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# DOPAS

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## Deliverable n°6.3.2

### Consensus memorandum for D4.4 Expert Elicitation

EE documentation from Expert Group EE meeting inputs and outcomes concerning Work package 4 final deliverable's Expert Elicitation

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**ABSTRACT:**

This memorandum summarises the quality assurance outcomes of the expert elicitation that was carried out for the DOPAS Work package 4 final report draft D4.4 dated 5 May 2016. This memorandum is based in addition to the discussion in the consensus meeting on 22 June 2016 on the written input by the experts including Dr. Stéphane Buschaert who was detained from participating the consensus meeting. The expert elicitation was carried out during 20 May 2016 to 10 August 2016.

**RESPONSIBLE FOR ORGANISING THE ELICITATION AND DOCUMENTING THE OUTCOME:**

Posiva Oy, Marjatta Palmu

**REVIEW AND OTHER COMMENTS:**

This memorandum was reviewed and approved by WP4 elicitation experts: Uwe Düsterloh, José-Luis Fuentes, David Luterkort, Jan-Marie Potier and Jan Prij by 5 August 2016. Experts' comments related to the consensus meeting were included into this memorandum.

The memorandum produced does not represent the views of the DOPAS consortium or those of the individual consortium organisations.

**APPROVED FOR SUBMISSION:**

by Johanna Hansen, DOPAS coordinator on 31 August 2016



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## Expert elicitation of WP4 final report D4.4 - Consensus meeting on 22 June 2016

Date Wednesday 22 June 2016 from 8:30-19:15 hrs  
Place GRS, Kurfürstendam 200, 10719 Berlin, Germany  
Meeting point at GRS reception (5th floor)

Participants: Uwe Düsterloh, TU Clausthal (Domain expert)  
José Luis Fuentes, AITEMIN (Domain expert)  
David Luterkort, SKB (PA expert) until 18 hrs  
Jan-Marie Potier (Domain expert)  
Jan Prij, NRG (PA expert) until 18 hrs  
Marjatta Palmu, Posiva Oy (EE facilitator)  
Slimane Doudou, GSL (observer, co-author of D4.4) until 18 hrs  
Dean Gentles, RWM (observer, WP4 leader)  
Stephane Buschaert, Andra (PA expert)

Prevented from participating

## 1 Introduction

### 1.1 EE - what is it?

The expert elicitation (EE) carried out in the DOPAS Project is based on the methodology developed for Posiva's Safety Case expert elicitation by Ms. Kristiina Hukki from VTT (Posiva Working Report 2008-66). This elicitation work belongs under the task T6.3 in Work package 6. The view taken in the elicitation is that the elicitation and validation process is regarded as a collaborative and cross-disciplinary whole.

The systemic character of the process sets requirements for the formal EE procedure (for expert judgment) as described in the report in detail. The procedure itself was deliberately designed to fulfil these requirements by supporting collaboration of the participating disciplines.

In general, structured performance, transparency and traceability are goals for an elicitation and validation process from the quality assurance point of view. If this process is considered from the safety case point of view as it was originally designed, the goal is to conduct the process in a way that efficiently produces valid input for safety analysis. The efficiency is dependent on the way of the participants' interact. Reaching a consensus on the validity of the input data or the common view formulated in the elicitation is desirable. A further desirable feature relates to the level of motivation and trust of individual persons participating in the process.

Thus the expert elicitation process aims at collecting and documenting the different expert's review comments related to the target of elicitation in a transparent manner using a preset framework of review comments.



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In the DOPAS Project, the objective of the expert elicitation (EE) is to be a quality assurance tool for the final deliverables of the project's RTD and DEMO Work packages WP2-WP5.

The application of this methodology for the DOPAS Project was tested in a pilot elicitation carried out during May - October 2013 on the POPLU test plan and its consensus meeting outcomes were documented as the deliverable D6.1.1 Pilot EE consensus memorandum for D3.25 POPLU test plan. The process was further applied to the WP2 deliverable D2.4 in September - November 2015 and to the WP3 and WP5 deliverables at the same time as for the WP4. This demonstration Work package WP4 is the last in the line of the DOPAS expert elicitations documented and this memorandum includes also input related to the D4.4 that has come up in the other elicitations regarding the D4.4.

The common grounds for the formal elicitation are based not only on the questionnaire tools used, but also on sharing the same descriptions about the elicitation target as a background. In the case of Work package 4 "*Appraisal of plug and seals system's function*", the descriptions used in the elicitation of D4.4 were modified by the experts of the WP3 elicitation and no further suggestions in the WP4 elicitation kick-off or consensus meetings. Unlike in the elicitation for safety case, the requirements for experts selected for the elicitation are that they are fully independent of the direct DOPAS work itself and that their backgrounds include different disciplines and professional experiences related to the work under elicitation.

The elicitation results reported in this WP4 EE Consensus Meeting memorandum present the outputs of the expert elicitation carried out on the DOPAS WP4 summary deliverable D4.4 "*WP4 Integrated report*" version 1.0, draft 6, dated 5 May 2016.

## 1.2 About DOPAS Work package 4

The DOPAS Work package 4 had the following objectives according to the project's description of work. The work in WP4 is to assess and evaluate:

- the construction methodologies and technologies for plugs and seals (WP3);
- the results of the subsequent monitoring phase and the outcome of the dismantling activities to evaluate the predictions against the actual measured performance;
- summarise the achievements made in design and the industrial scale implementation construction, in the light of the specified



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required performance of plugs and seals as defined in Work Package 2; and

- to provide a basis and direct input for performance assessment related activities carried out in (WP5).

Further, any remaining uncertainties that may need to be investigated through improvements in design, technologies of materials or modifications in the construction procedures will be addressed.

The Work package 4 has worked together with Work package 3 and the two work packages have agreed on changes in the scoping of each other's work together and thus the objectives of the work packages have been modified.

A request at the consensus meeting was made to ensure that the WP4 scoping is clearly described in the report and that no omissions (e.g. related to the test and monitoring plans) are resulting in the reporting of the WP3 - WP4 work due to these scoping changes.

The plan for Work package 4 included the production of a total of eight different deliverables including D4.4 integrated draft report version 1.0, draft 6, dated 5 May 2016. The D4.4 was scheduled for original completion at month 40 of the DOPAS project (end of 2015) and the deliverables D4.7 and D4.8 were scheduled for completion after the publication of the D4.4. Only two WP4 deliverables in addition to the D4.4 draft were available at the time of the WP4 elicitation kick-off.

- *DOPAS D4.2 Report on bentonite saturation test (REM) - draft version.*
- *DOPAS D4.3 DOMPLU experiment summary.*

In addition to the WP4 deliverables, the final version of D2.4 report and the final drafts for elicitation of D3.30 and D5.10 were also distributed as a background material to the experts together with other published deliverables from these work packages. The purpose of the background material was to ensure sufficient evidence for the experts that even though not all details are provided in the summary report D4.4, the background information is available and included in the other public deliverables of the DOPAS Project.

Additional elicitation challenges encountered were due to the following reasons:

- All three remaining Work package 3, 4 and 5 summary reports were in the elicitation process at the same time resulting in difficulty of finding common meeting dates and influencing the total work of the WP4 elicitation.
- The D4.4 *Integrated report* was originally foreseen for publication (end of December 2015) and the final draft was received on 5 May 2016. The original intention was that this





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report was providing a link from the experiments to WP5 work, which was reported in draft format already in the middle of April 2016.

- Due to the work in progress, the reports in the previous two work packages WP3 and WP4 and in some of the WP5 deliverables, the report did not have a clear referencing baseline to all of the relevant reports.
- Also the D4.4 draft report versions had a date mix-up resulting in the experts starting their elicitation work first with an earlier draft version of the D4.4 deliverable with a later date on it.
- Work package 5 assessment work and the WP4 assessments are not integrated or linked with each other - the emphasis on WP4 is on shorter term performance assessment in contrast to the aim of making predictions about the experiment behaviour or assessing the experiments or their material in long-term perspectives with the help of modelling in WP5. This missing link can attribute as one of the reasons to it that the D4.4 report's optimistic conclusions give an impression to a reader of the experiment designs have been justified and proved to be successful regarding final implementation with guarantee on long-term safety and integrity of a repository.
- Without the preceding work packages' (WP2 and WP3) summary deliverable drafts much of the justifications for conclusions in the D4.4 would have been left invisible. Especially the D3.30 deliverable draft was used by the experts as the background material. Due to delays in the POPLU experiment and due to the planned later delivery date of the FSS and EPSP summary reports, the D3.30 was the main background report available about the construction of the experiments.
- Due to a valid excuse one of the elicitation experts was not able to participate the consensus meeting. However, his input is included into the memorandum when it is in alignment with the consensus meeting outcomes.

### 1.3 Target of WP4 elicitation

The WP4 D4.4 target of elicitation was defined as:

"Is the D4.4 report complete and consistent regarding the objectives set for the work and is it "fit for use" i.e. representing an acceptable level of quality as a work package deliverable (not too much and not too little) and how well does the D4.4 achieve its task to integrate the Research and Technology Development (RTD) and Demonstration work done in DOPAS at the time of the writing of the report?"





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The elicitation's focus is to assess the completeness and (technical) performance of the constructed experiments in relation to the objectives set for them as described in the report and in the project's work plan.

In addition, the elicitation should identify potential uncertainties, ambiguities/deviations/ unjustified conclusions, and controversies in and between plug/seal experiment/s' inputs and test and technical feasibility output data and other outcomes and between the original design basis, the design itself and each experiment as implemented. This means an assessment of the alignment of the construction and test plan implementation and results with the design basis and design is expected. Further, the realised test/monitoring plan and the output data received from the plan and the interpretation or the plans for the interpretation of the results needs to be addressed as stated in the above. The reasons for deviations need to be transparently explained and an assessment made whether these could prevent the component (plug/seal) or subsystem (closure) from reaching the desired initial state or from performing according to the expectations (in the repository). Further the elicitation aims to look at

- the practical application and feasibility of the implemented technical design of the experiments as described in WP3 and as summarized in D4.4 and complemented with the experiment specific reports under WP4;
- contrasting the achieved performance results of the experiments vis á vis the original requirements and objectives set for them (the soundness of the compliance evaluation);
- the construction solutions' feasibility, including available dismantling results and lessons learned related to the desired performance of the experiments; and
- the appropriateness of the report's integration of the tasks carried out, its conclusions and suggestions for use of the results from the above; and the lessons learned from the experiences related to desired outcomes, the capability of the plug/seal to reach their technical performance and desired/expected initial state.

The assessment is carried out in respect to the original objectives, to the report content and to experts' previous experiences."

## 1.4 The steps in the elicitation process

The generic process for the expert elicitation as defined in Hukki (2008) included the following steps:

- Selection of issue (generally something not easily agreed, but requiring judgment and consensus)
- Selection of forum
- Selection of domain experts (probabilistic SA)



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- Selection of shared conceptual frameworks (description production)
- Preparatory work of safety analysts
- Training of domain experts
- Instruction of domain experts
- Independent work of domain experts
- Iterations (consensus meeting)
- Treatment of possible controversies (consensus meeting)
- Validation of expert judgments for later use
- Final documentation of the process (facilitator)

In the DOPAS elicitation process that does not require for example the use of probabilistic safety assessment, some steps have been omitted from the preparatory stage of the elicitation and both performance assessment and domain experts meet simultaneously at the same kick-off forum. If the elicitation process is applied in the original context of WR 2008-66, these steps should be maintained as a part of the process.

## 1.5 Participants and timetable of the process

The experts who participated in the expert elicitation were selected by the consortium from experts inside the participating organisations and from external experts. The European Commission representative screened the produced short list, the relevant experts were recruited, and their final number was based on their availability to participate in the elicitation within the agreed timeframe ranging from May 2016 to July 2016. Main extension to the timetable after the process start resulted from the difficulty of finding a common date for the consensus meeting. The kick-off meeting was held on 27 May 2016, the experts' review results were produced by June 13, 2016 and the consensus meeting was held on 22 June 2016 with the draft minutes out on 23 July 2016 for commenting and approval in a week.

