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NUCLEAR ENERGY AGENCY
RADIOACTIVE WASTE MANAGEMENT COMMITTEE

NEA/RWM/PEER(2012)1
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Second Questionnaire of ONDRAF/NIRAS' Surface Disposal Facility Safety Case Peer Review

At the request of the Belgian Federal government, the OECD-NEA International Review Team (IRT) is reviewing the safety case of the ONDRAF/NIRAS' surface disposal facility for low and intermediate level waste at Dessel. The first questionnaire, with questions related to the fundamental principles and good practices for developing safety cases, was submitted to ONDRAF/NIRAS in December 2011. Answers to the first set of questions have been received in January 2012. The 2nd set of questions, reflects the viewpoints of the IRT members after their extensive review of a series of ONDRAF/NIRAS documentation, is provided to ONDRAF/NIRAS in March 2012. A review workshop is currently planned for in April/May 2012 to discuss outstanding issues.

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SECOND QUESTIONNAIRE OF THE ONDRAF / NIRAS SAFETY CASE TECHNICAL PEER REVIEW

1.0 INTRODUCTION

The Belgian government has requested the OECD-NEA International Review Team (IRT) to examine the application of a construction and operating license by ONDRAF / NIRAS for a low and intermediate level waste (L&ILW) surface disposal facility at Dessel, Belgium. The IRT, composes of independent experts with diverse knowledge and experience in the field of radioactive waste management, has reviewed specific chapters of the ONDRAF/NIRAS (draft) safety report and relevant documents.

The questions presented in this questionnaire are numbered and organized by the chapters in the Safety Report.

2.0 QUESTIONS

2.1 Questions related to the Safety Approach, Strategy, an d Concept (Chapter 2)

a) Questions raised by IRT Member 1 (Q2.1.1 – Q2.1.13)
b) Questions raised by IRT Member 2 (no questions raised)
c) Questions raised by IRT Member 3 (no questions raised)
d) Questions raised by IRT Member 4 (Q2.1.14 – Q2.1. 19)
e) Questions raised by IRT Member 5 (Q2.1.20 – Q2.1. 40)

Q 2.1.1 **Chapter 2 General**:
Will the repository have to comply with the EC Groundwater Directive (Directive 2006/118/EC on the protection of groundwater against pollution and deterioration?

Q 2.1.2 **Section 2.3.1**: It is stated that EC Directive 2001/42/EC is not applicable to the Category A repository because the waste plan/programme was prepared formally before 21 July 2006. Notwithstanding this legalistic argument, it could be argued that it is best practice to assess the environmental aspects of such a development. Can reassurance be given, therefore, that the environmental impacts have been, or will be, assessed?

Q 2.1.3 **Chapter 2 General:** It is good that the safety report identifies EC Directive 2011/70/Euratom. Will the version of the safety report submitted for licensing in 2012 include further information that to address the requirements of the Directive more fully?

Q 2.1.4 **Section 2.3.2.4**: Why does this section only identify two NEA documents as being relevant? For example, what about the NEA's work and reports on Timescales and on Engineered Barrier Systems?

Q 2.1.5 **Chapter 2 General:** Could ONDRAF/NIRAS provide a diagram showing how the various Belgian National Federal and Flemish regulations implement the relevant EC Directives?

Q 2.1.6 **Section 2.7** Design Strategy refers to BAT (Best Available Technology). How has BAT been identified and assessed?

Q 2.1.7 **Section 2.7.4.2** begins with a paragraph that discusses the timing of facility closure, but which is not clear. The text indicates that '*closure will be done as soon as reasonable assurance is established in the future isolate and contain performance of the disposal facility through monitoring'*, but this is open to interpretation as, for example, it is not clear what monitoring results would be needed to confirm acceptable performance. Can ONDRAF/NIRAS please clarify what it means by facility closure and when it plans for the facility to be closed?

Q 2.1.8 **Chapter 2 General:** Where can more information be found about the chemical compatibility of the wastes with the cementitious grouts and other materials of the monoliths and the facility?

Q 2.1.9 **Page 2-43** notes that limitation of contaminant releases from the waste form is taken into account in the non-radiological requirements on the waste. Where can more information be found on the non-radiological contents of the wastes and the associated requirements?

Q 2.1.10 **Page 2-43** discusses the permeability of the cover and the other retention barriers. The assumed hydraulic conductivities of the cover and module basis/foundations are illustrated as a function of time in Figure 14-13. Figure 14-13 suggests that the hydraulic conductivity of the module base is lower than that of the roof. If the cover is more permeable than the module basis/foundations, could there be conditions in which the facility could accumulate water? What would be the consequences of drain failure or clogging?

Q 2.1.11 **Page 2-44** discusses the mechanical loads that might be caused by earthquakes as follows:

- *'The modules and monoliths are designed against a specific 'design basis earthquake' (DBE) for a lifetime of 350 year (until end of phase III), i.e. structure resists to DBE and no (permanent) macro fractures arise as a direct consequence of the DBE (the considered earthquakes are further specified in chapters 4 and 8).*
- *During phase IV, macro fractures can arise as a direct consequence of an earthquake larger than the DBE but the bypass of water flow remains limited. The lifetime of phase IV has been defined corresponding to one specific 'beyond design basis earthquake' (BDBE) for which it has to be shown that the bypasses of water flow remain limited (limited bypass of water flow toward retention barriers, limited bypasses of radionuclide contaminated water flow through retention barriers). The monolith also remains structurally intact during the considered BDBE, as required by the FANC in [R2-128]. The BDBE has been defined for a lifetime of ~ 800 year.'*

It is not clear how earthquakes of certain magnitudes (i.e. the DBE and BDBE) can be associated with particular time periods in the future in this way. Why, for example could a BDBE not occur in Phase III? Can Ondraf/Niras explain more clearly the basis for the approach taken with explicit reference to the relevant regulatory guide?

Q 2.1.12 **Section 2.8.4** discusses the long-term safety functions provided at different stages of repository evolution.

- Section 2.8.4.2 suggests that the structure top slab of the module roof will act as an anti-intrusion barrier during Phases III and IV. Would the top slab not also act as an anti-intrusion barrier during Phases 5 and 6?
- Section 2.8.4.2 suggests that the gravel inside the module middle provides a support safety function by limiting damage to the monoliths in an earthquake. Would this gravel also direct any water to flow around (rather than through) the monoliths and thereby provide an additional supporting safety function R2b?

Section 2.8.4.6 suggests that the inspection gallery backfill will act as an anti-intrusion barrier during Phases III and IV. Would the backfill not continue to provide an anti-intrusion barrier during Phases 5 and 6?

Q 2.1.13 **Page 2-58** notes that '*No mineral resources representing an economic interest in the repository and the site, which limits human intrusion risk'.* However, are there aquifers at the site from which groundwater could be abstracted economically?

Q 2.1.14 **Page 2-41**: Could you indicate if the functions S and R2a are independent or not? If there are independent, can you explain how?

Q 2.1.15 **Section 2.2.3**: indicates that "*Potential radiological impacts and/or risks of the disposed waste on human health and the environment*" is calculated. Could you indicate for which specific case (besides environmental impact) a risk criteria is used, and how are the associated density functions defined?

Q 2.1.16 **Section 2.2.3**: Could you indicate how the international feedback is taken into consideration in the definition and in the assessment of the concept (for example the definition of the earth cover, etc?

Q 2.1.17 **Page 2-41**: the safety functions R2a, R2b, R3 and to some extend R1 rely on the same basic material that is concrete; how is it established that no common failure mode can occur?

Q 2.1.18 **Page 2-41** states that "*operational safety is within common industrial practice*". Can you indicate what specific provisions would be taken to ensure compatibility between industrial practices and long term safety?

Q 2.1.19 **Section 2.7.1.3**: What type of alternative design has been learnt during the optimisation process? What are the reasons for preferring the final design with respect to the others?

Q 2.1.20 **Section 2.1 (page 2-3)** notes that "*the water table which is very close to the surface"*. The data on the water table contained in other SR chapters and supporting documents present some inconsistencies in the numerical data. Thus, whereas the document OD-007 (page 2) states that "*the average depth of groundwater table at the site ranges between 0,85 (summer) and 1.7 (winter)*", Section 1.8.2 of Chapter1 indicates "*the average depth of ground water at site ranges between 1 m in summer and 2 m in winter*". Could ONDRAF/NIRAS check these data and provide accurate information on the depth of the water table and its fluctuations?

Q 2.1.21 **Figure 2-2 and page 2-6**, discuss the implementation of the safety strategy: Fig 2-2 refers to "*knowledge management and preservation*" and last sentence of Sect 2.2.2 states that "*…the process for preservation of this knowledge in subsequent programme interactions so that traceability of decisions…*,". Could ONDRAF/NIRAS provide a description on the process of knowledge preservation? How the process is documented and where?.

