is, in fact, three separate components. There is the AERMET pre-processor which is used for processing meteorological data and characterizing the atmospheric boundary layer, the AERMET module which is used for developing terrain inputs to the model where necessary, and the AERMOD dispersion module itself.

The AERMET module takes available meteorological data, and uses it to characterize the atmospheric boundary layer.

I would like to point out; on this slide there are two small errors. The raw upper air data is actually taken from the site in Gaylord, Michigan, not from Buffalo, as suggested there. Gaylord, Michigan was identified in appendix
“C” to the atmospheric environment TSD as the source of upper air data.

The surface data, the left-hand box on the top, actually came from Wiarton airport, covering the period from 2005 through 2009. Again, it's described in appendix "C" to the atmospheric environment TSD.

Slide 169 describes the terrain pre-processor air map, which is used, and important for use, in situations where you have hilly or complex topography that can have a significant effect on the dispersion of contaminants from the source. That is not really the situation in the case of the DGR project.

AERMOD is a steady-state dispersion model, which means during each of the hours modelled it is assumed the meteorological conditions remain constant across the entire modelling domain.

The model assumes that dispersion in the horizontal and vertical direction occurs in a Gaussian manner during stable conditions, which means the plume spreads equally about either side of the centre line in the downwind direction. During unstable conditions, horizontal dispersion is assumed to be Gaussian, and vertical dispersion is not; it is a Bi-Gaussian dispersion.

The model includes special features for dealing with situations, such as complex terrain, dispersion in urbain settings, and dispersion in the wake of buildings that can cause lees (phonetic) that could capture plumes.

The model doesn't include a boundary condition, and is not constrained. AERMOD assumes that the emissions are dispersed radially out from the source, in the downwind direction.

The model models each hour separately and predicts a concentration at each of the receptor locations. The sequential hours can then be combined within the model to provide predictions of eight-hour, 24-hour, and annual averaging periods. Separate runs needs to be done with the model for each and every contaminant that's modelled.

In the case of the DGR project, the model was used to predict concentrations, and then background concentrations were added external to the model.

The development process used by AERMIC includes the extensive validation and calibration steps for recommendation to the EPA that it be adopted. Additional calibration steps were done by third party, interested groups and agencies, following its proposal in the process between 2000 and 2006.

The model code also undertook extensive verification, with several major changes in the code being put forward between the time it was originally proposed and the time it was officially adopted. Since adoption, there have been seven formal, major updates to the model, to make sure that the code is current, it reflects state of the art knowledge about dispersion, and any identified bugs or discrepancies within the code are corrected and verified.

There are three main areas of uncertainty with respect to the air quality modelling, namely, meteorological uncertainty, uncertainty with respect to the emissions inputs, and uncertainty with respect to the predictions within the model itself. These were managed in the assessment through the selection of the best available local data. In situations where local site-specific data were not available, we used the best available data from the nearest sources. We used conservatism where practical, and possible, and we also used multiple simulations to try and capture the range of possible conditions that could occur.

Primary sources of meteorological data used in the air quality assessment was from the 50-metre tower located physically adjacent to the DGR project area. That tower is instrumented at two levels, and it was selected to use the data at the 10-metre level to best reflect the processes that would disperse the emissions from the construction and operations in the DGR project.

In total, five years of hourly-sequential data were used in the model, totalling 43,824 hours; 1,826 days; so five full years of data.

Slide 176 shows how we addressed the uncertainty related to the emissions. Where available, we used actual on-site date, so we used the data from the traffic analysis for characterizing the existing traffic sources. We used data from the existing sources at the Bruce nuclear site to characterize the existing emissions.

The project emissions were based upon the actual engineering characteristics and features of the project itself, and local meteorological data was used when managing and estimating the fugitive emissions. The bulk of fugitive emission calculations were made using published emission factors from the U.S. EPA document AP42, which is widely accepted as being a conservative document.