The experts consisted of the following professionals in geological disposal:

**Mr. Jan-Marie Potier**, M.Sc., Domain expert being the expert that has participated in all of the WP6 elicitations for overall consistency of the process and its results. Mr. Potier has worked a long career in both underground mining industry and geological disposal at Andra, the French waste management agency. Since his retirement in 2009 from the position of IAEA's Head of Waste Management Section, he continues to be an active technical expert working on temporary assignments for the IAEA.

**Dr. Stephane Buschaert**, Performance Assessment/Safety Assessment Expert has worked at Andra, the French waste management organisation



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for over 20 years since his graduation as hydro-geochemist. Dr. Buschaert has a Doctorate in geosciences. He is the head of Andra's Environmental Survey and Disposal Monitoring Department since 2010 and has worked with the R&D activities related to monitoring strategies and development of monitoring, related instrumentation and analysis of the results in the Cigéo project. Dr. Buschaert provided his input to the process and this was included into the discussions at the consensus meeting, but due to unforeseen reasons he himself was detained from participating the meeting itself. He was not able to review this memorandum either.

**apl. Prof. Dr. Ing. Uwe Düsterloh**, Domain Expert, works as a professor at the Clausthal Technical University in waste disposal and geomechanics. Prof. Düsterloh graduated from Clausthal in mining in 1988 and was awarded his Doctorate in 2010 from geotechnical safety assessment of underground structures in salt mass. His special expertise is in salt related rock mechanics and related numerical calculations.

**Dr. José Luis Fuentes Cantillana**, Domain Expert, works as a Director for AITEMIN the Spanish company specialised in technologies for mining and tunnelling. Dr Fuentes has a Doctorate in mining engineering and has worked at AITEMIN since 1982. He has worked with radioactive waste management tens of years in several projects including with the plugs of the FEBEX and other experiments.

**Mr. David Luterkort**, M.Sc., Performance Assessment/Safety Assessment Expert, manager for development of geotechnical barriers, works at SKB, the Swedish waste management organisation since 2004. He works currently with R&D considering system design of buffer and backfill. Mr. Luterkort has a Master of Science in Mining and Civil engineering and has worked at the Swedish Geotechnical Institute and Clay technology since the 1990s specialised with R&D related to the clay barriers in geological disposal.

**Dr. ing. Jan Prij**, Performance Assessment/ Safety Assessment Expert, he works as a part time expert for NRG/ECN in Holland, from where he retired in 2009. Dr. Prij has a Doctorate in mechanical engineering and he has worked since the end of 1960s with the performance and safety assessment of nuclear and radioactive waste repositories including recent work done for the Asse experiments and performance assessment work for the Dutch nuclear waste management programme.

## 2 Agenda of the consensus meeting

The agenda of the consensus meeting was the following after it was modified somewhat during the meeting:





1. Opening, overall view and recap of the objectives of the WP4 EE process
  2. Introduction to the descriptions, safety envelope, and to context of the ELSA project and the scope of "ELSA" in DOPAS Project
  3. Discussions, general findings and improvement suggestions to the WP4 D4.4 and the way forward
    - 3.1 General findings and their handling
    - 3.2 Deliverable structure and content improvements
    - 3.3 Monitoring strategy and test plans
    - 3.4 Conclusions and other findings
  4. Timing of approval of consensus meeting memorandum
  5. EE process - experts' experiences from the process and feedback
  6. Technology readiness assessment - preliminary findings
- Closing

### 3 Inputs to the elicitation process - Summary of the experts inputs by quantity and type

The WP4 expert elicitation meeting's inputs were based on the replies of the different experts on the expert elicitation questionnaires. The questionnaire forms are attached as Appendices 1 and 2.

The replies on the questionnaires were compiled by the facilitator and they formed the basis of the discussion points 3 and 6 on the consensus meeting agenda.

As a result a total of around 430 comments were received from the six experts. Out of the total comments, around 180 included recommendations for complementing, correcting or otherwise improving the D4.4 reporting. Several of the experts' comments were overlapping.

Main comments requiring additions or modifications to the report D4.4 addressed the referencing (to e.g. safety functions); the descriptions of monitoring strategies and details of monitoring plans and their justifications as a basis for evaluating their performance; the structure and content of the "ELSA" Chapter 8; need to discuss the interface between the rock and plug and related grouting; and the detailed specifications of the technical readiness of the designs on which the report conclusions are made. These last specifications are needed to avoid giving a too progressive overview of the technological readiness of the plugs and seals designs used in the DOPAS experiments for the reader of the conclusions.

The themes and nature of the comments varied as summarized in the following table:

Types of inputs	Number of comments	Additional information and the handling of comments
Overall general	431 (184)	The overall general comments stated that the



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Types of inputs	Number of comments	Additional information and the handling of comments
findings (and total number of improvements)		report is consistent and well structured and without major weaknesses. The findings include both favourable and improvement comments about the report and its interfaces with the related work packages to ensure that there are no major gaps between the different work packages and that the conclusions give a realistic view of the state-of-the-art achieved. These recommendations will be included into the text D4.4 into a relevant chapter of this report. A part of these general findings will be used in the final project summary report D6.4, too, with the referencing to their original source when applicable.
Controversial findings between experts	1	No controversial findings resulted from the experts' inputs except concerning the Technology Readiness Level assessment. This topic was not discussed with all experts in the meeting as it was left as the last item and part of the experts had to leave the meeting earlier. The underlying assumption to the different views is that most likely the interpretation of the TRL scales (DOE and EC scales) in the assessment differs. Discussed in subchapter 5.1 and Appendix 6.
Omissions from the D4.4 report	5	Monitoring and test plan design work are not included in the reporting. How can the performance of the monitoring be evaluated, if the plans on which the evaluation is based are not available or referenced to. The monitoring plans cannot be compared either between the different experiments as their justifications and details are not known. ELSA description gives a partial picture only of the context and of the work done (see also structure of Chapter 8). The description of the division of work between WP4 and WP5 is not visible. Clarity about the scope of the work done in WP4 (and also in WP5) to be given. Referencing in detail. Including the link between the experiments and their long-



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Types of inputs	Number of comments	Additional information and the handling of comments
		<p>term safety requirements in their respective stage in the design basis development process (see D2.4 workflow). Some grouting recipes are missing and discussion about the importance of the rock and plug interface for the plugs meeting their functions is needed.</p>
<p>Improvement recommendations for D4.4 from the general findings and from the recap in the consensus meeting. These are broken down by themes in below:</p>		<p>The general findings include improvements that are intended to be put into the report. The chapter specifics are detailed in subchapter 4.2 of this memorandum. The other findings are summarized in section 4.1.2 and addressed in detail under subchapter 4.3. The additions also highlight the need to complement the gap between the WP3-WP4 work in terms of the monitoring and test plans and linking the WP4 PA with the WP5 PA. Recommendations to edit and correct some factual errors are included.</p>
<p>Report structure findings</p>		<p>The scope and objectives of WP4 and the related revisions done including the information about where these are addressed in the DOPAS Project reporting needs to be clarified. The D4.4 chapter 8 ("ELSA") in the report requires revision. Adding the missing monitoring related information to the report is needed or it requires proper referencing to sources containing the sufficient information as indicated in the general findings and in the section 4.2.8 of this memorandum.</p>
<p>Monitoring and test plan information</p>		<p>Monitoring strategy, details of the instrumentation related improvements to the D4.4 are included in section 4.3.1.</p>
<p>Content related findings</p>		<p>The information coverage in D4.4 regarding the experiment implementation is a challenge. There is a recommendation to include also a summary of this information to the D4.4 from the WP2 and WP3 work. A balancing between additional texts and referencing needs to be reached regarding the report D4.4 where the scope has already been</p>





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Types of inputs	Number of comments	Additional information and the handling of comments
		<p>extended in respect to the original work plan.</p> <p>Monitoring related reporting to be complemented (see above).</p> <p>A table containing the measurement results of the laboratory tests covering the behaviour of materials on the ELSA tests LASA, LAVA and THM-Ton in a similar ways as for the other experiments should be included into the D4.4.</p> <p>The quality management and assurance process regarding data collection for performance assessment is not visible in the report. A recommendation is made to address the quality management issues in a separate chapter in D4.4.</p> <p>Links to initial calculations and predictive modelling to be included into the experiment specific chapters.</p> <p>The interface between rock and plug and grouting related challenges were highlighted.</p> <p>D4.4 referencing to the other DOPAS deliverables requires more details (see 4.2 and the subsections).</p>
Experiments specific findings:		T = total comments, I = improvements
FSS experiment specific	T =48, I = 32	Improvement comments are included into the section 4.2.4 of memorandum (D4.4 Chapter 4).
EPSP experiment specific	T =32, I =18	Improvement comments are included into the section 4.2.5 of memorandum (D4.4 Chapter 5).
DOMPLU experiment specific	T = 30, I = 13	Improvement comments are included into the section 4.2.6 of memorandum (D4.4 Chapter 6).
POPLU experiment specific	T = 27, I = 16	Improvement comments are included into the section 4.2.7 of memorandum (D4.4 Chapter 7).
ELSA experiment specific	T = 34 I = 24	Improvement comments are included into the section 4.2.8 of memorandum (D4.4 Chapter 8).
Lessons learned, conclusions and future use of the		The experts agreed with the report conclusion to the degree that covers the work that has been carried out. The work





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<b>Types of inputs</b>	<b>Number of comments</b>	<b>Additional information and the handling of comments</b>
results		has contributed to knowledge and competence. However, since all of the plugs had leakage, the conclusions, that give an impression that that plug/seal design issue is solved, are too progressive. The discussion related to the interface of the rock and plug can potentially be also addressed in this section of the D4.4 report. The Chapter 10 covers well the future need for work to validate the plug and seal safety functions.
Referencing		Unclear referencing related to D2.4 and D3.30 (White & al. 2016 used for both ) Impossible to distinguish to which report the reference is made - use referencing as instructed by the coordinator and clarify the reference list in this respect. Generally, the references need to be more specific, not just to the report but more in detail to where in the referenced report.
Terminology and glossary		Reference to IAEA glossary (2007) is needed as agreed. Refer to it in Chapter. 1.4 of D4.4. Checking consistency with IAEA glossary about performance assessment and clarify the short-term/long-term differences including the definitions for "short-term" in the various contexts is needed.
Resolution of figures		Improved resolution required for figures 4.7 (upper part), 4.11, 4.15 (left side) and potentially figure 7.5.
Parameters and units		Use consistency in parameter units used throughout the report (see Appendix to IAEA 2007 glossary).
Factual corrections and editing comments	various minor comments	These are mentioned as a separate section 4.3.7 in this memorandum and also provided separately to the authors.



## **4 Main comments and outcome of their handling as input to D4.4 final draft for EE**

### **4.1 Overall evaluation of the content of the report - "Fitness for use" of the report**

#### 4.1.1 Overall findings and conclusions

The D4.4 report was seen as consistent and well structured facilitating comparison between the approaches, methodologies, results and findings between the different experiments (FSS; EPSP, DOMPLU and POPLU). No major weaknesses as such were detected.

The generic process is well schematized by the "DOPAS Design Basis Workflow" (D4.4, p.16). One of the main benefits of the systematic and rigorous method used by the DOPAS project partners to implement their design is facilitates the tracking work by external reviewers and licensing bodies also in the future.

The experts concluded that it appears that the material provided in the D4.4 deliverable fulfils the general objectives assigned to WP4 with few exceptions related to the scoping changes made to the Work package 4.