Q 2.1.22 **Section 2.3** refers to the environmental assessment report that will be submitted jointly with the safety report with the application. What institution/s is/are responsible for the review of this environmental report? What is the role of FANC in the environmental impact review?. How are environmental impact review results reflected in the authorization process? Could ONDRAF /NIRAS describe the process of public participation?

Q 2.1.23 **Section 2.3.3.1**: Licensing procedure, as described in Section 1.7 and Figure 1-4 of Ch 1 and supporting [OD-184], foresees that the beginning of the "operation phase" will be submitted to FANC for approval and "confirmation" of the conditions of the Authorization A1.

a) However, as this confirmation does not form part of the formal license, what process will ONDRAF/NIRAS use and what information has to be submitted to FANC?

b) The period of time between A1 and A2 licenses (at the "start of the Post operation monitoring and Cover emplacement") is around 95 years. Could you provide information on the "hold points" in which a formal review by regulator is foreseen, describe the process, specifying the necessary documentation and how

the regulator opinion is expected to be issued?

Q 2.1.24 **Section 2.3.3**. The list "Regulation-radiation protection and licensing" does not includes the Royal Decree on the safety requirements of nuclear facilities (called "WENRA Royal Decree" in supporting document [OD-184]). Is this Royal Decree applicable to the disposal facilities and if so to what extent?

Q 2.1.25 **Section 2.3.4**: The high level guide "Generic Technical Guide for Disposal", Note of FANC numeró 010-121, 16 Juillet 2010, that is described in the supporting document [OD-184], is not included in the list "FANC guidance documents". Could ONDRAF clarify the reasons for omitting this high level guide on this list?

Q 2.1.26 **Section 2.3.4** notes that the FANC guidance documents considered in the SR are those available before 1 July 2011.

a) The Rev 3 of the Note of FANC number 007-228 F "Surface Disposal of Low and Intermediate of Level Short-Lived on Belgian territory" (2011-07-13) and the "Technical guide Radiological Protection Criteria for the Post-Operational Safety Assessment for Radioactive Waste Disposal" (2011-06-27? draft 2011-08-23?) seem to have been issued after the mentioned date. Have these guides been accounted for the development of the SR? If not, what aspects would be affected and how will they be addressed?

b) According to FANC Note numéro 008-255, F. rev 2, other Guide on the content of the safety report (Note o1-223 F) have been developed or is in preparation. Has this guide been accounted for in the preparation of the SR?

Q 2.1.27 **Section 2.3.4**: "FANC Guidance documents" is reduced to a list. Most of the guides are described in the supporting document [OD-184]. However, most of this guides and in particular The "Generic Technical Guide for Disposal" and the "Technical Guide on Surface Disposal for Low and Intermediate Level short-Lived Waste on Belgian Territory" are directly related to the fundamental concepts set up in this Chapter, as the safety strategy, the Design Strategy, the Safety concept and others .

Could ONDRAF/NIRAS provide a scheme on how the Safety approach, the Safety Strategy, the Design strategy, the Disposal Concept (including the considered Safety Functions and timeframes) etc. take into account the requirements stated in these regulatory guides?

Q 2.1.28 **Section 2.3.4 (general)** Could you explain how FANC requirements GUR-SUR-1 on "Limitation of long-lived radionuclide content" (*The amount of long lived radio nuclides in the waste to be disposed of in a surface repository shall be as low as possible*) have been taken into account?

In this context, please justify the limit of the activity content of monoliths 10GBq/m^3, stated in page 15-40 of Chapter 15, and its compatibility with the values of the limits used for near surface disposal in other countries?

Q 2.1.29 **Section 2.3.5.2** regarding the Council of Ministers decision of 23 June 2006, as it is described in supporting document [OD-184], gave FANC the mission of conducting a formal and evidence-based follow up of the ONDRAF activities in preparation of the license application and a systematic analysis of the points of attention regarding the safety. Please explain the interaction process between implementer and regulator, the results of such interaction, and how the complete list of the "points of attention" issued by FANC has been implemented?

Q 2.1.30 **Section 2.4 General.** Most of the "Strategic safety orientations" come from international recommendations, as is recognised in 2.4.2.1. (Radiation protection principles), 2.4.2.2. (Optimization and BAT) 2.4.2.3 (isolation and containment) and in 2.4.2.7. (DiD). However, most of them are also addressed in the national regulations and guidance? Please specify the safety orientations which are also based on national regulation?

Q 2.1.31 **Section 2.4.2.2 (page 2-22),** 2nd bullet point, about the use of the best available techniques during system development which entails: "Test programmes for materials and implantation procedures that present novelties compared to existing facilities". Could ONDRAF identify and explain the novelties regarding other existing facilities?

Q 2.1.32 **Section 2.4.2.2 (pages 2-22 and 2-23):** "Use of best available techniques and feedback from experience during system implementation. The 3rd bullet point refers to "Continuous follow-up and assessment of disposal waste source term". How will ONDRAF / NIRAS achieve this? Please provide details including how to implement such process and follow-up / assessment frequency, etc.

Q 2.1.33 **Section 2.4.3, page 2-29**: "height and the openness from the galleries to the inspection room have been limited making the inspection rooms inaccessible to man"

a) Are these limitations a result of previous program steps or are they based on an interpretation of some regulatory requirement or regulator decision?

b) How will the decision of making the inspection rooms not accessible by humans be meeting the requirements of the local stakeholders which require building "inspection rooms" under the modules in order to: "allow for permanent visual inspection", respond and carry out repairs in the case of any significant cracks or leaks, have an additional collecting capacity for possible leak (OD-184, page 56 and Annex 1)?

Q 2.1.34 **Section 2.5**: The management system applies to all phases of the development of a disposal facility. Has a Management system been applied since the beginning of the "project phase" (2006-2012)? If so, please provide a summary of the implementation of such system up to this period?

Q 2.1.34 **Section 2.7.2 (page 2-37)** states that the during the closure phase "Drainage systems and inspection rooms and galleries are backfilled". In cases of an unexpected cover failure or any potential water ingress into the modules during the institutional control period, how will the problem be detected, remediated / controlled, and monitored?

a) How will ONDRAF / NIRAS demonstrate the system meet all of its design and performance requirements? In particular, how to verify the compliance with the long term safety functions and R2a in particular) during the regulatory control period?

b) How will this decision be accounted for in making Institutional decisions about "Controllability: each disposal facility must be controllable before and after closure" (2.3.5.1 Council of Ministers' decision of 16 January 1998 and stakeholder conditions)?

Q 2.1.35 **Fig 2-6 in page 2-37** illustrates the periods and phases and the different licenses as well as the phases after the institutional control period, phases IV (up to 800 years), V (few thousand years) and VI.

The Technical Guide on Radiation Protection Criteria for Post operational safety assessment" introduces the "Period of performance preservation" after which is no longer reasonable to attempt to predict confidently the evolution of this performance. (An illustrative figure on the link between timeframes, indicators and scenarios is

included in the appendix of this guided).

Although, this concept is directly related to the safety assessment, could ONDRAF/NIRAS explain how this concept would affect the approach of the Assessment strategy documented in Section 2.6 and how would the concept relate to Fig 2-6?

Q 2.1.36 **Section 2.7.4** lists briefly a set of requirements and design choices based on strategy safety orientations, on the boundary conditions and previous program steps which some of them have their origins included. Could ONDRAF/NIRAS provide an updated list of these requirements with their origins of each of them (either if they come from previous program steps, from regulatory guides or from decisions or from institutional and stakeholder conditions?

Q 2.1.37 **Section 2.8.1 Safety functions (page 2-42)** states that "*One of the objectives of future RD&D is to assess and if deemed appropriate at some time in the future to reduce the degree of conservatism of the assumptions of the duration of the fulfilment of the safety functions".*

Please indicate how to obtain a list of ONDRAF/NIRAS future RD&D program and objectives.

In this context, please explain the "Forward Programme" included in the Appendix 3 of the supporting document [ID-001]

Q 2.1.38 **Sections 2.8.3**, **Table 2-1, and 2.8.4.8** state that:

a) The site geology contributes to R3 during time frames III to VI. What are the site characteristics that contribute to R3?

b) "*Markers and archives contribute will contribute as a human intrusion barrier (I1) during phases III to V*" Can ONDRAF/NIRAS explain the basis of this statement and give examples that justify this assumption?

Q 2.1.39 **Section 2.8.6.1** "Stable system definition", 3rd bullet point: "Placing the modules and inspection galleries above the design basis inundation level to avoid ingress of surface water". Where is the "design basis inundation level"? In any case could ONDRAF/NIRAS provide this data?