We also used published emission limits for combustion equipment. Specifically, we assumed that the on-site diesel equipment would meet Tier II U.S. EPA and Canadian standards.

When we looked at the emissions for the construction site preparation phase, we identified that activities varies throughout the construction period, and broke it down into five separate stages, of which stage 1 was identified as having the highest overall emissions.

Stage 1 included site preparation, the construction of the surface facilities, and the initial work on excavation of the shafts.

On stage (sic) 178, we show how we addressed uncertainty with respect to the model predictions. Specifically, the EA was based upon the highest model prediction at all of our receptor locations off-site.

Modelling guidance in Ontario allows, in this case, for hourly predictions, to discard the highest eight hourly predictions in each year as being meteorological anomalies, and would use the highest, or the ninth highest, value from each year in your estimates. In the case of this assessment, we used the absolute highest of all of them, which is approximately 28 percent higher than what the MOE would have allowed us to use.

Similarly, for 24-hour concentrations, the highest 24-hour prediction in this case, PM 2.5 was used where MOE modelling guidance, which is similar to guidance in most Canadian jurisdictions, allows you to discard the highest daily prediction in each year from your modelling, and use the second-highest for your evaluation. We chose to use the highest. In this particular case, the highest was 29 percent higher.

To summarize, we have a high level of

confidence that the air quality predictions presented in the EIS for the DGR project do not under-estimate the air quality effects. There are several lines of reasoning for that.

And on the next slide, we've presented it in a tabular form, so our overall confidence is very high that the models do not under-estimate the air quality effects.

There are several lines of reasoning, some of the most important of which are, the use of the highest concentration in the assessment of the EA; using conservative modelled emissions; using on-site meteorological data; and on a full five years of data, at that; the model itself. It's extensively tested, validated and calibrated before it was proposed, and then undertook six years of external third-party scrutiny before it was accepted.

Thank you very much.

QUESTIONS BY THE PANEL

THE CHAIRPERSON: Thank you very much, Mr. Rawlings.

So if we can return back to slide number 174, please? The first question I have is, I heard you say that conservative assumptions were used where practical and possible. Could you please elaborate when conservative assumptions were not used?

MR. RAWLINGS: Martin Rawlings, for the record.

In some cases we used realistic estimates where we only had realistic data. For example, the traffic data was based upon actual traffic counts and we used the actual date in the situation, rather than conservative estimates. Similarly, for the existing emissions from the Bruce nuclear site, that was based on the actual certificate of approval data for the facility, and so in those cases we used the actual data rather than conservative data.

THE CHAIRPERSON: What would the consequence of that have been on the overall level of confidence in the conservatism of your model results?

MR. RAWLINGS: Sorry, can you please clarify that question?

THE CHAIRPERSON: I'm wondering, when we look at your summary slide and you gave a high level of confidence that air emissions have not been underestimated.

I'll just give you an example. So if you're using actual traffic counts, why did you not apply an arbitrary conservative let's say doubling of that as other modelling teams have done just to infer some of their input parameters just to ensure that you have that margin of conservatism added in?

MR. RAWLINGS: Martin Rawlings for the record.

I think specifically in the case of traffic there's a physical limitation to how much traffic we could include. The traffic data does reflect the number of workers on the site. So concepts such as looking at that and doubling it was not one of the things that we considered reasonable or realistic in the assessment.

THE CHAIRPERSON: Okay, thank you. Slide 175.

So you mentioned that you have data from the 50 metre tower at the Bruce site as well as data from Wiarton. So our question is how is the reliability of the data affected by the distance between those two data sources; i.e. the distance between Wiarton Airport and the 50 metre tower?

And do the data from Wiarton accurately represent conditions at the DGR and particular lake effects, site specific topographical features, the Bruce site buildings and vegetation such as the dense tree stems?

MR. RAWLINGS: Martin Rawlings for the record.