The structure and the organisation of the report are concise and the conclusions are traceable. The analysis is sound and flow of inputs visible for FSS, EPSP, DOMPLU and POPLU.

This and the WP2 and WP3 Work package summary reports have benefitted from the use of the same editor for the reporting. The same structure has made the comparison of the information related to the different experiments easier for the reader.

The designs and materials are suitable considering the different levels of maturity in the different repository programs. The performed work has created competence in carrying out the iterative process by having contributed greatly to the general mass of knowledge on design, construction, and testing of plugs and seals in full-scale in various environments, including repository environment.

The major question mark relates to the division of work between WP4 and WP3 related to the description of the justifications and details for the monitoring strategies and instrumentation plans. This is neither found in D4.4 nor in D3.30.

Including a summary of what is the main content of all the work package summary reports is a way to clarify explicitly the division of work between the different work packages which is currently not fully in alignment with the work package objective(s). This content explanation fits into the D4.4 Chapter 1.3. Alternatively this division of work can be clarified by giving a summary can about the WP3, WP4, and WP5 work done under these individual work packages.



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Sufficiency of information without unnecessary duplication in all three reports D3.30, D4.4 and D5.10 can be balanced by using appropriate referencing to each other's content, however some improvement recommendations to include text for transparency are made, too.

One of practical reporting problems that became evident in the report is the difficulty to integrate the German work with the rest of the experiments (for instance no direct references to the German work are included in D4.4 Chapter 10). As an individual experiment description, the ELSA experimental work carried out in the DOPAS Project requires clarification and the recommendations are included in the section 4.2.8.

Work package 4 integrated report D4.4 provides a good structure for reporting the conclusions, lessons learned and addressing the future work that can benefit from the work carried out in DOPAS Project. This structure can be used as benchmarking example for the same information in the other reports, too.

The experiments give useful results for adaptation and rethinking about the reference design and the conclusions on this point are well justified. The experts agree that prior to the determination of final repository site and a final repository configuration specific demands to plugs and seals are not determined, this iterative process is defined in the D2.4 workflow including a systematic approach to be used in moving from one step to the next in the future development work.

Important attention by the experts was however placed on the progressive nature conclusions of the D4.4 report to avoid giving conclusions that downplay the need for future proof of the designs taking into account that leakage was detected in all of the three crystalline rock plugs. Thus the formulation of the conclusions about meeting the reference designs need to be changed towards a more realistic direction with future work still ahead also for the plug/seal designs for their proof of safety. This can be clarified by explicit statements about the maturity of the design (conceptual, basic/experimental design), whose performance in the short-term has been assessed. It is also recognized that the work in WP4 also helps in establishing the leakage criteria for the plugs, where the requirements have not yet been established at detailed requirement or specification level.

One major challenge identified by the experts related to grouting. The grouting does not necessarily provide the solution to tackle with the concrete - rock interface, which is an important contact point in the plug and also requires modelling, currently not done in the DOPAS work. This issue was confirmed also by the experts of the WP5 elicitation. Grouting recipes are not included into the material descriptions of the DOPAS summary reporting either. It was also noted by the experts that



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the test period for the experiments was too short to give evidence of the tightness of the plug or seal itself.

The future development needs in connection with the national R&D programmes are a welcome content to be stated in the way forward of the D4.4 report as the DOPAS Project addresses only a small part of the closure related development and demonstration work. Giving the work carried out in perspective of the national requirements and with the process of building a safety case would be very useful (to be included in D6.4?).

#### 4.1.2 Summary of main needs to complement the report D4.4

This section summarizes the main improvement needs of the D4.4 report. Details of the corrections needs are explained in the sections 4.2. and 4.3

- Clarify the scope of the Work package 4 and explain the impact of the scope change to the DOPAS reporting including where the information can be found. E.g. the link of WP4 to WP5;
- In general it was not easy to track the references to the coupling between safety functions and the specifications. Also links to the initial calculations or predictive modelling for the experiments was seen essential.
- Explain the monitoring strategy/strategies and the details related to the developed test and monitoring plans, parameters for monitoring and input data, and their justifications for e.g. types, numbers and locations of the sensors and other monitoring instruments used in collecting the performance data as this information is missing from the D4.4 report and previous work package summary reports;
- The information documented in WP4 is not transparent and traceable without the knowledge provided in WP2/WP3 reports describing the safety functions, requirements, design, material selection, construction, testing technique, testing evaluation, and testing results. The report is intended to be a concise summary at the same time, so there is a balancing requirement regarding adding complementary information. Detailed referencing needs to be improved. However no uncertainties or omissions in the use of the other work packages' information was detected;
- Revise the D4.4 Chapter 8 structure clarifying the underlying experiments and sealing elements that are modelled in ELSA (as part of DOPAS project) i.e. give the context and revise the chapter structure (see also subchapter 4.3 and Appendix 7). Add a compilation table about the "ELSA" test results in alignment with the tables presented for the other experiments;



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- The interface of the concrete of the plug and the rock in crystalline host rock environment needs sufficient discussion in the assessment. This is linked with the difficulties related to grouting the gap and also to the lack of information about the grouting recipes.
- Information about concrete material available only in DOMPLU reporting part of D4.4. The relevant information is available in D3.30 report. Proper referencing about materials needs to be included into the D4.4 report.
- The acceptance criteria (regarding their safety or other function) against which the experiments and their performance are assessed are not fully clear. The comparison for the compliance assessment is made mainly against a set of selected key design specifications i.e. experimental design requirements and specifications derived from D3.30 after a screening process, which is not transparent or referenced in D4.4.
- The conclusions (especially Ch. 10.2) about the compliance of the designs are progressive and the state-of-the-art of the designs found compliant (experimental designs) needs to be clarified as more work is required for the proof of the even most reference designs.
- Further referencing and cross-referencing in the D4.4 to the other work packages final and supporting reports with traceable and detailed level for easy tracking of information.
- Key terminology to be complemented (time frames, assessment periods) and the IAEA glossary reference is needed.

The more detailed improvements and future applicability of the results that the experts recommend to be included into the D4.4 report are included in the subchapters 4.2 and 4.3. A part of the improvements is grouped under the relevant chapter of the D4.4 report in 4.2.

## 4.2 Chapter specific improvements to the report content

The D4.4 is intended to be an integrated RD&D report presenting compiled results of a research and development project. It does not fulfil the requirements of a research report in respect to the full reporting coverage of results and regarding traceability of information used.

### 4.2.1 Chapter 1

This introductory chapter needs to state also the mutual links of these Work packages. The text about the links needs to be in all of the summary reports: D4.4, D3.30 and D5.10.

The Work package 3 addresses the experiments until the start of their monitoring and pressurisation. The test plan development and details



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belong to the Work package 4 resulting from the scoping changes agreed between the two work packages. Simultaneously, the WP4 included more scope to the reported content of the D4.4 deliverable. This was the main cause resulting in a later delivery of the report than originally planned.

D5.10 contributes to long-term performance assessment and all short-term<sup>1</sup> (until initial state) performance assessment information is included into the Work package 4 reporting deals with the performance assessment of the experiments against their safety functions and requirements and their technical results in the short term.

It is better to separate Chapter 8 from the Chapters 4-7 to avoid giving a misleading introduction already in the D4.4 Chapter 1.5 describing the report chapter contents. Likewise what is stated about "ELSA" on page 6 as being a summary "in-situ" test is somewhat misleading.

#### 4.2.2 Chapter 2

The report gives an overview and history of sealing designs (in Chapter 2), but there is no factual state-of-the-art in geological disposal or referencing to it is included prior the DOPAS Project. It would be good to include complementing Chapter 2 by describing the state of the art information including references in the field of geological disposal about R&D carried-out about plugs and seals behaviour and technical feasibility.

The geological repository specific safety functions could alternatively be described in this chapter or in the following Chapter 3 in general terms and in more detail in the relevant chapters as done e.g. in the case of DOMPLU (section 6.1.1). Without the description of or referencing to the safety functions, the section 9.2.1 is not well grounded. It is also important in the repository and experiment context to differentiate between safety functions and other functions the plugs and seals serve.

#### 4.2.3 Chapter 3

A systematic approach seems to be underlying the D4.4 evaluation, but the used methodology is not well presented and synthesized in D4.4 (chapter 3.5?).

Chapter 3 starts without addressing the safety functions of the plugs and seals. It was concluded during the project that the safety functions or functions for the plugs and seals are similar. They need to bear the full load (mechanical integrity) to which they are subjected to and they need to limit hydraulic flow (limits not defined). Depending whether the plugs need to fulfil these functions in support of the safety function of another

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<sup>1</sup> note that the different definitions of short-term derived from the individual assessment periods of the different repository concepts is needed, too.





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sealing component like the backfill in the KBS-3V concept or whether they themselves are assigned a safety function, the assessment period (for safety) is different and also their life time as a result, too. The meaning of short-term time and long-term time frames are different depending on the national requirements on the disposal concept.

This link to (generic) safety functions and other requirements of the plugs and seals in geological disposal can be alternatively addressed in Chapter 2. In Chapter 3.1 the requirements capture or translate the assigned safety functions for the design basis in a hierarchical manner, but are complemented with other requirements derived from the plugs/seals other functions or other stakeholders. A design made in compliance with the design basis and with the lower level specifications derived from the design basis is thus expected to function so that the safety functions are met.

In general it was not easy to track the references to the coupling between safety functions and specifications. This is in many cases a complex task. Hence it is important to have clear references to the work, data, argumentation where the specifications have been set (detailed referencing to WP2 and WP3 work done in DOPAS Project).

#### 4.2.4 Chapter 4 FSS in D4.4

The FSS test has been carried out in a consistent manner, the plug can be constructed according to the physical specification and the results give a qualitative indication that the seal will function. It has not been shown that the same constructional methods can be applied in a real repository. Several constraints and uncertainties (work safety, and liner removal and the consequences from the removal to the surrounding rock) related to the underground construction are mentioned e.g. in the WP3 elicitation that need to be addressed in the future. It also remains unsure whether the safety function will be met by meeting criteria given. The results however can be used in planning the underground full-scale in-situ test that is required by the regulator in the future.

The documentation of the FSS production process was stated as the most important part of the experiment. Photographs as part of the documentation were seen as an important means of conveying the information also to the future user of the results. This applies to all of the DOPAS experiments.

The main difference in the target dry density for the emplaced bentonite, which in the design basis is  $1.62 \text{ g/cm}^3$  and in the experiment it was set to  $1.5 \text{ g/cm}^3$ . In some parts of the report it is said that this density should be enough to achieve the safety functions in terms of swelling pressure (min. 5 MPa), however later results (D4.4 last paragraph section 4.7.2) have shown that the swelling pressure at this dry density could be only





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3.88 MPa when saturated with the argillite formation water. This is an important design modification made that should be cleared up, as it could invalidate the conclusions obtained about the bentonite seal emplacement method. For that reason the values from the REM experiment and the references are needed to be included into this report. Thus the dry density after emplacement is the main uncertainty related to the performance of the seal. Uncertainties are identified also in terms of the methods for defining the dry density. The main concern in argillite is the chemical composition of the groundwater reducing/modifying the swelling pressure of bentonite. In a similar way the change of the mechanical loading requirement from 7 MPa to 5 MPa requires justification or referencing in detail for traceability. Other similar referencing needs are identified in also the other experiment texts in the D4.4.

Concerning the material choices, they are well described except the shotcrete recipe has not been clearly justified and future development needs for it are foreseen. A discussion about the differences between the FSS and EPSP shotcrete could be useful due to the differences in their properties. The EPSP shotclaying technique could also prove to be useful in the French context (see next section 4.2.5).