Q 2.1.39 **Section 2.9.1** addresses the question of "preservation of nuclear expertise and archival/transfer/ distribution/ of information on presence of the facility". Which is the Plan of ONDRAF for the preservation of expertise and information?

Q 2.1.40 **Section 2.9.1. "Activities surrounding the disposal".** Please indicate what studies has ONDRAF / NIRAS performed to assess the potential evolution of activities around the site? These studies should be included in the environmental impact assessment report?

2.2 Questions related to the Phenomenological Issues of the Engineered Barriers (Chapter 5)

a) Questions raised by IRT Member 1 (Q2.2.1 – Q2.2.7)
b) Questions raised by IRT Member 2 (Q2. 2.8 – Q2.2. 43)
c) Questions raised by IRT Member 3 (no questions raised)
d) Questions raised by IRT Member 4 (no questions raised)

Q 2.2.1 **Page 5-5** suggests that in the absence of vegetation, the average erosion rate for the

cover would increase to less than 1 cm per year. What is/are the actual value(s) assumed and what is the source of this data?

Q 2.2.2 **Section 5.2.6.1** discusses the possibility of sliding of the cover in response to earthquakes and notes that Peak Ground Accelerations (PGA) of 0.224 g and 0.283 g were used for the DBE and BDBE respectively. The text does not explain or refer to the origin of these PGA values, and they do not seem to appear readily from the seismic hazard analyses described in Chapter 4 (Section 4.3.4). Can the source of the PGA values used in the analyses be explained / clarified?

Q 2.2.3 **Section 5.4.10** discusses freeze-thaw processes and suggests that '*ONDRAF/NIRAS cannot exclude a short period before the installation of the cover during which the modules could be subject to frost. This period should however be relatively short*.' Could it not be arranged that the period between the removal of the steel roof and the installation of the cover occurs in summer?

Q 2.2.4 **Page 5-26**, with regard to carbonation:

- '*Since calcite is characterised by a molar volume greater than that of portlandite, carbonation results in reduced porosity'.* Is it possible to address whether carbonation could cause cracking as well as porosity reduction?
- What is the reference to the source of the carbonation equation on page 5-26?

Have any sources of CO_2 within the modules (e.g. in the wastes) been considered in the evaluation of the extent of carbonation?

Q 2.2.5 **Page 5-31** suggests that *'The propagation phase (active corrosion) is not taken into consideration given the high level of uncertainty characterising the evolution of the system during this period*'. This seems a rather weak reason for not taking account of active corrosion. Can more information be provided (e.g. from scoping calculations) to show that the additional effects of active corrosion would not be significant?

Q 2.2.6 **Section 5.6.4** discusses the long-term chemical evolution of cement pore water. It states that *'two different water types are considered for a case marine inundation (not probable before 6,000 years see HS-04: sea water composition and the composition of rain water (wet-only deposition) of a measurement station close to the sea (Braakman in The Netherlands).)'.* However reference HS-04 is not listed. Where can more information be found about the possibilities of marine inundation?

Q 2.2.7 **Section 5.6.7 (page 5-42)** describes what appears to be a sensible and pragmatic approach to the assessment of radionuclide retention in the cementitious near-field as the cement and concrete materials gradually degrade. The approach involves the use of distribution ratios (R_ds) which have been established through informed expert judgement. The extension of this approach to take account of the effects of organics by using '*sorption reduction factors'* is an area of greater uncertainty. Although the impact of organics on radionuclide solubility is mentioned in the text, it is not clear whether or how this solubility enhancement has been taken into account. For example has solubility enhancement due to organics been factored into the '*sorption reduction factors*' in table 5-3?

Q 2.2.8 **Section 5.2.2 (page 5-3**): *The clay in the infiltration barrier will assist in maintaining stable chemical conditions….* How fast does the sand layer react with the underlying cementitious structure? Is the sand comprised of calcareous material? Is the compacted clay influenced by the high pH environment of the concrete?

Q 2.2.9 **Section 5.2.4 (page 5-5):** *Carbonates may accelerate dissolution of…….* Has the formation of AFm-monocarbonate phases been considered? Water reaching the concrete cover may include dissolved silica. Is there an impact of this silica to be expected? Which impact?

Q 2.2.10 **Section 5.2.5.1 (page 5-5):** *Average erosion rates of the earth cover……*The expected erosion rate is below 1 cm/a. Is there a reference to this value?

Q 2.2.11 **Section 5.2.5.2 (page 5-6):** *It is expected that the clay itself will remain…..* Is it possible to give a clear hint whether the climate remains stable for sufficiently long periods of time?

Q 2.2.12 **Section 5.2.5.2 (page 5-5**): *During the nuclear regulatory control period…..will be repaired*…. Arguments in this section, as do arguments in several other sections (i.e., 5.2.5.4, 5.2.5.5), strongly rely on the important fact that the nuclear regulatory control phase properly works over a foreseen time period of 350 years. Where are the arguments given (societal, political) which support the proper operation of this long regulatory control phase?

Q 2.2.13 **Section 5.2.5.4 (page 5-7):** *…and it is unlikely that roots will penetrate the compacted clay layers*…..Are there good natural examples supporting this assumption? Are observations available that would invalidate this argument?

Q 2.2.14 **Section 5.2.6.1 (page 5-8):…***single event with two PGA at ground surface were used: 0.224 g for*….The two PGA's are given with three digits. Where do the values come from and why are they provided with an accuracy of three digits?

Q 2.2.15 **Section 5.3.1 (page 5-9**):…..*the drainage into the disposal facility is numerically estimated as* $3.41 \cdot 10^{-12}$ *m/s*…..Does this mean that during the nuclear regulatory control phase of 350 years the total infiltration from top is 35 litres/m^2?

Q 2.2.16 **Section 5.3.2 (page 5-9):….***However, it is <u>expected</u> that even degraded, an earth cover with a sufficient thickness will remain*……and later on:……*since vegetation is <u>expected</u> to be present*…..Independent of the plausibility of the statements: are these expert opinions supported by additional indications?

Q 2.2.17 **Section 5.3.2 (page 5-10):…..***Values of the effective infiltration in the soil layer*…..Is it correct to say that the two specified values (359 mm/a and 413 mm/a), based on present and future annual precipitation, assume the presence of an unspecified soil cover (of "sufficient" thickness)? Is it then reasonable to express the effective infiltration with a precision of three digits?

Q 2.2.18 **Section 5.4.2.1 (page 5-12**): This section gives arguments supporting the exclusion of degradation caused by sulphate attack. The arguments rely on standards (EN …..) applicable for "sulphate resistant cement" and are valid for a certain live expectancy. Are the arguments still valid after this technically established live expectancy?

Q 2.2.19 **Section 5.4.2.1 (page 5-12):…***reported results demonstrate the concrete's high degree of resistance to this type of attack……*What is a "high degree of resistance"? Compared to what? How is it measured and judged and what were the amounts of water involved, relative to the amounts of cement?

Q 2.2.20 **Section 5.4.2.1 (page 5-12):….***The materials selected for the earth cover will have to satisfy*….Where in [HS-08] are these strict specifications actually given?

Q 2.2.21 **Section 5.4.3 (page 5-13):…***The use of calcareous aggregates with low silica content is used(should probably be replaced by foreseen!)*…..What is a low silica content of the aggregates in accordance with the standards? Can this be quantified in terms of amounts of available silica per amount of portlandite? The ASR is in any case thermodynamically favored. What is known on the kinetic aspects of such reactions?

Q 2.2.22 **Section 5.5.3.2 (page 5-22):….***Significant effects should only appear when the Ca/Si ratio of CSH hits a value of 1.2*….Why? Where is this described?

Q 2.2.23 **Section 5.5.5.1 (page 5-24):…** *Portlandite and hydrated calcium silicates (C-S-H) make up the bulk of the carbonatable material….*Would it to be worth mentioning the potential formation of AFm-CO_3? Otherwise, why not?

Q 2.2.24 **Section 5.5.5.3 (page 5-26):….***Depending on the case and the formula of the cement matrices, gas permeability increases or decreases, or even remains comparable for carbonated and non-carbonated material*……This statement is difficult to understand, is it possible to clarify the actual meaning of this statement in this section?

Q 2.2.25 **Section 5.5.7.1 (page 5-29):....***HSR (high sulphate resistant) in order to reduce any risk of sulphate attack*.... What would be a guaranteed time span during which the concrete structure would be protected against RSA?

Q 2.2.26 **Section 5.5.7.1 (page 5-29):.....***The results clearly show....the concrete is largely insensitive to formula variations*....With respect to which properties?

Q 2.2.27 **Section 5.6.3 (page 5-33):** ....*The properties and performance of concrete*.....It could be worthwhile to emphasize that many processes concerning water saturation (including their impact) are coupled?