Part of this answer was provided in two supplemental responses, EIS01-10 and EIS04-133. The vast majority of surface meteorological data including wind speeds and wind directions came from the ten metre tower at the Bruce Nuclear site. There was only a limited number of hours where data for those parameters needed to be substituted from the station at Wiarton.

The data that came primarily from Wiarton were data that were not collected at the Bruce Nuclear site, such as cloud ceiling height and cloud cover. Those parameters are not expected to be significantly different between Wiarton and the site itself.

THE CHAIRPERSON: Thank you. Dr. Muecke?

MEMBER MUECKE: Yes. Could we go to 176, please?

And my question here is, could you explain the absence of modelling of any particulates from blasting and truck dumping of waste rock at the storage sites? I don't see it in your list.

MR. RAWLINGS: Martin Rawlings for the record.

There are actually two separate supplemental questions during the process that asked, one, about blasting. And if you give me a second I will track that one down. Blasting was addressed in EIS04-136. Emissions from blasting activities were included in the air quality assessment.

The second item you asked for was about dust from the haul trucks. That was addressed in our response to EIS04-148, and the travel and dumping of rock to the waste rock pile and the dust generated by that activity was included as part of the air quality modelling.

MEMBER MUECKE: Thank you.

THE CHAIRPERSON: Slide 181, please.

So again in the sum-up given the overall confidence is high and the conservatism, how confident are you that as you stated earlier the results for the decommissioning phase you are assuming are similar to the construction phase. How confident are you that that is actually true given the nature of decommissioning activities such as demolition?

MR. RAWLINGS: Martin Rawlings for the record.

The quantity of equipment that's expected to be used during the decommissioning phase would be considerably less than the quantity of equipment used during the construction phase.

I believe that the demolition of buildings can generate dust, but the quantity of equipment would be lower.

In the case of the construction phase there is a reshaping and restructuring of the site to construct the surface facilities, to construct the base for the waste rock management area, and to construct the storm water management.

Overall I believe it's a very conservative assessment that construction emissions would be higher than the decommissioning emissions.

THE CHAIRPERSON: Thank you, and one final question.

You noted that after the modeling is finished then that is when you added in, back in the background concentrations. So you're probably getting used to the nature of these questions, so how conservative are the background concentrations you're using?

MR. RAWLINGS: Martin Rawlings for the record.

The background concentrations were described in the TSD. They were based upon the 90th percentile available monitoring data in the area.

We believe those background values are conservative because monitoring in the region of the project would include the contribution from the project as well.

In the case of our modeling we included modelling sources of existing activities at the Bruce Nuclear site in addition to the DGR project sources, and then added the background to it. So there is a degree of double-counting.

We model the onsite sources and then we include the background which includes a portion of that contribution as well.

THE CHAIRPERSON: Thank you. I think that concludes our questions on AERMOD. Yes. So may we now proceed with the CADNA presentation?

MS. BARKER: Diane Barker for the record. The second presentation on atmospheric emissions focuses on modeling noise emissions resulting from the DGR project excluding noise from blasting.

This presentation is focused on noise modeling techniques using the CADNA-A noise modelling software.

The CADNA-A noise modelling software was not used in predicting air blast or air vibration levels. This information is presented in Appendix I of the atmospheric environment technical support document.

Mr. Danny Da Silva, Senior Noise Specialist with Golder Associates will now discuss CADNA-A the model used to predict noise levels associated with emissions from the DGR project.

MR. DA SILVA: For the record Danny Da Silva. Thank you and good afternoon.

My presentation this afternoon focuses on the noise modelling that was carried out as part of the DGR project, and specifically the use of CADNA-A and ISO 9613-2.

The noise assessment focused on human responses to noise. Specifically we looked at the two closest dwellings to the project site, and the closest campsite within Inverhuron Provincial Park.

Noise was predicted was A-weighted equivalent hourly noise levels. In addition we provided specific predictions to the wildlife and human health disciplines.

Now because the assessment of noise may not be intuitive, it's appropriate now to define a few terms such as a decibel. A decibel is a logarithmic ratio between a measured quantity and a reference level.