The level of detail regarding the instrumentation varies in the compliance approach table. Regarding the instrumentation and monitoring, it seems that some parts of the reporting are not clear on what is included in the FSS monitoring as the question came up about the pressurisation or actually the lack of it in the FSS monitoring discussion. It was noted that pressurisation was not planned for this construction feasibility mock-up. A check on the report text, why such a misunderstanding could arise when reading the text is required.

Uncertainties related to the experiments, the input data from them for performance assessment and in the performance assessment itself are not addressed in D4.4.

Further points to be addressed in or added into the D4.4 chapter about the FSS experiment are:

- Justification why not all requirements are not presented (selection of key design specifications);
- The level of specifications for "compliance approach" given in table 4.1 of D4.4 vary in detail, for some lines a specific sensor is given (e.g. TDR on page 24) and for other just the parameter (e.g. strain on p. 22) and not the measurement instrument. This type of information requires consistency in the tables.
- Dismantling (on page 25) is mentioned, a reference to the dismantling results is required (in detail).
- Need to include some more information (on page 26) about the FSS construction without needing to visit the D3.30 report;



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- Include the number/location of the sections stated in tables 4.2 and 4.3 onto the figure 4.3. Also explain why the information in section 3 is not available (no date or no sensor?)
- Complement the legend of Figure 4.5 on page 30 to include an explanation of the meaning of the legend (DFO - for deformation and TEM for temperature). Check other figures legends, too.
- Resolutions of figure 4.7 to be improved;
- Figure 4.9 (page 35) - what test is meant with "metric emplacement test" - is it just a calibration aid or some relevant test, please explain or edit text.
- Figure 4.11 (page 36), improve resolution of text.
- Sections 4.4.1 and 4.4.2 need improvement as the results are difficult to follow. The other requirements verification is not detailed (like for pH in Table 4.1).
- The technology maturity: e.g. on page 37 and in other chapters (e.g. 5.6), too. Technology maturity is not estimated except by "not mature". Some of the used techniques are laboratory level techniques. What is the survival rate of the sensors (e.g. after installation and after x months of monitoring)?
- Section 4.6 does not quantify the adequacy of monitoring strategy, tools or technology.
- No quantitative data about the cracks (on page 39) is given. Requires addition.
- The changes in/adaptation of the next experimental design basis need to be included. The design (as the text in section 4.8 may lead to conclude) is not the final design or final methods for construction. There has already been a density requirement adaptation during the construction of the FSS.

The main objective of the instrumentation system has been to monitor the parameters that are critical during the plug construction phase, and to assess the final quality of the built components. The measuring methods are based on previous experiences on this field, but also on current practice in civil engineering. See comments related to monitoring later in this memorandum.

The experience on industrial construction of SCC retaining wall and the bentonite core seal is valid for other repositories especially in clay, although there are also other experiences in these fields. The trials made for shaft seals, but some of the design and methods applied could be applicable for ramp sealing. Shotcreting issues are still partly to be developed. A method for filling the upper gap must also be developed; in this respect shotclay is promising but requires further testing.

Although it is probably beyond the scope of the project, some information explaining the reasons for the differences in the temperature



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limits for concrete in the different experiments would be very convenient for a reader (this is done in D3.30, so please reference).

Documenting the FSS production process is the most important part of the experiment and can be used also other applications.

#### 4.2.5 Chapter 5 EPSP in D4.4

Include into the introduction of the chapter, that the EPSP experiment is at the Conceptual Design Basis stage (of the D2.4 workflow) targeting to develop the more detailed requirements for their future reference plugs or seals and its objectives and the use of materials therefore differs from the FSS, DOMPLU and POPLU. The selection of materials for use in the experiment is also influenced by the national strategy.

The reason for constructing the plug using shotcrete is not traceable in the report. A comparison between the EPSP shotcrete and FSS shotcrete and the used criteria is of interest. E.g. why is there a 10 degree temperature difference in the setting of the two shotcretes.

The experiment has addressed the basic aspects and objective assigned to it as a basis for future development work for developing a reference design for the Czech geological disposal programme. The conclusions (section 5.8 in D4.4) and lessons learned would in this respect add information and emphasize also what was learned in terms of developing the preliminary design requirements in the Czech experiment for the future tunnel plug.

It was also noted that the shotclay technology might be of future interest for development and testing especially for filling in the upper part of the plug/seal (e.g. for the French seal, taking into account the dust in the underground environment). Information about the dry density achieved with the shotclay technology is missing and should be added to the report. This is needed for assessing the usefulness of the method.

Section 5.2.2 or the Section 5.6 needs an addition about the design of the test plan and its justifications (or detailed referencing to the experiment summary report for the rationale of the selected 10 parameters) like the other experiment chapters on FSS, DOMPLU and POPLU. The evaluation of the monitoring system and its outcomes are not justified (or references), since the baseline or approval criteria for the outcome parameters for the evaluation are not given. Despite of this, the system was found to be suitable for checking the first of all material behaviour and second, the experiment design.

It is unclear from where the used shotcrete samples originate (measured in parallel, but not from the plug?). The constraints related to the use of the experiment materials in the repository are not addressed in the reporting, but can be found in D3.30 report (reference). The pressurization data was not available by the time of the reporting and the



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experts express their doubt about the representativeness of the pressure applied to the plug (this additional uncertainty should be addressed in the D4.4 report).

A construction related uncertainty is seen in the scale of the experiment as the EPSP plug is smaller than a foreseen future plug and the larger size is likely to influence the emplacement and emplacement techniques of the plug. The possibility to repair a leaking plug is one uncertainty. It is important to make it explicit that the rock conditions for the plug construction have not been selected according to criteria required for a repository plug and most likely the rock conditions in an actual repository may never be of such a poor quality.

In respect to the lessons learned about the EPSP, it is important to make sure that the supporting information can be found in the background reports and is referenced in detail in D4.4.

Chapter 5.6 gives a comprehensive review of the monitoring system and concludes that the monitoring system has caused leakages, but they have been manageable.

The permeability of the shotcrete has apparently been measured in parallel tests and it is not clear from where the samples came from, from a parallel samples or from actual plug. The question of the representativeness and related uncertainty of the samples is raised.

The chapter is judge very clear and complete and the amount of illustrative results and diagrams are much appreciated like the table 5.2.

Two details noted: on page 49 section 0 is different compared with section 5.6 in the bullet list. Reference is made to "2012 study", but this is not to be found in the reference list. A figure of instrumentation plan is necessary

#### 4.2.6 Chapter 6 DOMPLU in D4.4

The safety functions are addressed in the chapter (section 6.1.1 can serve as a model for the other experiment chapters, too).

Monitoring of the DOMPLU plug was the major task by SKB in the DOPAS project. The compliance assessment in 6.1.3 is unclear in terms of the lack of referencing to quantified acceptance criteria or to the monitoring strategy and expected monitoring results of the plug. This information is mainly available in the other DOPAS reporting, only referencing to it is pending.

It was stated in the requirements for both the DOMPLU and POPLU plug that the plugs need to limit hydraulic flow. However no quantifiable value for the accepted flow was given and the experiments were seen as a way of quantifying the acceptable flow. A discussion related to this is



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expected in the conclusions, e.g. the need of future work for determining this criterion or requirement.

The requirements of the design basis are perfectly identified and well explained in Table 6.1.

The main modification compared with the reference design is that the concrete is not steel reinforced; however the reference design is being revised on this aspect. Also some modifications have been introduced in the materials used to build the filter and the delimiters between the different plug components. These modifications do not affect the basic functions of the plug and are well explained and justified in the report. A future decision on the reference design will be taken.

An explanation for the reasons why it is convenient that the concrete releases from the rock during the construction phase is helpful (see also the discussion on rock - plug interface and grouting issues). Also the grout recipe is not included (potentially due to work done outside DOPAS project).

The instrumentation plan is sound and well justified. The monitored parameters have enabled to observe all the key aspects of the plug construction and behaviour (more details in D3.30). D4.4 does not give any results on the statistical evaluation of the measured data on the sensors for reliability assessment.

No specific approval criteria are given for the outcome parameters, and the related uncertainty is not mentioned in the report.

This experiment benefits from previous experiences with the same plug design and the construction methods are well known. As the bentonite seal could not reach saturation, it was not possible to test the hydraulic sealing function of the plug. However this is a very well known process and therefore has low risk. A continuation of the experiment until reaching full saturation would be interesting. The potential long term chemical effects of the grouting could be an issue, depending on the formulation finally applied.

D4.4 gives a comprehensive overview of the lessons learned from DOMPLU. Learning from the water collection system is of value.

DOMPLU and POPLU experiments have obviously a large potential for integration, due to the similarity of the repository conditions and input data. The POPLU results could have an influence on the plug design for both concepts. Also the grouting issue is a common problem in both cases, and would benefit from a closer collaboration.

Parts of DOMPLU experiment work have been performed outside the scope of DOPAS. However, it is summarized in a comprehensive way in the D4.4.



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#### 4.2.7 Chapter 7 POPLU in D4.4

POPLU Section 7.6 needs an addition about the design of the test plan and its justifications (or detailed referencing to the experiment summary report on this topic). The evaluation of the monitoring system is not justified, if a baseline for the evaluation is not given. The information is available in the other DOPAS Project reports. No specific approval criteria are given for the outcome parameters, and the related uncertainty is not mentioned in the report.

Predictive modelling for POPLU design is not evaluated or compared with the actual results.

Again the grouting issue seems not to be fully stable. The results show that the formulation applied was not good enough, and requires a revision.

The pressurisation phase has lasted only a few weeks. Although it is said that the final version of the report will include additional information, perhaps the experiment time plan could have been optimized to tackle the time constraint.

D4.4 concludes that the plug will meet the safety function, which is of a qualitative nature. This is not accurate. The plug does not have a safety function.

The results in Table 7.4 raise the question about the POPLU feedback to the reference design, which would also influence DOMPLU design basis.

Add word "Slot" to the title on the excavation method to differentiate from the tunnel excavation works.

D4.4 summary of the lessons learned from the POPLU experiment is excellent.

#### 4.2.8 Context of the "ELSA" and Chapter 8 in D4.4

All of the experimental work done belongs to the conceptual design phase of the shaft sealing concept as described in the D2.4 Design basis development workflow. The objective of these experimental activities is to come up with the preliminary design requirements for the following stage/phase of the German ELSA project's phase 3. In the shaft sealing concept, the assessment period for the "short term" sealing elements is 50000 years and for the long-term sealing element over one million years. Thus, check the appropriateness of the chapter title and remove the word "reference" from the chapter text. The shaft sealing concept is still a conceptual design stage with no "reference design" status e.g. in Fig. 8.1 and similarly referring to German strategy is too broad a generalisation. The expert view is that using a semi-probabilistic,





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reliability orientated concept in some cases in the German work does not manifest to be the German strategy.

Chapter 8 is very different chapter compared to the previous experiment chapters. It seems to be based on an upstream/ theoretical / calculated approach and thus "ELSA" does not provide "real scale" experimental data.

The overall structure of the work done in DOPAS under "ELSA" title and the text in the Chapter 8 requires revision and clarification for the reader and the experts noted that the "ELSA" work description in Chapter 8 of the D4.4 requires a revision.

The headlines using verbalism "ELSA in-situ experiments" are perplexing because there is no full scale experiment within ELSA or its subprojects LAVA, LASA or THM-Ton at now. Results regarding mock-up tests performed within ELSA have been documented in D3.30, but not considered within D4.4 (no reference in D4.4). To get a clear and transparent impression about the more theoretically respectively conceptual based design of the German shaft sealing (concept!) it is recommended, to point out whether or not the mock-up tests described in D3.30 are part of DOPAS project respectively used as input data to justify the actual proposed shaft design.

Similar to the compilation of measurement results taken from the FSS, ESPS, DOMPLU and POPLU experiments, a compilation of the laboratory test regarding creep behaviour, strength, permeability, e.g. should be integrated into D4.4.