Q 2.2.28 **Section 5.6.3 (page 5-33):....***An outer shell of a few centimeters will be relatively quickly in equilibrium*....What is relatively quickly? Instantaneously, if compared to other processes?

Q 2.2.29 **Section 5.6.3 (page 5-33):....** Several studies have indicated that self-desiccation will result....What is the real conclusion of this little paragraph?

Q 2.2.30 **Section 5.6.3 (page 5-33):.....***will then develop within the concrete, at a rate that depends on the value*.....How does the rate depend on the moisture diffusion coefficient?

Q 2.2.31 **Section 5.6.3 (page 5-34):....***water saturation of the concrete structures will be monitored in-situ*....What are possible consequences of such in-situ measurements? Are the concrete structures re-wetted when the saturation is low? Why are such measurements performed when no actions are planned? For how long can such measurements be performed?

Q 2.2.32 **Section 5.6.4 (page 5-34**):....*The state ends when C-S-H phases are depleted and state IV controlled by calcite establishes at pH < 10*.....The potential neo-formation of clayish-type materials seems to be excluded from being considered. Is this correct?

Q 2.2.33 **Section 5.6.4 (page5-34):...***four clay water compositions (two without Si and two with Si)*.....Is it reasonable to assume a clay water composition excluding Si?

Q 2.2.34 **Section 5.6.4 (page 5-33 / 37):** General comment to this paragraph: The discussion on how the cement pore water evolves is comprehensive, very detailed and obviously based on state of the art thermodynamics of cementitious materials. The fact that all concrete aggregate consists of calcareous materials helps supporting such a view. However, clay type (soil, clay) and silicate (sand) materials are present in the close environment of the degrading structure. It would thus be helpful to discuss the potential impact of silicate materials on neutralizing pH and to discuss the potential neo-formation of clayish-type materials. Such neo-formation might also have a potential impact on the evolution of porosity. Have such considerations been done somewhere?

Q 2.2.35 **Section 5.6.6 (page 5-40):...***Implicit representation of fractures by including the effect of fractures in an upscaled value of the water permeability*..... On which basis has this up-scaling of permeability been performed?

Q 2.2.36 **Section 5.6.7, Table 5-2 (page 5-43):** Rd values for Cl^- at Cl^- < 1 [mmol/l] are given as 20, 50, 20 and 0 [l/kg] for the states I to IV. Why are the values for I^- much lower (1, 10 and 1 [l/kg]) for states I to III and substantially higher (0.4 [l/kg]) for state IV? Conversely, the potential ranges for chloride are lower than those for iodide. Please explain.

Q 2.2.37 **Section 5.6.7, Table 5-2 (page 5-44):** Rd values of Sr show an up and down when going from state I to IV. Why?

Q 2.2.38 **Section 5.6.7.2 (page 5-45**):....*High impact, Ag, Pb, Pd*.....What means a high impact in the case of silver? One primarily would expect the precipitation of AgCl(s) and at higher chloride the formation of $AgCl_2^-$. And why especially under reducing conditions? The potential formation of elemental $Ag_{(s)}$ does not depend on chloride.

Q 2.2.39 **Section 5.6.7.2 (page 5-45):** *Ni (due to its position in the periodic table), Cl and I due to direct competition with Cl^- and CO_3^{2-}*.....What does this statement really mean?

Q 2.2.40 **Section 5.6.7.2 (page 5-45):…..***It was thought Nb (but also Cl) is likely to from outer (sphere?) complexes not inner (sphere?) complexes, with the sodium effect (ionic strength effect) still present but it does not bind strongly to chloride*…..Nb is not mentioned in the "low impact" list above. In addition, the information content of the sentence is highly unclear. What should be expressed here?

Q 2.2.41 **Section 5.6.7.3 (page 5-45):…..***As concerns the high molecular weight organics evaluated*…..at which time scales no effects have been observed? What would be potential reaction products?

Q 2.2.42 **Section 5.6.7.3 (page 5-45):….***expected effects from use of naphthalene-sulphonate on sorption will be negligible……..possibly plutonium may experience a small increase in solubility*…..When effects from naphthalene-sulphonate are expected, why are they negligible? How big is a small increase in Pu solubility?

Q 2.2.43 **Section 5.6.7.3, Table 5-3 (page 5-47):** The reference [OD-106] leads to nowhere. Can reference [OD-106] be included in the reference section?

2.3 Questions related to the Disposal Packages (Chapter 7)

a) Questions raised by IRT Member 1 (no questions raised)
b) Questions raised by IRT Member 2 (Q2.3.1– Q2.3. 22)
c) Questions raised by IRT Member 3 (Q2.3.23 – Q2.3. 24)
d) Questions raised by IRT Member 4 (no questions raised)
e) Questions raised by IRT Member 5 (Q2.3.25 –Q2.3.36)

Q 2.3.1 **P.7-3; Sect.7.2.2**: *Footnote 2*: except for a small number of monoliths ….. What is a small number of monoliths?

Q 2.3.2 **P.7-3; Sect.7.2.2**: *The immobilization matrix must also be able to ensure the confinement of radionuclides….* This sentence includes some kind of "demand of absoluteness" and should be specified, for example for a certain time span. Will ONDRAF/NIRAS consider this suggestion?

Q 2.3.3 **P.7-9; Sect.7.3.4**: *The superplasticizer is of an NS type (..) or equivalent for what concern the…….* What is the meaning of this statement? Is it correct that the superplasticizer should not influence the solubility and speciation of RN's? Please explain it..

Q 2.3.4 **P.7-10; Sect.7.3.5**: *The filler material and sand are mainly based on limestone, but a certain ratio……*What ratio of quartz sand would be allowable assuming potential neutralization reactions with CSH or CH are the background of this statement?

Q 2.3.5 **P.7-10; Sect. 7.3.5**: *The superplasticizer is of an NS type (..)…..* Similar to Q 2.3.3, please explain the meaning of this statement

Q 2.3.6 **P.7-10; Sect. 7.3.5**: *Fly ash and silica fume are allowed……* Silica fume reacts quickly with CSH and CH and in principle produces low-pH concrete. Are there any restrictions in the use of silica fume?

Q 2.3.7 **P.7-10; Sect. 7.3.5**: *The ratio of waste volume to mortar volume must be less than 1…..* Why? What is the reason to restrict this ratio and on which consideration is the threshold selected at a value of 1?

Q 2.3.8 **P.7-10; Sect. 7.3.5**: *The immobilization mortar fills……*How is the technological free space limited?

Q 2.3.9 **P.7-10; Sect. 7.3.5**: *The shrinkage of the mortar shall be limited……*How?

Q 2.3.10 **P.7-11; Sect.7.4.2.3**: *Under semi-permanent load, concrete……*What does "never not exceed" mean?

Q 2.3.11 **P.7-11; Sect.7.4.2.5**: …*The total mass taken into account*……. Are the weights with or without the waste (the list in parentheses does not include wastes)?

Q 2.3.12 **P.7-12; Sect.7.4.2.6**: This section seems to be a strongly shortened summary of much longer section providing more details (including the justification of this section). What is the reason to project the centre of gravity into a 118 mm circle?

Q 2.3.13 **P.7-12; Sect.7.4.3.1 to 7.4.3.3**: These sections include a collection of parameters without the context for how theses parameters are used. Can further information be provided particularly about the partial safety factors, their meanings and uses in these sections?

Q 2.3.14 **P.7-12; Sect.7.4.3.4**:……The design of the lifting anchors…….This paragraph would certainly benefit from re-wording. To my understanding it finally says that the loss of steel due to corrosion does not affect the integrity of the anchors in the first 300 years. Is this correct?

Q 2.3.15 **P.7-13; Sect.7.4.4.1**:…..*Handling of caissons that contain primary packages but do not contain*….The wording seems unclear here. When lifting using four anchors, the caisson cannot have an angle of more than 90° in relation to horizontal direction. What is the meaning of "at least 90° in relation to the horizontal surface"?

Q 2.3.16 **P.7-16; Sect.7.5.1.8**:…..*The cured concrete will also be submitted to a testing programme…..* This declares an intention to do some testing that is more extensive and will last longer. What is covered by this extended programme, what tests are performed, and is durability verified?

Q 2.3.17 **P.7-16; Sect.7.5.2.1**: This is identical to 7.5.1.1. Is it necessary to repeat?

Q 2.3.18 **P.7-16; Sect.7.5.2.1**: *If during the placement of the immobilization matrix*…..consider re-formulating the statements in this paragraph. At the beginning we find some weakly defined potential risks and later on we see very distinct temporal (40 hours) and dimensional (10 cm) arrangements. Under which conditions are what measures necessary, an why (key word dust?)?