When we're out in the field measuring noise levels we measure what's called sound pressure level and that's in units of pascals, and the reference level that we use is 20 micro-pascals. The reason for converting to a decibel scale is because the range of hearing that we have as humans is vast. So converting to a decibel scale makes it more manageable, it allows us to make comparisons between levels.

In the decibel scale we can apply weightings to the levels that we measure or predict and one specifically because we're dealing with the human response to noise is what's called the A-weighting scale or DBA.

This weighting tries to mimic the way the human ear responds to sound, do we are less sensitive to low frequency noise and a little less sensitive to high frequency noise and more sensitive to midrange frequencies. So we filter out much of the low frequency noise and don't adjust the mid-frequencies.

An additional weighting that we can apply is referred to as time weighting. And this, depending on the time interval that we are interested in, if a source of noise only operates for a fraction of that time we can actually reduce the contribution of that source by applying a weighting to it.

Some other definitions, the existing noise levels are those noise levels that exist in the absence of the project. The project noise levels are those levels that are predicted based on the noise emissions from the project at a point of interest, and the ambient noise levels combine both the existing noise levels and the project noise levels.

Noise modelling was done using the commercially available software CADNA-A. The software is used around the world and it can implement numerous standards or model packages.

The model or standard that was used in this assessment was ISO 9613-2. And this model is accepted in various jurisdictions to assess road, traffic, industrial sources and construction activities.

ISO is used in Ontario for all types of environmental noise assessments. The Ontario Ministry of the Environment uses this model within the CADNA-A software package, and ISO is the most widely used and accepted noise model worldwide.

The basis of the model is that it is an empirically based model, so the algorithms are derived from measurements which captures wave propagation. In addition to the empirical basis of the model it incorporates what we call "ray tracing techniques" and this technique is used to identify intervening objects between a source and a receptor.

So if a ray of sound in this case is blocked or interfered with by an obstacle it identifies it as a barrier and the appropriate attenuation is applied.

When you combine the empirical basis of the model and the ray tracing techniques this combination is an approximation to the three-dimensional wave equation.

The model can incorporate geometric divergents which is how sound attenuates with distance, atmospheric absorption, ground effect, reflections by surfaces and screening by obstacles.

With respect to calibration, once again the model is empirically based so the algorithms are based on measurement. Since its publication in 1996 there have been numerous studies that have been carried out comparing the predicted levels from ISO to actual measured levels. And these studies have confirmed that the standard is within the accuracy that is published based on the specific assumptions.

Several studies have also been carried out comparing ISO to other recognized standards. And what these studies have shown is that ISO is within one to two decibels of those predictions when sources are not screened. And when sources are screened the ISO model may predict significantly higher noise levels.

We have had the benefit of carrying out several noise assessments on the project site. So we have source-specific noise emissions from the backup generators at the Bruce Nuclear site. We also have general noise emissions from site activities. So we've been able to capture noise emissions from large areas.

Site specific propagation of noise, two receptors was calibrated using previous and current measurements. So we've got short-term spot measurements, long-term offsite measurements, and this has allowed us to tweak our model to adjust specific parameters to modify the propagation from the site to offsite locations.

Once again noise was predicted as A-weighted equivalent hourly noise levels. They were predicted at the two closest dwellings and the closest campsite within the Inverhuron Provincial Park. And factors that were considered in the noise predictions include all receptors were downwind from every source at the same time.

Wind speeds were less than or equal to 18 kilometres per hour. All sources operating simultaneously. Sources were modelled appropriately as points, areas or lines.

So as an example vehicles traveling on-site would be modelling as lines. A surface that would be radiating acoustic energy would be modeled as an area, and an emission point from a stack would be modeled as a point.

We used a proposed site layout plan, buildings and equipment lists for predicting offsite noise levels, and topographic data and existing ground conditions was incorporated into the noise model.