As mentioned in the report indirectly and stated by the experts, the work done in DOPAS under the title "ELSA" is part of the German ELSA project's phase/stage 2 that is to be followed by the full-scale experiment. The "ELSA" work in DOPAS addresses mainly the three "short-term" sealing elements. The LAVA, LASA and THM-Ton subprojects in laboratory scale address these three sealing elements. In addition compaction tests for the long-term sealing element were carried out in-situ as mock-up tests (see also Appendix 7 including a draft clarification of the ELSA work that resulted from the WP5 elicitation consensus meeting).

The shaft sealing elements of the current concept are described in Figure 8.1 in D4.4. A clarifying description can be attached to this figure context. The conceptual models used in ELSA to assess the functionality of the shaft seal are of a theoretical nature. It has been shown that the shaft seal will function theoretically. It has not been verified experimentally that a real shaft will also function well. The material presented in D4.4 on the experiments performed is not enough to give a good answer on this question.





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In case of ELSA including LAVA, LASA, THM-Ton it is recommended to add some information given in D3.30 regarding the used testing equipment, testing techniques and compilation of test results to the chapter 8 of the D4.4 report. The laboratory derived results including the link with the theoretical work is missed in D4.4.

The lessons learned for the preliminary design requirements from the DOPAS "ELSA" work included:

- Improvements to sealing element's compaction in the current design have been developed by the combination of crushed salt and clay mixture
- Improvement of the gravel column by adding viscous bitumen in the lower part of the column. The gravel column was originally foreseen as the abutment for the overlying bentonite sealing element.

Based on the work, the future work can start to develop and decide on safety functions for shaft seal and its component enabling moving to the next stage of the design development. The work carried out is specifically oriented to shaft seals in salt formations, and it is only applicable to this case.

#### 4.2.9 Chapter 9 Progress in D4.4

The chapter talks about the design without specific description of its maturity. As the workflow in D2.4 is used as a basis for clarity, it is required that the maturity of design is defined: e.g. conceptual design, basic design (basic reference design) or experimental design. This clarification helps preventing giving the reader an overoptimistic impression of what has been achieved in the DOPAS project in terms of the technical readiness of the plug and seal designs. Thus the statement in 9.2.1 "All of these experiments have helped to build confidence that the safety functions are met by the designs tested in the DOPAS Project" is considered a bit too strong especially with the pressurisation on-going still in e.g. the POPLU experiment. Also the experts stated that for the plugs that need to limit erosion during saturation of buffer and backfill, the performance is still doubtful. As an overall clear conclusion of the work done, the DOPAS experiment designs are not able to replace the need of a final proof of functionality at the real repository site.

To completely answer the adequacy and suitability of the applied design, other information is needed. The related question to this placed by the experts was how many experiments are still needed for producing the final proof i.e. plugs/seals that meet the requirements of the detailed reference design. Alternatively an expert stated that the adequacy of general design can only be demonstrated after years or decades of monitoring.



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There are statements in the report that the leakages observed can be avoided by future modifications. This is not proved at now. Emphasis should be given to that point in each case in the discussion.

Without the D3.30 information the conclusions in D4.4 regarding construction methodologies, methods and material tests are not visible to the reader. A need to add a referencing statement into D4.4 about "the detailed photography based documentation of structurally engineered realisation of the experiments" that is described in D3.30 either in the introduction or in the chapters related to the experimental work (chapters 4-8).

Despite the fact that the long-term behaviour of the experiments was not in the scope of WP4, the expert recommend to include more links to initial calculations (numerical modelling) either from WP5 or from earlier work into the introduction of each experiment chapter to give idea of what was the planned behaviour of the experiment plugs/seals (even if is a long-term calculation). Further linking the experiments more explicitly to the safety cases was requested. This is the part of the WP4 that would link the work with the WP5 work done.

The criteria are used to check whether the seal can be built according to its physical specification. However, no specific approval criteria are given for the outcome parameters. For the FSS, the dry density is main monitoring outcome data. For the longer term experiments (EPSP, DOMPLU, and POPLU), the most relevant data is also the initial density, but for the long-term issues, they include: water/pore / total pressures, relative humidity and leakage water. All other data are more conventional or technical and include concrete material parameters (like curing temperature, strains, presence of cracks). Their parameter quality is addressed with the quality plan on the recipes and on their production and logistics. The related uncertainties are not mentioned in the D4.4 report.

Gaining work experience and competence in terms of plug/seal and experiment construction is mentioned as an objective for several experiments. Conclusions about the experience and competence build up have not been made in D4.4.

#### 4.2.10 Chapter 10 in D4.4

Basically the chapter 10 was seen to include all the remaining issues that have been well identified. The experts noted that new issues may arise once the layout of the whole repository has been developed; when the total quantity, types, location and exact functions and required performance for all plugs and seals have been determined on the basis of the safety analysis and performance assessments; and when the repository site has been adequately characterized from geological,



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hydrological, mechanical and chemical standpoints. Also the changing regulatory requirements need to be considered in this connection. Industrialisation concerns and cost optimisation for the future are also to be considered.

The section 10.2 is too optimistic with a statement that *"the DOPAS experiments have provided good evidence that the designs tested are able to meet the safety functions assigned to them, both in terms of qualitative and quantitative consideration of performance"*. It has been demonstrated by the work done that such a statement cannot be justified at the moment. For some of the experiments, work in defining the safety functions is still on-going and the long-term performance assessment cannot be made in the run time of a four year project. The statement needs to address the achievement in respect to the relevant technology readiness level of the experiments in the DOPAS project. The question posed by the experts is: "How many future experiments are still needed to provide the proof for meeting the safety functions?" The title of this section 10.2 and its content do have a mismatch.

This chapter addresses the remaining work after the DOPAS project and the content was interpreted as a discussion of uncertainties of the results from the experiments in a more generic or technical perspective. However, the potential uncertainties related to the different stages of the DOPAS experiments as a part of the assessment made are not discussed in the D4.4 report using the identification and classification of uncertainties for the more mature experiments FSS, DOMPLU and POPLU. Discussions related to uncertainties are addressed mainly in connection with the ELSA work and when discussing the instrumentation in the EPSP experiment.

Conclusions in 10.3.8 states "any monitoring of plugs and seals in repositories will have to be significantly reduced in scale to allow disposal to be achieved efficiently and effectively", but how to qualify an industrial plug in future disposal without a minimum monitoring? These considerations should be detailed here to be sure that there is a clear recommendation to have or not monitoring in industrial plugs. It is just said that it is possible to have a monitoring for compliance with requirements. But does the DOPAS project have a conclusion on having a monitoring for industrial disposal facilities?

In that part, one would also expect to have a discussion on possible differences between demonstrator conditions and industrial conditions and thus what are the limits and uncertainties of DOPAS results.



## 4.3 Other specific improvements

### 4.3.1 Reporting coverage of monitoring in the D4.4

Information on monitoring strategies or the models for testing and assessment or analysis methodology and approval criteria for performance assessment (and technical feasibility assessment) are not transparent in the D4.4, monitoring is presented more statement like in the text. As a basis the physical processes for the modelling need to be known in order to select the right parameters and to ensure that the monitoring is correctly installed and that the information received for WP4 and WP5 assessments is reliable.

Other information in the background documentation has not been found except some potentially constraining factors regarding the location of sensors are roughly documented in D3.30 (minimise disturbances, not to intersect the sealing elements by cables). The information produced in WP3 from compliance point of view is not found in the D4.4 report either. Either additional text or referencing in detail is needed to be included in the D4.4 report.

Information looked for by the experts includes: There experts expect to find information or a separate report or corresponding documentation in the D4.4 regarding a detailed description of installation techniques and procedures used to select the location used, to fix the sensors, and to install the logging cables. The information should preferably be highlighted by photographic views in alignment with the documentation given about the technical construction of the full-scale experiments in D3.30.

Due to the short duration of the experiments, the efficiency of the instrumentation and of the methods cannot be judged or conclusions made about them from the performance assessment point of view for the long-term. One cannot make sure that the right parameters are measured in order to compare the experimental data with the pre-modelled values and this is an uncertainty in the performance assessment. An estimate of the technology maturity of the used techniques would be needed, since some represent laboratory level techniques. What is the survival rate of the sensors (e.g. after installation and after x months of monitoring)? The information available does not quantify the adequacy of monitoring strategy, tools or technology.

Additionally remarks regarding measurement principle, measurement accuracy and measurement evaluation should be integrated into the report. The tightness of cable lead-through has been a problem in some of the tests and its importance in the experiment design has been demonstrated.



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The report does not include or reference to a comparison of the monitoring strategies and to the adaptation of the monitoring based on the experienced collected. Referencing to such a source is needed.

#### 4.3.2 Performance assessment, predictive modelling and uncertainties of the assessments

The monitoring and the performance of the plugs and seals are based on modelling and calculations performed for the designs of the plugs and seals and for the designs of the instrumentation and monitoring plans. Also these modelling results and calculations in addition to the defined safety functions and safety envelopes provide the criteria for the evaluation of the performance based on the results.

The choice in the evaluation is made in using technical requirements only described by the requirements or key design specifications derived from initial calculations or (sometimes) from engineering statements. However structural calculations according to e.g. Eurocodes are not used as the basis of the evaluation.

The experts recommend more links (referencing) to initial calculations (numerical modelling) in introduction of each experiment chapter especially about what is the planned/expected behaviour of these plugs and seals even if the information is derived from long-term calculations.

The uncertainties related to the information used in the performance evaluation are addressed only in very few examples of the D4.4 report. The experts gave few examples of uncertainties:

- Ability to up-scale (space and time) from experiment design to reference design (physical and geometrical representativeness);
- Quality of data measurements provided by experiments or other sources;
- Material properties / material behaviour in case of two-phase-flow;
- Possibility to justify and proof repeatable integrity and tightness of full-scale experiment as well as reference design;
- Complete understanding of THMC(RG) coupled processes within the bonded system composed of technical plug, contact zone, EDZ and undisturbed rock mass to simulate numerically the long term behaviour of the repository taken into account time depending features, events and processes;
- Techniques to justify and proof performance assessment past to final installation (to avoid the need to "believe" a successful seal has been constructed).

The report conclusions do not address the methods or techniques to justify and prove the performance assessment of a final reference design to be implemented. Such a conclusion is an important learning point from the DOPAS Project for the future if the plan is to use the outputs for licensing the plugs and seals.



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#### 4.3.3 Coverage of assessments, linking and quality assurance of the work

All experiments and their related work are required to have a quality management system. The reporting does not include any description of the management system /quality system or comment on the importance of using such a system in the work in producing the D4.4 results and conclusion. However in some individual cases the aim to develop the quality of procedures is included as an objective for the work. A quality system is needed to address the formal process how and on what basis to move forward to the next step of the design basis development work (as in D2.4 workflow). These decisions need to be based on the performance assessment results of the DOPAS work or the following development work. I.e. in the work carried out, the use of the results acquired are required to have consistency with the identified workflow since they serve as inputs to the safety assessment/safety case as a part of the iteration process defined in this workflow. The D4.4 report does not mention details of the quality and quality assurance of the data collection.

The expert suggests that all quality management issues are regrouped under one chapter in the D4.4 report (e.g. Chapter 9) to highlight the relevance and the lessons learned in terms of quality assurance, quality plan development and quality management. Quality management is also crucial for the industrialisation process of the plugs and seals and for their optimisation in terms of design, construction and costs. It is also part of the contingency planning.

#### 4.3.4 Rock - plug interface and grouting

Hydraulic conductivity was identified as the most relevant parameter for the plugs and seals (D4.4 Chapter 10). Taking this into account the influence of interfaces between seals /plugs and host rock is not discussed adequately and no experimental setups cover this aspect as presented at least in the D4.4 or D5.10 reports.