Q 2.3.19 **P.7-17; Sect.7.5.2.5**: This section seems to be equivalent to section 7.5.1.4. However, 7.5.1.4. includes a statement concerning humidity conditions, the present section includes statements on moving during critical time periods. Is humidity not an issue in this case?

Q 2.3.20 **P.7-17; Sect.7.5.2.7**: Raw material shall be shielded from torrential rain only, but monoliths shall generally be shielded from precipitations (7.5.2.6). Why this difference?

Q 2.3.21 **P.7-18; Sect.7.6**: …..*Construction units may be subject to repair measures, provided that this does not affect their long-term durability and the safety*….. What does this actually mean? Is it possible to specify distinct actions that are allowed or are not allowed?

Q 2.3.22 **P.7-18; Sect.7.7**: *Such adaptions must have an added value for* ……What does this mean? If an adaption has an added value, why is it not applied to all waste streams/packages, but only to certain waste streams?

Q 2.3.23 **Section 7 (general):** which parameters concerning disposal packages shall be checked in the context of limits and conditions of operation?

Q 2.3.24 Section 7 (general): how is the life time of disposal package considered in safety assessment?

Q 2.3.25 **Section 7.1** could ONDRAF/NIRAS provide the scheme of the acceptance system (i.e. procedure and/or details) for the primary waste and the disposal packages? Please indicate the role of FANC in both processes.

Q 2.3.26 **Table 7-4 (page 7-5),** 3rd column titled "Types of monoliths available [not excluded]"

a) What does "not excluded" mean?

b) Please clarify if caisson type III (intended for bulk waste to be filled in origin) can be

used for all types of primary waste (immobilised in any of the foreseen drums)

Q 2.3.27 **Section 7.4.3.4** states that *the design of lifting anchors did not include extra allowance for corrosion*. However, as states in Section 7.2.4 (Other functions of monoliths) one of the functions of the monoliths is to simplify any waste retrieval that might be required in the future and comply with the conditions set by the Minister on 16 January 1998 and on 23 June 2006.

On the other hand, the Table 4-1: List of design inputs and design requirements in page 21od the "Detailed design monoliths" include the requirement of allowing flexibility and retrievability. In this respect the supporting document [OD-001] notes that the "retrievability period is around 350 years ".

With these premises to preserve the potential of retrieval until the end of the institutional control period, should extra allowances in the lifting anchors to avoid corrosion not be included?.

Q 2.3.28 **Section 7.4.4.3** states that *Monoliths have <u>only</u> been checked for their earthquake resistance (maintain waste confinement) in their final position in the modules (shielded with gravel, presence of precasts shielding slab, structural top slab and the multi layer cover) and on a BDBE basis (Beyond Design Basis Events).* Could you clarify what is the meaning of "only" in this sentence?

Q 2.3.29 **Section 7.5.1** notes that "Caissons, being a primary packaging of disposal waste, are subject to approval according to the Royal Decree of 18/11/2002 for waste management".
Could ONDRAF/NIRAS provide details of this approval process?

Q 2.3.30 **Section 7.5.1.**2 distinguishes between the manufacturing caisson plant and the concrete manufacturing plant and states that the procedures for manufacture the concrete will be defined by third parties in charge of the design of the concrete plant.
Could ONDRAF/NIRAS provide details of how to demonstrate conformance to the technical specifications of the concrete ?

Q 2.3.31 **Section 7.5.1.8 (page 7-15)** states that the operator of the production unit will implement a QA/AC programme to guarantee the quality of the manufactured caissons and that this programme requires approval from ONDRAF/NIRAS or that an independent institution will carry out audits.

Could ONDRAF/NIRAS explain the process for seeking approval of the QA/QC programme and provide details of audits by an independent institution in maintaining the QA/QC programme?

Q 2.3.32 **Page 7-16** of the same Section indicates that the production tests will be carried out in accredited laboratory or one that meet equivalent criteria (foot note 9) Could ONDRAF/NIRAS clarify this sentence?

Q 2.3.33 **Section 7.5.2 (General)** according to the cAt project , the manufacture of the monoliths will be carried out in the MPF (Monolith Production Facility) located at Belgoprocess that will be the applicant of the license

As monoliths or "disposal packages" are an important component of the repository and they play a key role in long-term safety, how will be taken into account these interdependences in the license of the MPF? Will the types of monoliths to be produced specified in the MFP license?**.**

Q 2.3.34 **Section 7.5.2.8** states that the QA/QC programme requires approval from ONDRAF/NIRAS <u>or</u> an independent institution will carry out regular audits.

Similar question as Q 2.3.29**.**

Please provide audit plans / details in ensuring the quality of the QA/QC programme

Q 2.3.35 **Section 7.6** Are defects and corrective actions part of the QA programme? What criteria are used to apply corrective actions or not?

Q 2.3.36 **General:** Monoliths prototypes. Why they are not described in this chapter? Has there been the manufacture of prototypes carried out in conditions which are representatives of the actual manufacturing.

2.4 Questions related to the Design an d Construction (Chapter 8)

a) Questions raised by IRT Member 3 (Q2.4.1 – Q2.4.6)
b) Questions raised by IRT Member 4 (Q2.4.7 – Q2.4.18)
c) Questions raised by IRT Member 5 (Q2.4.19 – Q2.4.25)

Q 2.4.1 **Page 8-4:** what is the assumed rate of filling the modules, with respect to possible degradation of construction?

Q 2.4.2 **Section 8.4.2**: List of events – in the summary column, quantitative data related to consequences would be helpful, if applicable, especially in the case where radiological impact has been evaluated (ch. 13 is not available)

Q 2.4.3 Direct support to Ch.14 - justification of starting time 2000 yrs. How is 2000 year justify in the intrusion scenarios?

Q 2.4.4 **Section 8.6.1.8**: to better understand the isolation capabilities of the applied components, can the service time (life time) be specified?

Q 2.4.5 References [HS-XX] not listed. Can this reference be listed?

Q 2.4.6 **Page 8-55**: impervious top slab has to prevent from bathtubbing effect. What is the time perspective of this function?

Q 2.4.7 **Page 8-18**: Are the results of the liquefaction analysis mentioned on this page available? If so, what are the main conclusions?

Q 2.4.8 **Figure 8-22**: it appears that the bitumen layer lies above a concrete layer. The impervious top slab is then placed above the bitumen layer. 4 questions below:

- Can you justify that pouring the impervious top slab won't deteriorate the bitumen layer?
- Have you studied the potential interactions (chemical, mechanical etc…) between concrete and bitumen in the long term?
- What could be the possible effects of cracks in the overlying concrete layer and build up of water pressure within the impervious top slab?
- What is the waterproofness objective (in $L/m^2/yr$) of the bitumen layer

Q 2.4.9 **Section 8.6.5**: Regarding the multi-layer cover, have you considered a situation in which the earth cover and/or the side embankments are not properly drained? What margin does the earth cover provide with respect to sliding of the side embankments when (i) a hydraulic pressure equivalent to poor drainage conditions is considered? (ii) an earthquake is combined with such a hydraulic pressure equivalent to poor drainage conditions?
Also aside from modeling and calculation, what is the experience feedback considered to assess the dynamic stability of the earth cover? In particular, what is the experience feedback considered from the covers in place at Andra and ENRESA, as well as the cover tests already in place that are mentioned in your document?

Q 2.4.10 **Page 8-54**: Cover tests are mentioned. Could you elaborate on the program of such tests, what they aim at demonstrating (functions, scenarios) and how they will be performed?

Q 2.4.11 **Page 8-56**: it seems that there is no water collection system within the earth cover: what are the provisions to monitor the global hydraulic flux that crosses the earth cover during the surveillance phase?

Q 2.4.12 **Page 8-87**: How do you plan to verify that the earth cover does not deteriorate since the drainage system and inspection rooms below will no longer be available at the start of the nuclear regulatory control phase?

Q 2.4.13 **Figure 8.23**: Only the reference profile of the earth cover is shown. Could you elaborate on the differences between this profile and the alternative one?

Q 2.4.14 **Section 8.6.5.8**: "*The floating slabs will also collect infiltration water from the top layers of the multi-layer cover and send it further away from the module walls*" + "*The objective of this impermeable layer* [the impervious top slab] *is to reduce the percolation of potential water leaks*".
Since concrete layers are subject to cracking, how do you ensure that they will remain waterproof over the times considered? Also, in case of settlements within the repository, can the floating slabs change their orientation, and act as potential pathways to direct water towards the modules?