With respect to verification the international standards organization has one of the most rigorous verification protocols prior to adoption by any standard.

ISO 9613-2 is currently -- actually there's an update to this slide here. The ISO standard was actually adopted by the CSA, The Canadian Standards Association, however the CSA has stepped away from looking at noise in the environment, and as a result the CAA, The Canadian Acoustic Association, has now adopted this standard. But at the time that it was recognized by the CSA this was the definitive national standard in Canada.

ISO is currently undergoing consideration for acceptance by the American National Standards Institute. And in 2005 Golder carried out its own study looking at the implementation of ISO within CADNA-A.

Looking at the uncertainty analysis there are three major factors that contribute to the uncertainty. Noise emissions, so the amount of noise energy that's omitted into the atmosphere and the timing of those noise emissions.

Factors affecting propagation; screening, directivity of sources and ground effect. Directivity refers to how a source emits noise. Does it emit noise equally in all directions, or is it more focused in specific directions?

And the model accuracy. The model predictions are plus or minus 3Db within one kilometre. For this project we have receptors that are greater than one kilometre from the various sources. The equations can be extended to distances greater than one kilometre, however the standard has not provided any degree of certainty or relative accuracy for these distances.

In managing the uncertainty, looking at emissions, the input data was based on measurements of similar sources using Type 1 analyzers. So when we go out in the field the instruments that we use are Type 1 analyzers with a level of accuracy of plus or minus 1Db.

Noise and -- it puts our base on worst case noise emissions from sources. So we would measure and include in the model a loader with a full bucket loading a truck as opposed to a loader idling, or simply moving on the road.

The backup generators for the DGR project were included as part of normal operations. Typically these are tested once a month for an hour or half an hour and don't operate continuously.

All sources operating simultaneously during every hour for each of six construction stages, and the maximum level of activities operating simultaneously for operations.

In dealing with uncertainty and propagation, when we look at screening we did not include screening from any trees. There's significant tree cover in the area, none of that was included in the model in terms of predicting noise of receptors.

Directivity was only included for the vent exhausts. Directivity for a source such as a vent exhaust is better defined and understood in terms of how to adjust a source such as that. No other sources were adjusted.

Ground effect we used site specific ground conditions, and all receptors assumed downwind from all sources at the same time. No reduction in noise levels was considered for upwind receivers.

In managing the prediction uncertainty, we modeled six construction stages and used the highest prediction for each receptor.

So in this case it turns out that stage one of the construction activities resulted in the highest levels at each receptor location.

We compared the predicted levels to the

quietest existing hour. So what you see here in this figure here is the grey area represents the existing noise levels at R2, which is located at Beta Doré, and this is over a week.

The blue line represents the quietest hour that was monitored over that period. The red line shows the project-predicted noise levels at that location, and the green line represents the predicted change in the ambient level when you combine the existing quietest hour with the predicted project noise levels.

To see how that would affect the existing monitored levels and how that changes over time, the green shaded area is basically superimposing the project-predicted noise levels with the existing ambient.

This figure identifies the three receptor locations and it also includes the seven ecological points of interest that were on site.

It shows the predicted noise contours and how they are affected by the buildings onsite, and it also shows localized differences in ground effect. And this can be seen when you look close to the shore, the contours are actually pulled out further over the water than they are over land. And this is because water would be considered acoustically hard and would result in better propagation.

Noise predictions were provided to other disciplines, specifically the wildlife discipline. Seven onsite ecological locations were identified and predictions were provided as linear equivalent hourly noise levels. We did not weight, as in a weight, these levels because it'd be a little presumptuous for us to think that animals would hear the same way we do as humans. And the assessment of noise effects were provided in terrestrial environment TSD.

Predictions were also provided to the human health discipline at the two closest dwellings and the closest campsite within the Inverhuron Provincial Park. We predicted percent highly annoyed and the specific impact or impulse noise. Assessment of health effects was provided in Appendix C of the EIS.