In the crystalline host rock environment, the EPSP, DOMPLU, and POPLU all leaked. Part of the leakage was attributed to the cable lead-troughs for instrumentation. In the experiment beginning no requirement was set on the allowable leakage and the DOPAS experiments aim to contribute to the setting of the leakage limits. The experts note that the water leaks through the EDZ, and in particular along the contact between the concrete and the rock seems to be a currently unsolved problem in crystalline rock environments and warrant more discussion in the D4.4 covering the technical performance of the plugs as mentioned already. The main method used so far to solve this problem is grouting, but there is not a final definition of the grouting process and of the grout





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composition (or even the used grout recipes) given as a result of the experimental work in DOPAS.

Currently no other methods than empirical observation are used to control the quality of the grouting operation. If water leaks across the EDZ and the rock-concrete contact are critical for the safety function of the plugs, a more formalized approach would be required for the grouting operation. The alternative of the bentonite bands used in POPLU seems a more systematic and easier to control alternative, at least for the concrete-rock interface.

The experts state a need of detailed investigation into procedures, techniques, materials useful for grouting as well as R&D work to justify and proof the effectiveness of different grouting techniques, grouting materials and the composite action between grouting materials and different host rocks.

#### 4.3.5 Other **content** improvements

The referencing to DOPAS and other input reports is of big importance for the future reader of the report. As all information cannot be included into one intermediate summary report, balancing between new information and referencing is required. Part of the justifications, descriptions discussion is done in WP3 and WP4 work from the short-term perspective and in terms of the predictive modelling in the D5.10. The WP4 experiment summary reports provided the detailed experiment descriptions.

Influence of potential inadequacies in implementation and their influence on the performance are not discussed in D4.4, but the experts did not find uncertainties or omission in the use of the work done in the earlier work packages when applied to the D4.4. It was acknowledged that the DOPAS Project work does not consider radiation hazards in the experiments (out of the scope).

The report needs to address how the link between WP4 and WP5 is established according to the objectives of the WP4 and WP5. If such a link does not exist, a justification for it needs to be given in both reports D5.10 and D4.4. The D5.10 report and simultaneously the D4.4 report needs to be described in clear terms the division of work between the two work packages WP5 and WP4 as this is not clear in the reports (see also the chapter specific comments above):

- For the experiments FSS and EPSP (include clarifying figure of experiment as part of the context), the main objective was to test the technical feasibility of the plug construction and this objective was achieved and the technical feasibility and performance assessment of these experiments during the run time of the DOPAS Project is





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- included in the WP4 reporting, especially in the experiment summary reports D4.8, D4.7, and D4.4 Integrated Report.
- POPLU experiment's two functions of the plug (mechanical integrity and hydraulic limitation) were clearly defined in the D5.10 chapter 4 text. The pressurisation of the POPLU plug was started in January 2016 after the data freeze date of 30 September 2015 for the D4.4 report. The results addressing the relative short term performance are included in the POPLU experiment summary report D4.5 of WP4. An additional section 7.5 was added to the report D4.4, too.

The connection of the experiments described in the report and the PA cases considered needed improvement, too, as discussed earlier. The use and handling of the experimental results in PA was questioned as it was seen that the linking is via defining the need for experimental results from PA. The different PA methodologies should be linked to technical methods to prove functionality.

And the experiments performed should be investigated whether they could form a basis for suitability tests included in their terms of reference. A known problem is that industrial scale suitability tests for materials have to be included in the experiment's terms of reference. However, if suitability tests last too long they cannot be performed in an adequate time period and thus the results are not available. Also the long-term behaviour of the plugs and seals is excluded from the scope of the WP4.

#### 4.3.6 Terminology and acronym listing

##### **Key terminology additions**

Since the national and host rock contexts and the underlying safety concepts are so different, the terminology and expressions clarification. One term having an important underlying influence is the duration of the "assessment period" in the different geological disposal concepts since the length of this period varies significantly depending on the national legislation. Like in the case of Germany, a "short-term" seal is expected to last for 50 000 years and in the crystalline KBS-3V concept the plug design life is couple of hundreds of years. Thus clarifications about the expressions short and long-term in the different contexts are needed.

##### **Glossaries**

Definition of "short-term" and "long-term" in the different repository contexts (ensure the same definition in D4.4 and D5.10) is also required. The assessment periods differ significantly in the different repository and experiment contexts and this requires clarification for the reader. "Assessment period" itself needs a definition.



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In general, in the DOPAS Project it has been agreed that reference to IAEA glossary (2007) is made in the introductory text and reference list as it has been agreed in the project to use this glossary for the terms, which are not specifically described in the report's glossary.

#### 4.3.7 Some **editing** and technical corrections to D4.4

Editing comments are handled as edits into the final report not requiring further discussions. Some of the edits are listed in this section and additional comments are provided to the author in a separate file.

Corrections are needed in the D4.4 report to:

- References format - confusion due to two references named White et al. 2016 (mixing D2.4 and D3.30)
- Some of the figures were quite low in resolution like figures 4.7, 4.11, 4.15 and potentially 7.5. The poor resolution reduces the traceability of the information further in addition to the lack of detailed referencing.
- Check the identification of the concrete mixtures for FSS to avoid repeating error in D3.30 draft (esp. FSSD01)
- The FSSD02 temperature is not from the design basis.
- Check also the feedback statement in FSSD03 - seems to be out of context (belongs to FSS02 as a new requirement).
- The IAEA 2007 safety glossary provides a listing of SI units and prefixes according to ISO 1000 in its appendix as a guideline.

The references' formats need to be checked to comply with the instructions given by the coordinator on their format. This requires checking of the referencing in the text and references in the reference listing.

#### 4.4 WP3 and WP5 elicitation as an additional check list for D4.4

The experts carrying out the elicitation for the WP3 have identified the following uncertainties, which are included in the approved consensus memorandum of the WP3 elicitation. As these uncertainties are potentially already included into the reporting of the WP4, this listing is presented in this memorandum and in the WP4 memorandum to serve as a check list for the D4.4 work package summary report.

- The crystalline rock experiments highlighted the uncertainties related to rock conditions and selection of the underground site and also the need to develop construction contingency procedures to take care of possible problems like unexpected water inflows (in DOMPLU site). Such a risk was also identified for the POPLU experiment location, but it did not realised. The missed water bearing structures may lead to hydraulic bypass of the plug and eventually to faster than intended



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radionuclide transport through the host rock. There is a need develop contingency plans to address unexpected deviations from the desired state as these result from various environmental underground conditions and cannot be always prevented in advance.

- The WP3 EE experts concluded that for the plugs without hydraulic limitation function there is no relevant uncertainty regarding performance assessment/safety assessment as they play neither a short-term nor a long-term safety role concerning radionuclide transport from the repository. It was also noted that the length of short-term and long-term in time is dependent on the stipulated safety assessment periods for the different repository concepts.
- For the seal made of crushed salt the inherent uncertainty is related to the host rock permeability: too slow decline of permeability leads first to a large inflow of brine and after the full flooding into the expulsion of contaminated brine due to salt creep induced convergence. The combination of inherent uncertainty concerning host rock behaviour and the procedural uncertainty can also be overcome by strict quality control.
- A main uncertainty relates to the up-scaling of the results from this experimental work to industrial scale in a repository.
- All of the experiments were challenged by logistic concerns. This will be the case in the future, too. The quality of the sufficient quantities of high standard quality of concrete materials and other materials is a concern resulting from the transportation needs of industrial scale material quantities. This challenge has already been experienced and addressed at LLW<sup>2</sup> repositories.
- One uncertainty relates to the inadequate quality and heterogeneities in the bentonite material emplacements into the underground openings especially into the upper parts of the sealing structures. In bentonite seals too low swelling pressure leads to high hydraulic conductivity and potential erosion of the seal. The relationship between the void and dry density of the bentonite used is a critical parameter. The successful filling of voids and requirement for a smooth surface are limitations of the construction technique causing procedural uncertainty. This can be addressed with adequate working procedures and strict quality control during the construction.
- The approval criteria for the designs are not very clear for the DOPAS experiments. In addition to the workflow from D2.4, the use of the recent GEOSAF work (IAEA TECDOC 2015-12-09 *Managing integration of post-closure safety and pre-closure activities in the Safety Case for Geological Disposal* in preparation) about safety envelopes and design targets in dealing with the risk of the potential outcomes and achieving approval criteria is useful and recommended for future use.

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<sup>2</sup> Low-level waste



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WP T6.3 EE for WP4

Document name  
**WP4 EE Consensus Meeting  
Memorandum**

*Written: Marjatta Palmu  
Date: 19 July 2016  
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For this purpose the concepts of safety envelope and design targets (*ref. to GEOSAF final draft IAEA TECDOC 2015*) an extract of the concept of the safety envelope and design targets is given resulting from the WP3 elicitation:

*"The Safety Envelope represents the boundaries within which, at the start of the post-closure phase, the state of the disposal system (i.e. the parameters expressing the safety functions important for post-closure safety) must fall in order to deliver the post-closure safety functions.*

*The Design Target represents the boundaries within which, at the start of the post-closure phase, the state of the disposal system is designed to fall. The Design Target is derived by taking into consideration appropriate margins with respect to the Safety Envelope, in order to take into account the principle of optimisation of protection (and safety) and also the uncertainties associated with the anticipated state of the disposal system and its evolution.*

*This also means that the Design Target is situated within the Safety Envelope."*

Likewise the As-built results and be compared with the design target. The WP3 elicitation group saw it serving as an input to the WP4 reporting and expected its use to be found in the D4.4 report. This was also presented in the consensus meeting of WP4 elicitation.

See also the Appendix 3 for more information on the GEOSAF concept.

## **5 State-of-the-art at the end of WP4 work and the future opportunities**

### **5.1 Assessment of Technology Readiness**

The experts gave their views on the technology readiness level (TRL) of the plugs and seals at the end of WP4 work as reported. The results deviated from each other quite a lot (Appendix 6). The discussion about the TRL was taken up in the consensus meeting too late by the facilitator and part of the experts had already left the meeting so that the potential different interpretations could not be checked. The two different scales and the DOE figure provide to some degree conflicting information. Their explanations are included also as a part of the draft assessment on the technology readiness level presented in Appendix 6.

Despite of this main differences in the maturity of the experiments were also noted in the technology readiness level (TRL) assessment made by the experts (in Appendix 6) and the comparative readiness of the experiments was in alignment with the WP3 elicitation experts assessments. The conclusion of the experts who participated the meeting was that the maturity on the DOE scale does not go over level 6 in any of the experiments. The Appendix 6 also presents a figure based on the average of the experts TRL level assessments.



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Also it was noted that it would have been useful to do an assessment on the TRL maturity of the sensing technologies used in the DOPAS experiments (a pre- and post assessment). Such a pre-assessment was carried out for the POPLU test plan as part of the DOPAS EE pilot elicitation process.

Additionally the experts noted that also the authors of the report should propose the technology readiness level assessment as part of the report's conclusions (in Ch. 9 of D4.4).

## 5.2 Future development needs and opportunities

The future monitoring of the experiments that have not been dismantled is currently an open question in terms of how and what is done with the experiments. Also the time and budgeting of the potential dismantling of the experiments and related testing is open. Some planning for the work after the DOPAS project is on-going.

Customers identified are many. Outputs will be used at least by applicants and waste management organisations to prepare for the facility license.

Related to the other influence of results from WP4 in improving state-of-the-art of performance assessment of the plugs and seals is not addressed in the report neither is further iteration planned. At the moment the outputs at now have not been used for this purpose or this purpose has not been stated as it was not known. They results have been used and continue to be used for the development of next steps and in forward planning of the WMO's work related to closure as a part of their RD&D programmes (to be included in D6.4).