Q 2.4.15 **Section 8.6.5.8**: Avoidance of the "bathtubbing effect" within the repository is mentioned in the description of the impervious top slab. However, components made of concrete under the monoliths (support slabs and foundation slabs) are designed with a very low permeability to act as "M" SSCs (see table page 27 for instance) for the "containment" safety function, along with the module walls. How do you ensure that the cover permeability will remain lower than the concrete permeability under the waste packages?

Q 2.4.16 **Page 8-73**: it is mentioned that "*The sliding element at the basis of the walls may be either Teflon or steel plates*". The use of such materials will introduce heterogeneities within the concrete components. What is the influence of such heterogeneities on the modules' containment on the long term?

Q 2.4.17 **Page 8-73**: it is mentioned that "*The drainage system is tested for leaks* »: Could you provide a brief description of these tests and conclusions if available?

Q 2.4.18 **Page 8-87**: regarding closure activities and surveillance: After closure, why isn't surveillance of the drainage system (dismantled at the end of phase II) kept as long as possible during the surveillance phase?

Q 2.4.19 **8.3.3, Table 8-2:** The design choice DC3 (*The materials and the construction and operation technologies shall have proven effectiveness*) addressed in Section 8.3.3 is not included as design inputs in Table 2. Could ONDRAF check this omission?

Q 2.4.20 **8.4.2 List of events (General):** Could ONDRAF/NIRAS explain the difference between "2. Events considered in the design, likelihood < 10-7 by design measures" (page 8-12) and "3. Events not considered in the design because likelihood < 10-7" (page 8-13)?

Q 2.4.21 **Section 8.4.2,** "3. Events not considered in the design because likelihood < 10-7" in the 4th line include the event "Wind/climate: erosion of multi-layer cover, degradation of multi-layer cover during nuclear regulatory control phase" and the 2nd column "Summary of measures" states that "Proper design of the cover and maintenance for remaining events". How does ONDRAF / NIRAS ensure permanent or continuous maintenance during the whole period of institutional control?

Q2.4.22 **Section 8.4.2**. "4. Events with likelihood > 10-7 not considered in the design because radiological consequences are acceptable with current design measures" 3er line regarding "Impact of airplane" states that the probability and radiological consequences is evaluated, cfr. Chapter 13". Could ONDRAF provide detail and results of the evaluation of this event?

Q2.4.23 **Section 8.4.3 page 9-19:** "The event considered to dimension the drainage system is a 3 day period of rain with intensity related to a 10 years return period. The infiltration basin is calculated for a 10 years return period with overflows to the south for 100 years return period". Could ONDRAF/NIRAS provide information on the basis of these return periods?

Q2.4.24 **8.9.2 Construction QA/QC: "**An important part of the control programme will be carried out by the contractor in a systematic manner as will be described in the tender documents".
Please clearly indicate who will be formally responsible for the compliance of QA/QC of the construction, what role is played by ONDRAF, which department in ONDRAF´s organisation will be in charge of the compliance of the QA and the verification of the QC..
Is the construction QA programme submitted to approval?

Q2.4.25 **General:** Could ONDRAF/NIRAS explain the organisation for the construction that is outlined in figure 1-6 of Chapter 1 and the corresponding responsibilities**?**

2.5 Questions related to the Assessment of Long-Term Radiological Safety (Chapter 14)

a) Questions raised by IRT Member 1 (Q2.5.1 – Q2.5.3)
b) Questions raised by IRT Member 2 (no questions raised)
c) Questions raised by IRT Member 3 (Q2.5.4 – Q2.5.56)
d) Questions raised by IRT Member 4 (Q2.5. 57– Q2.5. 76)

Q 2.5.1 **Section 14.4** describes a process of '*radionuclide screening'*, which has been undertaken to determine which of the radionuclides in the inventory have the potential to be significant and, therefore, need to be included in the assessments. The description of the approach used for the groundwater pathway on page 14-25 is not clear. Can ONDRAF/NIRAS provide further explanation?

Q 2.5.2 **Section 14.4.1 – 14.4.3**: The pathways considered during the radionuclide screening are discussed in Sections 14.4.1 to 14.4.3, but none of these sections addresses the possibility of repository inundation as mentioned in Chapter 5 (e.g. on page 5-34). Have all of the relevant pathways been considered during the radionuclide screening?

Q 2.5.3 With regard to the discussion of potential major crack features on **page 14-38**, could a BDBE cause a fracture in the module base that might later allow rising groundwater enter the facility?

Q 2.5.4 With regard to radionuclide sorption:

- **Section 14.5.2.4** discusses the near-field model and the evolution of chemical properties and how this affects radionuclide sorption. Does ONDRAF/NIRAS's research and development plan include further sorption experiments to reduce the uncertainties associated with the sorption properties of degraded concretes under relevant conditions?
- The assessment results presented in **Section 14.7** highlight the potential impact from 239Pu (e.g. Figure 14-45). Does ONDRAF/NIRAS's research and development plan include further sorption experiments to reduce the uncertainties associated with the sorption of Pu under relevant conditions? and/or other work to confirm the appropriateness of the Biosphere Conversion Factor (BCF) for 239Pu.
- Figure 14-16 indicates that Rd values increase when passing from cement State I to State II. Can ONDRAF/NIRAS explain this increase?

Page 14-47 discusses the potential significance of 14C (see also Figure 14-17). The text notes that, as modelled, 14C has a distinct behaviour because its sorption values differ from those of all other radionuclides. Given that 14C may participate in various isotopic exchange and precipitation reactions, is it appropriate to use a sorption (Rd-based) model to assess its behaviour?

Q 2.5.5 **Section 14.5.3** summarises the hydrogeological model. Can ONDRAF/NIRAS clarify if there is a vadose (partially-saturated) zone at the site and if so, whether and how this is represented in the hydrogeological model?

Q 2.5.6 **Page 14-51** suggests that for the current climate state, the dilution factor derived from the local groundwater flow model is relatively insensitive to the assumption that flow in the aquifer can be represented as steady state flow through a unit with uniform hydraulic conductivity. This may be correct for the current climate state, but the effects of future climate change on hydrology at the site (e.g. on the amounts of rainfall on the cover, on groundwater dilution factors) do not appear to be considered in the assessment. Page 14-58 states 'The reference calculation case for the biosphere involves a constant biosphere, based on present-day climate conditions; and agricultural land and water use, including the application of sprinkling irrigation.' What would be the implications of climate change on water flows at the site and on disposal system performance?

Q 2.5.7 **Page 14-51** suggests that for the current climate state, the dilution factor derived from the local groundwater flow model is relatively insensitive to the assumption that flow in the aquifer can be represented as steady state flow through a unit with uniform hydraulic conductivity. This may be correct for the current climate state, but the effects of future climate change on hydrology at the site (e.g. on the amounts of rainfall on the cover, on groundwater dilution factors) do not appear to be considered in the assessment. Page 14-58 states 'The reference calculation case for the biosphere involves a constant biosphere, based on present-day climate conditions; and agricultural land and water use, including the application of sprinkling irrigation.' What would be the implications of climate change on water flows at the site and on disposal system performance?

Q 2.5.8 **Page 14-56** mentions the possibility of future sand mining. The report addresses the potential effects of sand mining on water levels, but it is not clear if such mining activities might lead to the creation of additional exposure pathways?

Q 2.5.9 **Section 14.5.4.8** discusses Biosphere Conversion Factors (BCF) and the relative importance of various exposure pathways (pages 14-61 and 14-62). It is not clear, however (certainly at this stage in the report), whether the BCFs listed cover the possible exposure to radon of people in buildings, or whether they cover exposures associated with wetland processes and uses?

Q 2.5.10 With respect to wetlands **(Sections 14.5.4.8 and 14.7.3.2),** various radionuclides can become concentrated in peaty material which is a common feature of wetland environments. Has this been considered?

Q 2.5.11 **Section 16.6** describes and discusses a set of alternative reference scenarios. The alternative reference scenarios are:

1 Poor Construction – Cover Failure.
2 Poor Closure – Non-backfilled Inspection Rooms.

3 Poor Closure – Unsealed Drainage System.
4 Earthquake Larger than BDBE [sic] at Start of Phase IV – Effects on Components other than the Monoliths.

It is not clear that the list of alternative reference scenarios is as complete as it needs to be (or that other conceivable scenarios have been screened out earlier in the process). For example, why there are not further alternative reference scenarios for marine inundation, glaciation or 'bath-tubbing'?

Q 2.5.12 The alternative reference scenarios listed are said to be less likely than the reference scenario **(page 14-71),** and table **14-6** variously describes the probabilities of the alternative reference scenarios as 'low likelihood', 'medium likelihood' or 'slightly higher likelihood'. The probability of alternative reference scenario 4 (which involves a BDBE) is given as < 4 x 10-2 a-1 (4%). How were these probabilities and likelihoods assessed? What is the assessed probability of the EES?