We are confident that the noise effects at all receptors will be lower than predicted. We used conservative bounding assumptions with respect to emissions and activities. We have not taken credit for all attenuation factors.

Adverse effects are based on the existing quietest hour. Adverse effects are predicted to occur during late night/early morning hours when people are typically indoors. And predictions for construction and operations are at or below the Ontario Ministry of the

Environment noise level limits.

The relative contribution of the various lines of evidence is presented here. We are highly confident that we have not over-predicted the effects of noise at all receptor locations. Thank you.

THE CHAIRPERSON: Thank you very much.

If we could bring up Slide Number 188, please?

So this slide you're explaining calibration and so we have a question regarding that. In one of the bullets there, you state that attenuation factors were adjusted to achieve the measured results.

How confident are you that you adjusted the appropriate model assumptions and parameters during your calibration? In other words, are you confident that your adjustments did not bias your model predictions?

MR. DA SILVA: Danny Da Silva, for the record.

We had the benefit of having specific sources such as the backup generators operating while we were onsite and then go offsite and do offsite measurements; then put that data into a model and adjust the model to match what we measured.

Because the distance is so great, it's actually rather difficult to hear these sources at these locations, and we actually used a different indicator rather than the hourly equivalent level we use, what's called the L90, which is the sound level that's exceeded 90 percent of the time. And basically that represents something that's in the background that's there all the time.

And using that, we were able to calibrate the model by adjusting the various parameters such as ground effect. And our understanding of the site, being there, looking at the various ground conditions, we adjusted from that point on to try and match what was measured.

THE CHAIRPERSON: Thank you. If we could move to 189, please?

So we noted that you have a range of wind speeds up to 18 kilometres per hour. What is the basis for going up to 18 kilometres per hour and how does this range of wind speeds chosen affect the overall conservatism in your model?

MR. DA SILVA: The ISO standard specifically states the wind speeds that the standard is relevant for; so within wind speeds of 1 to 5 metres per second, which is up to 18 kilometres per hour.

Under higher wind speeds, you might suspect that the noise would travel further, higher levels would be measured, but the background noise level would also increase. So the relative change may not be any different.

THE CHAIRPERSON: Follow-up to that.

So I understand from your answer that the ISO standard only goes up to 18 kilometres per hour.

Remind me, did you have a qualitative discussion though regarding what you've just explained around higher wind speeds and the chance that sound would be propagated farther; that those nearest residents would actually be exposed to a little bit more of an incremental noise level?

MR. DA SILVA: Sorry, can you just clarify the question?

THE CHAIRPERSON: I'm just wondering if, in your documentation, you have a further explanation of what you just described to me, which is ISO only goes up to 18 kilometres per hour. Wind speeds above that may or may not create greater noise levels at your receptor locations and why or why not?

MR. DA SILVA: Danny Da Silva, for the record.

We did not include a specific discussion related to that, but the ISO standard looks at a couple of different things, one being this wind speed limit and also a temperature inversion. So it combines these things. It's either this or that and, generally, the predictions tend to be conservative and typically we don't go into this discussion but it's something that was not included, no.

THE CHAIRPERSON: Okay, thank you very much.

If we could move to Slide 196, please? So, unfortunately, this graphic does not show up particularly well. So we are going to be asking you to just guide us through it a little bit more.

So if you could please explain the colours on the graph, i.e. what do the greens versus the blue blobs mean and where really are the noisiest conditions here on your graphic?

MR. DA SILVA: Danny Da Silva, for the record.

The contours that you see represent the predicted noise levels associated with construction of the project.

The green contours more closely centred on that image are where the sources are. So the higher noise levels would be located there, and as you move out further there's different shades of blue as the sound propagates from the source out to the environment.

There are three receptors that we identified in our assessment; one located at Beta Doré, which is R2; one located on Albert Street towards the south is R1; and then R3 located inside Inverhuron Park which is to the southwest.