In each case of the experiments in crystalline rock a leakage has occurred. Regardless to remarks regarding the reasons for leakage and assumptions / statements how to avoid them in future applications, it is recommended to repeat the experiments taken into account the improvements learned by the previous experiment until the requirements will be fulfilled completely.

Due to the interdependencies of the performance/safety assessment, site conditions, and the facility, a toolbox now developed of potentially available plugs and sealing elements is an essential by the experts but not the only requirement to optimize plugs and seals with respect to site and repository layout specific boundary conditions in the future. The impact of working with radioactivity also needs to be considered as part of the whole repository system. Currently the experiments have addressed only a single part of the closure subsystems.

The D4.4 overall conclusions are to some degree in conflict with the results from the D5.10 elicitation that states that much of the work is still not finished and needs to be continued to confirm e.g. the predictive



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modelling. This means further detailing of the results with updated models including e.g. better physical processes and geometry also with more experimental results. Most of the results from the work cannot be directly used in PA/SA at larger scale in overall safety point of view.

Especially for the future there is a need to define: Which processes are better understood at the end of the DOPAS project and what are the underlying performance measures? Which advancements of the sealing concept have been made? How is the confidence in concept and models gained?

Although all repository sites should be chosen for long term safety reasons based on limitation of radionuclides transfer to the biosphere, each site has its own geological stability and characteristics and its own phenomenological behaviour. Thus, THMC<sup>3</sup> conditions prevailing in and around a repository are specific. However for all repositories, experimental demonstrators are made today for a (very) limited time compared to the repository lifetime and more specifically compared to the total duration they should be efficient. This duration is also plug/seal dependent.

The transferability of the experimental design to the reference design is not discussed from long-term performance point of view. From the technical solution perspective this is discussed in D4.4 and D3.30. The referencing can be made. The more mature the design, the more applicable are the results for the use in the future. The early phase experiment performance assessment results can give input for setting up the requirements and future feasibility studies.

In addition, it is important to note that the experimental setup may simplify or make the reality of the plug more complex in producing results that are setup specific. In a real repository, the situation is unlikely to be so specific and for this reason the number of experiments with different experimental setup may need to be increased for reducing the sources of uncertainty. The number of experimental cases to cover the varying in situ conditions especially for the cases in the conceptual design basis development is partly depending on the national legislative or regulatory requirements. At the moment it is not clear how many experiments are still needed for producing the proof for an acceptable (detailed) design for the repository operations.

In addition to the above, large amount of constraining (technical) factors are identified by experts and these needed to be addressed in the future work (as identified in both D3.30 and D4.4).

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<sup>3</sup> thermo-, hydraulic, mechanical and chemical process relevant to the repository site, far-field and biosphere





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### 5.3 Applicability of the D4.4 experiences and the results in the repository implementation

The experts were asked for their assessment on the potential applicability of the work experiences and results presented in D4.4 for other plugs and seals or even for other repository components implementation.

The experts noted that

- Lessons learned are good. All information is transferable to a further developer of the basic design or experimental design. The D4.4 report needs to be complemented with the information to be found in the other DOPAS project results to give all the tools for the developer for further modifications of the design basis.
- Systems engineering approach applied in the DOPAS project is widely applicable. The design basis work flow (the iterative process) can and should be applied to other components in disposal (e.g. in Modern2020).
- The experiences obtained with sensors and instrumentation systems are widely applicable to all types of “in situ” experiments.
- The monitoring techniques in the three crystalline experiments could have a broader application potential to similar underground facilities.
- The approaches carried out to develop concrete (especially low pH SCC) recipes, emplacement techniques and their quality control are widely applicable. The same applies to use of shotcrete and shotclay, and to the techniques used to build the filters and the delimiters.
- Low pH cements, and methods to avoid shrinkage and fracturing when setting are applicable in many other parts of a repository. They may be also interesting in other civil engineering applications.
- The different plug slot excavation methods are applicable for crystalline formations. Same applies for grouting methodologies with the limitations stated earlier.
- The bentonite seal construction/emplacement with granular materials is applicable in all plug design using this type of materials, but is similar to the techniques used in other experiments. The methods proposed for density control, although not fully operational at this stage, are also of high interest for these cases.

It would be worth to assess how the five experiments carried out in parallel under DOPAS may have influenced one another.



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Outside the DOPAS context the learning is estimated to be very helpful for third parties and future generations in general because main properties regarding load bearing behaviour, integrity, performance, functionality, e.g. are proved and justified by the experiments. There might a possibility to be able avoid or limit the need of repeating the experiments by third parties or future generations in case they want to implement similar tests.

However, to assess the application universally the specific applicability assessment needs to answer questions regarding material properties, measurement techniques and structure engineering requirements in the relevant context. In the case of the interplay between a site specific rock mass and a seal / plug where an element made of bentonite or concrete is demanded, universally application is significantly reduced, respectively not even possible.

DOPAS WP4 shows that each experiment has their own specificities in terms of experiment objectives, priorities, design and construction requirements, context and scale of the in-situ experiments, availability of materials, technologies and know-how. All these considerations result in design and construction features quite different from one experiment design to another, although similar methodologies have been used to drive the design and construction process. Consequently, it is quite difficult to extrapolate the results of plugs' / seals' development and construction work and to assess their applicability to contexts which are not yet precisely known.

Outside the context of geological disposal, underground plugs and seals are demanded in case of separating underground mining areas in production against abandonment areas and in case of underground storage facilities (natural gas storage, compressed air energy storage, underground pump storage).

## **6 Recommendations and expectations on content for inclusion into the other Work package reports**

There is a need to include a clarification about the scopes of work carried out in WP4 and WP5 and also to address in both D4.4 and D5.10 about the link of the work between Work packages WP3, WP4 and WP5. Such text about the links needs to be in all of the summary reports: D4.4, D3.30 and D5.10.

The experts concluded that an estimation of expected experimental risks before tests would be of interest. The project plan includes a risk plan for the individual experiments and this can be addressed as a part of the final DOPAS report D6.4.

As stated by the experts in WP3 elicitation and noted in the WP5 elicitation, the results of the full scale experiments in WP3 cannot



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directly be used in Performance or Safety assessment (as defined in WP5): these results will only become available in the work described in WP4 D4.4 except for the initial state, which can be used in simulations of WP5.

During the elicitation, the need to cross-reference to the summary reports D3.30, D4.4 and D5.10 in sufficient detail for finding the relevant information was identified. And this applies not only to the items listed above, but also in general. Also the use of the D2.4 work flow forms a basis for each work package giving an overall process and context of the work carried out in DOPAS as included already in D4.4.

DOPAS includes experiments and tests related to different national programs, which are in a different state of development. This can be seen also in the experiments design and the test plan. In the case of DOMPLU and POPLU the reference plug design is more advanced than in the others, and they also benefit from the previous experience in different experiments carried out at Äspö, whereas the EPSP experiment is a first trial of constructing a plug. The French experiment is also a first experience, but the plug design is pretty well developed. The contribution of DOPAS to the current body of knowledge is important, but each experiment provides lessons and findings that are relevant for each agency at their respective level of program development.

The future development needs in connection with the national R&D programmes are a welcome content to be stated in the way forward of the D4.4 report as the DOPAS Project addresses only a small part of the closure related development and demonstration work. Giving the work carried out in perspective of the national requirements and with the process of building a safety case would be very useful (to be included in D6.4).

An estimation of the expected experimental risks by implementers before test would be of interest to evaluate against the results. The project has produced experimental risks assessments and they can be evaluated against realised risks and addressed in the D6.4 report.

## 7 Good practices in addition to the lessons learned

The way of structuring the conclusions and lessons learned in D4.4 is a good model for other similar reporting.

## 8 Use of the Expert Elicitation results

The expert elicitations form an integral part of the quality assurance of the DOPAS Work packages' final deliverables. Thus the consensus outcome approved by the experts shall be included into the next version of the final draft or to the final report. This timing is dependent on



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whether the report will still undergo an organisational quality assurance review or if the report draft that has been submitted to the expert elicitation has already been reviewed in the organisation in lead of the work package in question.

The main author or editor of the reviewed deliverable is responsible for the inclusion of the experts' recommendation and the final check is made by the coordinator of the DOPAS Project when approving the final deliverables for submission to the European Commission and for publication on the DOPAS website at <http://www.posiva.fi/en/dopas>.

## 9 Feedback related to the EE process

The typical features of the EE process include

- looking at the same target from different perspectives
  - applying a defined role in working for the project
  - looking at the face evidence provided by the documents
- producing a transparent view of one's underlying thinking
  - contrasting the evidence with one's own experience
  - explaining and making visible why one is in agreement or why something is not agreeable or is omitted from the material subject to elicitation =>
- providing an opportunity to expand both sides' knowledge and views on the EE target of the process

with the purpose of giving directions for improved and more structured and complete outcome for the future work that has been elicited.

Based on the WP2 elicitation feedback, the WP3-WP4 elicitation forms were commented by the main elicitation expert Mr. Potier prior the elicitations started. Also a Czech expert was sought for the WP4 elicitation, but an expert was not available for this task.

### 9.1 Feedback from the experts on the process and tools

#### 9.1.1 On experts' work and the questionnaires

The questionnaires contained redundancies and the formulation of some questions was seen complex (too long and combining several questions under one package). It was acknowledged that each expert also understands the question differently and provides thus different answers. The appearance of the form not so attractive and the use of boxes on the form complicated working with the form. The focus of the questions was seen to be more on the formal process, instead questions regarding quality content were considered to a lesser extent. An expert wondered by there was no question about the experts conclusions about the report.



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The time allocated to review the report and answer the WP4 elicitation questions much too short, only less than three weeks as in principle a month should be available for the work. This was due to the lack of finding common dates for the kick-off and for the consensus meetings and partly due to the overlapping elicitation of especially the WP5. Several experts noted that to interpret and reply the amount of questions the time was definitely too short.

A concern was related to the impact of the elicitation taking into the consideration the late time of the elicitation in the schedule of the DOPAS project especially for the author/s of the report to improve it. At the same time it was noted that not all of the experts' remarks were so specific that the author could directly locate them and address them in the report editing.

Based on the experiences from the other work package elicitations, the general editor's role was seen very important in providing a comparable and common structure for the summary reports.

### 9.1.2 Timing of the elicitation

The question about the timing of the elicitation was placed. This timing was considered too late for the reporting process and for improving the structure of the reported work.

The original timetable for the elicitations did not work out due to the delays and uncertainty about the availability of the work package summary reports for the elicitation being one of the last steps in the reporting process.

Also an earlier EE of the work planned could be of advantage to improve the structure of the work in general; however, e.g. in two steps at the project planning phase and at the end like done now.

Overlapping of the elicitations (not originally planned or desired) resulted also in difficulties to find earlier common dates for the kick-off and consensus meetings. The summer season also caused some delays due to author's and experts holidays.

### 9.1.3 How to carry out the process

The purpose of the questionnaires was seen as catalysing the process and at the same time it was difficult to be innovative in the process. Lot of issues were brought up in the replies and the process was considered interesting. The expert's individual overall conclusions on the report under elicitation are the starting point of the consensus meeting itself.

It was important and advantageous to have the one expert to participate all of the elicitations (and also this person could have been involved in the beginning). This also provides the opportunity to highlight potential



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gaps between the different work packages as it was noted in this elicitation process.

A suggestion was made that it could be useful that the authors of the reports would give answers on the questions of the forms or use it themselves as a checklist for their reporting work. This recommendation is worth to take into account if the process is repeated in another context to have the authors use the forms before submitting the final draft for the elicitation.

A suggestion was made to have all reports elicited in one elicitation for the overview. This was discussed in the original WP6 plan, but it was decided that it is not feasible in this project.

Using a web form or macros that would speed up the processing of the raw inputs of the experts by the facilitator would be a useful improvement, too.

The independence of the experts of the work is important. For this work package elicitation the total number of the experts was largest and it was reflected in the number of findings. This was also good for the contingency planning since one of the experts was detained from participating the consensus meeting and this could also happen in the future.