Q 2.5.13 **Section 14.2.6.1** discusses the dose and risk criteria that need to be considered. It suggests that radiological risks to humans can be evaluated, but quantitative risk estimates are not actually presented (there is one qualitative mention of risk in Section 14.6.5). Does ONDRAF/NIRAS have plans to further develop its presentation of radiological risks to humans?

Q 2.5.14 **Section 14.8** summarises the assessment of a range of human intrusion cases. A feature of the results presented is that assessed doses from radon seem only to make up a small part of the total assessed dose (e.g. Figure 14-66) even for the scenarios involving people living at the site after excavation of the waste. The report does not provide enough information on the assumptions made regarding the concentration of radon in homes built on contaminated material to allow the reader to understand what has been assessed or understand why the results are as they are. Can ONDRAF/NIRAS explain what assumptions have been made and why the assessed doses from radon are so low?

Q 2.5.15 **Section 14.9** describes some radiological impact calculations for 'penalising' conditions:

- Why are the exposures considered under these hypothetical scenarios considered to be 'existing exposures' in the terminology of the ICRP?
- The description of the assessments for the penalising conditions is rather brief and it is not fully possible to follow the calculations that have been made. For example, what do the terms of the equation on page 14-126 represent?

Q 2.5.16 **Section 14.9.2.3** states that 'The biosphere is simplified in that only ingestion of drinking water (Qw = 0.73 m^3/a [R14-38]) is considered', but this seems to conflict with the subsequent text in Section 14.9.4 that indicates that (i) the ingestion of foods contaminated with 14C and (ii) irradiation from 94Nb are important to the assessed doses. Can ONDRAF/NIRAS clarify which exposure routes are modelled?

Q 2.5.17 **Section 14.1.1:** "hazards associated with the repository" It seems to be a strong expression. Would ONDRAF / NIRAS consider using impact or potential impact in the case of radiological effects, also to connect hazard to emergency situations and/or accidents?

Q 2.5.18 **Section 14.1.1**: From radiological point of view – hazard should be connected to a certain level of effect, usually with high probability of exceeding a general dose limit for population (1 mSv per year?)

Q 2.5.19 **Section 14.1.1**: *radiological impact is acceptable* – Would ONDRAF / NIRAS agree with

rephrasing "radiological impact is acceptable" to "radiological impact is under regulatory limit" ?

Q 2.5.20 **Section 14.1.1:** What is the measure of performance? *"Adequate level of defense in depth", safety functions*

Q 2.5.21 **Page 14-2**: loss of repository at 2000 yrs. – please explain how "2002" was derived.

Q 2.5.22 **Page 14-4**: What is the difference between reference scenario and expected evolution scenario for gradual leaching?

Q 2.5.23 **Page14.-4:** description of chapter 14.11 – should operational limits be also developed with respect to operational safety?

Q 2.5.24 **Figure 14-2**: What is the relation between the waste inventory and WAC in the operators commitment box?

Q 2.5.25 **Section 14.2.3:** Bathtubbing excluded – Why is "bathtubbing" excluded?

Q 2.5.26 **Page 14-16**: validation. Should the paragraph "Validation" be referring to Figure 14-4 instead of 14.2? Can "validation" be adequately / appropriately documented in limited time frames?

Q 2.5.27 **Section 14.2.6.2**: complementary safety indicators - radiotoxicity flux in groundwater as a function of time and time-integrated radiotoxicity flux in groundwater – As these indicators are not directly related to dose, can further explanation of their use be provided?

Q 2.3.28 **Section 14.2.6.3**: activity flux is considered as a safety indicator and as a performance indicator as well. Would ONDRAF / NIRAS consider "isolation times, groundwater travel time and/or barriers life time" as performance indicators? If so, please elaborate.

Q 2.5.29 **Section 14.4**: screening. Can the procedure [OD-114, in preparation] be described more explicitly?

Q 2.5.30 **Page 14.26**: screening out of Co-60. Is it possible to clarify the compliance of long term safety relevant radionuclides and operational safety relevant radionuclides in this section? From the point of view of WAC, can limits for important operational safety radionuclides be set? – e.g. Can volume activities be derived from dose rates on waste package surface or with respect to technological processes in waste production?

Q 2.5.31 **Table 14.3**: for better understanding is it possible to explain the safety functions of this table?

Q 2.5.32 **Section 14.5.1.2**: the use of biosphere factors. As the use of biosphere factors does not accommodate change of a single input easily, would ONDRAF / NIRAS consider repeating the calculation with other set of data (e.g. using different transfer factor for a special radionuclide) which shall allow the transparency to be maintained as well?

Q 2.5.33 **Section 14.5.2.7**: near field/aquifer fluxes calculation. Can further explanatory description of the processes involved in the model be provided? It seems that the model is working with various changing conditions. What is the driving process of transport: diffusion, sorption, chemical equilibrium? In what time periods?

Q 2.5.34 **Section 14.5.2.7**: is it possible to show the derivation of pore/fracture water activity considering, that bathtubbing is a potential scenario after loss of upper barrier integrity?

Q 2.5.35 **Section 14.5.2.7**: For transparency reason, would ONDRAF / NIRAS consider including , input data for near field calculation Secton 14.5.2.7 or in Ch. 14?

Q 2.5.36 **Page14-55**: dilution factor – would ONDRAF / NIRAS consider indicating dilution factors in terms of the potential of the hydrogeology system in diluting the radionuclides? More specifically, relating this effect to half time, transport time (i.e. retardation)?

Q 2.5.37 **Page14-55:** radionuclides concentration in the aquifer is a well informative indicator , but radiotoxicity, usually derived as a product of activity and dose factor has lower information value than dose. Can the use of radiotoxicity in the confidence building

process be explained?

Q 2.5.38 **Section 14.15.4.3:** changes as a consequence of human actions are estimated to be small. Would the dilution factor be increasing or decreasing? Would higher dilution lead to lower potential doses in all considered cases?

Q 2.5.39 **Table 14.7:** ARS-1 – what is the consequence in the term of migration? Can the bottom be sealed and bathtubbing could take place?

Q 2.5.40 **Section 14.6.3:** dilution factor seems to be a ratio of near field and far field flow? How does radionuclide specific retardation being considered in hydrogeology system?

Q 2.5.41 **Figure 14-3 and Figure 14-4:** the graph shows the impact up to 10^5 yrs., but scenarios is limited to up to 350 yrs. after closure. Does it imply scenario initiating event is limited to 350 years after closure and impact is evaluated till 10^5 yrs?

Q 2.5.42 **Page 14.82:** alternative assessment cases - waste emplacement: what is the measure of heterogeneity permitted in the repository (in acceptance criteria) and how is the heterogeneity regarded in intrusion scenarios?

Q 2.5.43 **Section 14.7.3.2:** no dilution and dispersion in the case of entering the source flow the river system. Would it be better to say that there is no hydrogeological system in the pathway than that there is no dilution in hydrogeology?

Q 2.5.44 **Table 14.10:** in some cases (Ag, Be, Pa, Pu-236, Tc) a later occurring peak leads to higher doses, what is assumed not usual in the transport scenarios? For Ra-226, the peak occurrence in EES and reference scenarios differs nearly in two orders, what is the reason and any other radionuclides not shown?

Q 2.5.45 **Page 14.91** and following: in figures, the radiation impact is shown for different period than the scenario is defined. Should it be clearly stated that the initiation event occurs during operational period etc?

Q 2.5.46 **Section 14** – a general question for Section 14.8.2: solution of transport scenarios and intrusion scenario – there exists an eventuality to calculate the impact together – the activity potential for intrusion lowers with gradual leaching from the near field. Was it applied in that manner?

Q 2.5.47 **Section 14.8.5.3:** what is the difference between residence post-drilling scenario and residence scenario, when drilling does not take place? Contaminated area vs. well water scenario?

Q 2.5.48 **Page 14.126:** Should vertical flow be included as an concurrence process in the initial conditions? Not only decay is contributing to radionuclides content in the near field?

Q 2.5.49 **Section 14.9.4:** impact of radionuclides is affected not only by decay rate, but by their initial concentration as well. Should the first sentence be supported by knowledge of initial activities (projected inventory)?

Q 2.5.50 **Section 14.11.1.3**: critical radionuclides – average concentration. In intrusion scenario, the maximum concentration in smaller volumes is more important than average concentration throughout the repository. What is "average" here?

Q 2.5.51 **Page14-141**: DCF_i – what exposure pathways are included?

Q 2.5.52 **Section 14.1.3.1-3:** use of initial unit activity for derivation of WAC – using initial unit activity could be a disadvantage in the case, that the vector of radionuclides is relatively well known. Using vector, you can better use the part of dose limit to radionuclides that are substantial in the mixture, with relatively high activity. Could the procedure for deriving WAC in the licensing process be explained?