THE CHAIRPERSON: Would it be possible to, as an undertaking, provide the panel with a slightly more clear version than this slide so we can clearly distinguish the location of the receptors, and also the wildlife receptors? It would be helpful. And include a legend, that would also be helpful.

MS. BARKER: Diane Barker for the record. We will undertake to provide a clearer map with a legend on it.

THE CHAIRPERSON: Thank you, very much.

MEMBER MUECKE: If I could just jump in here. I see both blue and green lines on the graph, is that just graphics, or is it supposed to convey a different meaning?

MR. DA SILVA: Danny Da Silva for the record. Each contour is actually a different colour, and so there's different shades within a given interval, they're just very subtle and difficult to see.

MEMBER ARCHIBALD: If I could ask also on the undertaking, at each of the receptor sites would it be possible to put the DBA level to identify what the source reception is?

It's a little difficult to try and track these contours around each of the receptor sites. Thank you.

THE CHAIRPERSON: Could we move to Slide 197, please?

Under human health you mention the so-called predicted percent highly annoyed. You didn't provide a definition of that or what "highly annoyed" means. So could you give us a little bit more of an explanation of that?

MR. DA SILVA: Percent highly annoyed is criteria that comes from Health Canada. And typically it looks at some other indicators, it looks at the L-night which is the average night time level, and it also looks at the L-24 or the 24-hour average.

Into regression type analysis where it looks at the percentage of people that would be highly annoyed dependant on the change in noise level using these different indicators that Health Canada looks at.

THE CHAIRPERSON: So does Health Canada, to your knowledge, apply a fairly conservative definition of what it would take to be highly annoyed?

MR. DA SILVA: If we were to have applied some of the indicators that they have in looking at percent highly annoyed for example, if we defined an adverse effect based on the L-night, we would not have identified an adverse effect.

So we used a more conservative approach in looking at the minimum night-time level or it ended up being night-time level obviously. But had we taken their approach in terms of using their indicators I believe what we've done is actually more conservative, but what they have done is actually applicable to the human health discipline.

THE CHAIRPERSON: Thank you. That clarifies that. I have one last question based on your summary slide 198.

The Panel, we were just curious, in this particular type of modelling did you perform any type of sensitivity analyses, and if so what were the key results?

MR. DA SILVA: The sensitivity analysis was carried out primarily in the construction phase, construction and site preparation stage, because there were multiple stages or years of construction involving difference pieces of equipment and locations that from a noise perspective are actually very important.

From an operations' perspective everything is fixed other than maybe just surface movement of some activities. So the sensitivity analysis was done for the six years or stages of construction that were modeled, but from an operations' perspective there wasn't any done simply because everything is fixed in space.

THE CHAIRPERSON: So could you give us just a quick, some rundown on the parameters during your construction phase sensitivity analysis that really created the most difference in your model output?

MR. DA SILVA: The big sort of driver for the construction stage was the number of pieces of equipment on surface, and these tend to be large construction types of equipment, so dozers, loaders, trucks.

And what we were able to do as well is based on the information provided to us we would locate that equipment in the direction that would result in highest offsite predictions.

So we have some flexibility in where to put these things because when you're looking at a construction operation nothing is absolutely fixed. So conservatively we push sources to where they would result in higher noise levels and that would then sort of govern how we would model the various stages of construction.

THE CHAIRPERSON: Thank you.

Dr. Archibald, Dr. Muecke, do you have any further questions?

Good. Well, that concludes the proceedings of this technical information session. On behalf of my two fellow panel members i would like to offer our sincere thanks for the hard work put into the presentations today.

We're going to make a lot of use of the information we're heard today. As you know based on our questions we are particularly interested in establishing the margin of safety in the safety case, the level of conservatism such that there is a lot of transparency around that, notwithstanding the complexity of many of the modelling exercises, and I think we've achieved at least some of that today.

So thank you very much again and I wish you all a very good evening.

--- Upon adjourning at 5:11pm