Q 2.5.53 **Table 14.15**: is it necessary to limit total activity of some radionuclides by excavation scenario, which is not related to total volume of the repository? Should total activity be explicitly related to reference scenario?

Q 2.5.54 **Table 14.16**: Could volume activities be more transparently derived from

intrusion/excavation scenarios?

Q 2.5.55 **Table 14.25**: Should / Can dust load in the air be expressed in [kg/m3]?

Q 2.5.56 **Section 14.9.1**: what is the justification for starting the post containment phase at 2000 yrs? (Same question as Q2.4.3 and 2.5.8)

Q 2.5.57 **Page 14-13**: "*Relevant AESs for performance analysis and assessing the level of defence-in-depth provided by the disposal system are described in section 14.10*". However, Section 14-10 is not available at the present time. Could details of the elements of robustness that are considered to appraise the confidence used in the defense in depth principle (as mentioned in Section 2.4.2) applied in the CaT Project be provided?

Q 2.5.58 **Section 14.2.6.1**: "*The assessed committed effective dose (rate) [Sv(/a)] to a representative person is the primary quantitative safety indicator [R14-18]. Alternatively, individual risk can be used as an indicator for potential exposure situations (i.e. exposures that are not planned to occur, although the situation (disposal) is planned".* Does the terminology "*exposures that are not planned to occur*" refer to a quantitative evaluation of a dose or risk? Or does it refer to a situation not planned to occur (for which the related level of dose or risk should be evaluated and compared to possible ranges of dose or risk)?

Q 2.5.59 **Page 14-2** indicates that the FANC guidance requires that scenarios related to extreme conditions at 2,000 y have to be explored: this timeframe is very long with respect to the type of disposal and category of waste to be disposed: what are the reasons for such a requirement and identification of a 2,000 year timeframe?

Q 2.5.60 **Table 14-3** indicates that the "*drainage layer of the foundations is considered 'effective' in that the groundwater level is considered to remain constant and does not affect the repository (no water ingress)*" during all the different phases, that is, until the end of the post-containment phase (VI). Can this strong assumption be justified?

Q 2.5.61 **Section 14.5.3.4**: "*Changes in river (canal) geometry. In the framework of flood prevention and integral water policy of the Flemish government, the river geometry may be changed to a form resembling its original state, which may induce higher surface water levels in the rivers and influence groundwater flow*" Can you indicate the influence of this type of modification in terms of highest possible water table under the repository?

Q 2.5.62 **Section 14.5**: Can you give feedback information justifying (i) that a hydraulic conductivity value of the order of 10^{-12} m/s is cautious at the scale of a several-meter object and (ii) that the performance of the earth cover will remain that efficient during at least 350 years?

Q 2.5.63 **Figure 14-10**: As mentioned in Section 8.6.2.8 – Identification and influence of voids on settlements - : In order to ensure retrievability of the monoliths, you plan to only place gravel in the residual space between the outer monoliths and the module walls. No other filling of the modules seems to be foreseen. In Figure 14-10, we can see that voids are present between the monoliths. What approximate size will these voids be? What influence will such voids have on repository settlements?

Q 2.5.64 **Section 14.5.2, Page 14-36**: Can you explain the meaning of Cs and Cr in "future Cs/Cr climate conditions"?

Q 2.5.65 **Figure 14-13**: Regarding the hydraulic conductivity values considered in the reference scenario, the hydraulic conductivity of the monolith is taken at 1.42×10^{-13} m/s and that of the module base at 1.75×10^{-12} m/s, during 350 yrs. Can you present feedback data showing that you will be able to achieve such low hydraulic conductivity values for the

concrete, at large scale (several-meter objects) and during 350 years since no repair work can be foreseen on such buried objects?

Q 2.5.66 **Section 14.5**: The hydraulic conductivity of the impervious top slab is of $3.41x10^{-12}$ m/s, taking into account a postulated network of cracks. Can you explain how the value of $3.41x10^{-12}$ m/s was obtained?

Q 2.5.67 **Figure 14-27**: Can you explain why only ^{137}Cs starts to be released during the regulatory control phase?

Q 2.5.68 **Table 14-9:** for the assessment case called "lower infiltration rate" the conceptualisation is "upper flow boundary condition increases from 3.41×10^{-12} m/s to a maximum of 3.16×10^{-9} m/s" (which should mean a higher infiltration rate); from Figure 14-50 though, it seems that you have indeed tested a "better performance of the earth cover" and thus a lower infiltration rate. Can you provide the hydraulic conductivity values considered in Figure 14-50 (i) for the base case, (ii) for the "better performance of earth cover" case? Can you edit and/or clarify Table 14-9?

Q 2.5.69 **Figure 14-49**: Can you explain why ^{239}Pu, ^{94}Nb, ^{234}U and ^{238}U suddenly drop around 70 000 yrs?

Q 2.5.70 **Section 14.6**: Regarding alternative reference scenarios (ARS), please provide details / explanations for the following:

- on what basis is the result, higher than 0,1 mSv/a, judged acceptable?
- Can you explain why advection leads to higher leaching of crack openings given that, on the other hand, p14-40 states that water flow through large throughgoing cracks induces slow transport inside intact matrix and only provides limited surface allowable to water leaching through cracks?
- Can you give more explanations to for us to understand the very similar results obtained, compared with the reference scenario? In particular, can you clarify the influence of the assumption that the water flux starts at the isolation phase?
- What is the basis for judging the influence of such an earthquake acceptable?

Q 2.5.71 **Section 14.8.5.3**, regarding human intrusion: "*Ingestion of water does not contribute as one year is insufficient to allow for significant leaching of radionuclides into the aquifer*". For a residence scenario where polluted soil is considered, it seems odd not to take into account ingestion of polluted water. Why don't you consider that the residence scenario starts once the aquifer is fully contaminated?

Q 2.5.72 **Section 14.8.5.4:** *"^{14}C and ^{36}Cl, which leaches from soil almost instantaneously and no longer significantly contributes to the impact after a few years"*. If these two radionuclides are no longer present in the soil, why don't they contribute to the impact due to ingestion of contaminated groundwater?

Q 2.5.73 **Section 14.9** regarding penalizing scenarios, please explain the following:

- Can you justify that the uncertainties tested in the penalising scenario cannot happen earlier than 2,000 years?
- Before 2,000 years, the disposal is considered perfectly waterproof. After 2,000 years, the containment properties of the components are no longer considered; what is the reason for choosing a date of 2,000 years, and not sooner?
- The results are provided for the "groundwater pathway" and for the "soil" pathway, separately. Why do you present these two pathways separately without considering the addition of these two human habits?

Q 2.5.74 **Section 14.7.1.1, Page 14-82**: regarding waste emplacement: "*exploring the effect of a heterogeneous distribution of activity content over the stack of monoliths*". Do you plan to fix massic activity (Bq/kg) limits per waste package in addition to those for the whole repository, in order to avoid "hot spots" within the repository?

Q 2.5.75 **Section 14-10** is not available at the present time: can you provide the margins that can be expected with respect to dose estimations for the various scenarios assessed?

Q 2.5.76 **Page 14-40:** Assumption made on water flow through large throughgoing cracks considers that transport inside intact matrix is levelled down and that only limited surface is available to water leaching through cracks. According to this principle, forcing advection may lead to reduce the amount of radionuclides transported! This mechanism, if possible, strongly depends on the ratio between advection and diffusion as initial conditions: are different situations considered to assess the influence of cracks on water regime?

2.6 Questions related to the site's geology and hydrogeology (supporting documents)

a) Questions raised by IRT Member 4 (Q2.6.1)

Q 2.6.1 **NIROND TR 2010-02E**

- **Page 41, Figure 18**: Can more details of this figure be provided?
- **Section 4.4.2.3:** Please indicate how the levels fluctuate under (or close to) the repository from the beginning of monitoring (i.e. highest and lowest levels)?
- **Page 41**: "*The Kasterlee Clay was further shown to have a sufficient thickness and sufficiently high clay content to be a hydraulic separator or aquitard between the upper* […] *and lower aquifers.* […] *Transport simulations were carried out to determine the dilution factor*". Does the dilution factor of 2.2×10^{-5} Bq/m3 per Bq/a considered in Section 14.5.3.3 come from these transport simulations mentioned in the NIROND-TR report? Does this value represent dilution in the upper aquifer (Mol and Kasterlee sands) only?
- **Section 5.6.2**: a hydrogeological model, calibrated on the water table measurements, is presented in this section. Can you indicate the highest level of the water table simulated below the repository when considering extreme infiltration conditions and briefly explain the assumptions used for such calculation?