It was also suggested that there would need to be a view on the final report (D6.4), too.

## 9.2 The facilitator's underlying views on the forms and process

The forms are intended to speed up the process. The use of the forms enables a faster tracking for the facilitator of the different perspectives from the experts vs. reviewing direct comments on a track changes or commented report as the forms have matching questions though from a different perspective. This highlights the discussion topics for the consensus meeting quicker. Also to ensure the different perspectives, the directions for replying the questions are with purpose left open for the experts. In the replies, this has proven to provide a wider range of comments from the experts. During the process the length of the questionnaires has increased and some redundancies were identified.

The D4.4 elicitation was the last of the elicitations and it followed also the DOPAS seminar with a lot of information accumulated from the project. This was also noted in the total number of comments received from the experts.

The time for the WP4 elicitation was definitely too short. Also the consensus meeting would have required at least one and half days for the discussions. However, this was not possible due to the unavailability of the experts for two consecutive days and due to the overall timing of the





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DOPAS project. If the elicitation would have been allocated the full time of three months as originally scheduled without two overlapping elicitations at the same time, the time constraint could have been managed somewhat better taking into account that both the main elicitation expert and the facilitator were tied up simultaneously on three different elicitation processes.

The practical elicitation in just one elicitation meeting would be very difficult to manage feasibly since the extent of the input material would be large and elicitation results would be available at too late a stage in the process to be able to provide the needed quality assurance for the deliverables. Already now the overlapping elicitations had an adverse impact on the last consensus meeting and on the reporting of the elicitation results.

The question of engaging the experts earlier into the project in the role of project advisers would potentially change the role of the experts from independent reviewers to reviewing work where they themselves have provided input. The expert elicitation was from the beginning of the DOPAS Project intended to be an alternative approach compared with the expert advisory review group of the Euratom RTD projects.

## 10 Final acknowledgement

The DOPAS Project thanks the experts for their valuable input for the DOPAS Project. The research leading to these results has received funding from the European Union's European Atomic Energy Community's (Euratom) Seventh Framework Programme FP7/2007-2013, under Grant Agreement No. 323273 for the DOPAS project.

## Appendices

### **Tools:**

1. WP4 Performance assessment expert's form
2. WP4 Domain expert's form
3. GEOSAF concept of safety envelope and design target

### **Descriptions:**

4. Simplified structure of WP3 work based on lessons learned
5. Summary experimental and analysis work in WP3 and WP4
6. Technology readiness assessment draft at the end of WP4

### **Other materials:**

7. Draft of ELSA context and work carried out for improvement



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## APPENDIX 1

DOPAS Expert Elicitation for WP4  
Domain Expert (Form 1)

19 May 2016

V.3

### DOMAIN EXPERT'S ELICITATION FORM (DOPAS EE WP4)

The outcome of the work in DOPAS WP4 is reported in the final report D4.4. This report is currently at the draft stage. After the elicitation, the D4.4 will further undergo RWM's internal quality assurance prior publication. This report is strongly linked with the work carried out in WP3. The D4.4 report also summarizes previous work with the intent to integrate the DOPAS work. In your elicitation keep in mind the main objectives of the Work package 4 as described in the DOPAS project's WP4 description.

#### Elicitation Task/Topic under elicitation (WP4)

Is the D4.4 report complete and consistent regarding the objectives set for the work and is it "fit for use" i.e. representing an acceptable level of quality as a work package deliverable (not too much and not too little) and how well does the D4.4 achieve its task to integrate the Research and Technology Development (RTD) and Demonstration work done in DOPAS at the time of the writing of the report?

The elicitation's focus is to assess the completeness and (technical) performance of the constructed experiments in relation to the objectives set for them as described in the report and in the project's work plan.

In addition, the elicitation should identify potential uncertainties, ambiguities/deviations/unjustified conclusions, and controversies in and between plug/seal<sup>1</sup> experiment/s' inputs and test and technical feasibility output data and other outcomes and between the original design basis, the design itself and each experiment as implemented. This means an assessment of the alignment of the construction and test plan implementation and results with the design basis and design is expected. Further, the realised test/monitoring plan and the output data received from the plan and the interpretation or the plans for the interpretation of the results needs to be addressed as stated in the above. The reasons for deviations need to be transparently explained and an assessment made whether these could prevent the component (plug/seal) or subsystem (closure) from reaching the desired initial state or from performing according to the expectations (in the repository). Further the elicitation aims to look at

- the practical application and feasibility of the implemented technical design of the experiments as described in WP3 and as summarized in D4.4 and complemented with the experiment specific reports under WP4;
- contrasting the achieved performance results of the experiments vis à vis the original requirements and objectives set for them (the soundness of the compliance evaluation);
- the construction solutions' feasibility, including available dismantling results and lessons learned related to the desired performance of the experiments; and
- the appropriateness of the report's integration of the tasks carried out, its conclusions and suggestions for use of the results from the above; and the lessons learned from the experiences related to desired outcomes, the capability of the plug/seal to reach their technical performance and desired/expected initial state.

The assessment is carried out in respect to the original objectives, to the report content and to experts' previous experiences.

Name of expert replying

<sup>1</sup> address the seals only to the degree they have been addressed in the compliance evaluation section of the report D4.4





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Explain your expertise\*) in regard to the target under elicitation:

\*) I.e. your personal involvement in experimental and structural design and monitoring and in the technical implementation and feasibility assessment of large structures planned or designed for underground, and/or supervising such structure constructions or test plans, and other relevant experience in the area in general including previous engagement in similar activities.

**DE1. Assess the role of expert judgment used in the implementation of the designs for the construction and their feasibility for the DOPAS experiments plugs in relation to the desired outcomes and in relation to the developed design basis (incl. requirements).**

- a) How and to what extent have the requirements and the design basis (the input data) identified in D2.4 and the design produced in WP3 been used in the construction of the plug/seal experiment /s (as described in D3.30 draft<sup>2</sup>). Is this analysis sound and flow of inputs visible for the reader of the report?
- b) What type of modifications was made to the input data and into the design including the material choices in the implementation process and how have they been justified? How feasible are these modifications in respect to the original input requirements and design basis?
- c) Do you identify any omissions or uncertainties related to the application of the construction methodologies, methods and material tests for the implementation that have not been identified in the report?
- d) What influence does it have from the implementation and plug performance point of view that the DOPAS experiments were based on an experiment design instead of the reference design intended for the repository/-ies?
- e) What type of uncertainties and differences can be potentially identified in the expected initial state of the plugs resulting from the implementation compared with the implementation of plugs for a final repository design?
- f) What would be in your view on the potential applicability of the used construction, test and experiment performance assessment methods and conclusions about technical feasibility for other types of repository subsystems (and specifically to shaft seals) or components outside the DOPAS context? Please justify your view.

**DE2. Technical feasibility and performance of selected and tested materials for the experiments and related uncertainties.**

- a) How have the criteria for the material choices been met in the experiment implementation phase? Are the evaluation results against these criteria and the related choices transparently presented and well grounded in D4.4 draft or do you think they include direct or embedded expert judgments?
- b) What is your assessment on the soundness of technical implementation and performance of the

<sup>2</sup> please note that your background draft D3.30 is a version prior the final review of the report





experiments and their components using the materials and based on how their use and performance have been described in the D4.4 draft report (see also DE4 below).

c) Are the input data and/or criteria sufficiently described in the report (or in related background references) to make the conclusions made in the report on the technical feasibility or performance of the experiment designs, construction and/or components of the plugs/seals in DOPAS?

d) What judgment would you make on the conclusions and lessons learned from the construction feasibility/technical performance point of view relating to the materials, methods and designs used based on your reading of the report and experiences. Are they in alignment with the report's conclusions and lessons learned? What uncertainties do you identify at this stage of the process related to the implementation and technical performance of plug materials?

**DE3. Rationale underlying the production and use of the test plan/s for instrumentation, and monitoring and pressurisation/dismantling, the types and quantities of instruments and methods applied with potential uncertainties and potential for improvement.**

a) For what purpose is the test plan/s produced and by whom? What type of input has been used for preparing the test plan? How have the measured or observed parameters, sampling and/or testing methods been chosen? On what grounds?

b) Who is the main customer using the outputs of the test plan? How have the (performance) outputs from the implemented test plan been used (e.g. to come up with the conclusions of the report)? Your view on the soundness of their use (uncertainties, ambiguities, omissions, too far fetching conclusions...)?

c) What type of view do you have on the technical feasibility and performance of the implemented test plan (instrumentation, pressurisation and like)? Is your view in alignment with the report's conclusions and lessons learned? Why/Why not?

d) What are the uncertainties related to the desired initial state of the plugs taking into consideration the collected outputs (and parameters) from the test plan implementation (from the instrumentation and methods used)? What are the potential limitations related to making conclusions about these?

**DE4. Rationale and the practical feasibility of the used construction methods for the experiments and potential uncertainties. Potential for implementation experience integration.**

a) What have been the drivers in the selection and use of the construction methods for the experiments and their components? Have these been reported in a transparent way?

b) What type of potential limitations exists in the use of these methods in a repository environment?

c) What type of uncertainties or limitations can be identified resulting from the construction method choices (construction as implemented) in relation to meeting the experiment requirements?

d) What technical and operational issues related to plugs have been now resolved and how? And what outstanding technical and operational issues remain? How well have their potential





commonalities been identified and justified from the project results?

e) What type of integration potential has been identified from the implementation of the different construction and other methodologies used among the experiments and beyond the experiments for other uses?

**DE5. Adequacy of and uncertainties about the work done in respect to instrumentation and construction in the experiment/s including the plug location selection/s to achieve the expected outcomes/objectives for plugs/seals (initial state)?**

a) Do the results of the work carried out (originally described in D3.30 and further described in D4.4) demonstrate consistency with the state of the art or improvements in it in relation to the input data (requirements, reference design basis, designs and construction methods for plugs, and further for seals and other closure components) in general?

b) Do you feel any doubt concerning the adequacy of the used experiment design/s, construction methods, test plans and their outcomes? If so, about what and why, what are the reasons?

c) What type of constraining factors have been taken into account and which approaches or methods have been used to tackle the constraints during the implementation of the experiments and in measuring their performance? Are these adequate when keeping the set objectives of the plug experiments in mind?

d) Could the identified inadequacies in the implementation and in the interpretation of the performance outcomes influence the desired performance (or the performance assessment results) and the compliance with the desired initial state of the plugs (as defined in the safety case)? If so, in which ways?

**DE6 Rationale for lessons learned, conclusions, and suggestions from the experiment implementation from both technical feasibility and technical performance point of view.**

a) How have the lessons learned and the results from the DOPAS project learned to date contributed to the ability of plugs and seals designs to meet safety functions specified in disposal concepts? (DOPAS contribution to the current technical body of knowledge?)

b) What judgment would you make on the conclusions and lessons learned from the technical performance, test results, and feasibility point of view related to the design, materials used, monitoring parameters chosen and results achieved? What uncertainties do you identify at this state of the process related to them?

c) Do you feel that the practical lessons learned from constructing the DOPAS experiments plugs have been well captured and reported in the D4.4 report? What is your assessment of the value of the feedback resulting from the experiments in terms of constructability or performance monitoring to possibly strengthen the plugs/seals reference design?

d) Based on the information provided in the D4.4 report, have you identified any major remaining technical or operational issues in addition to those listed in Chapter 10 and, if so, how would you address them in the future?



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### **Challenges in producing the D4.4 report itself and its completeness**

DC1 Have there been identified difficulties / what were the difficulties possibly encountered in producing the report and its conclusions. What were / might have been the reasons for the difficulties (are these transparent in the reporting)?

DC2 What areas do you see that need complementing in the construction, instrumentation and performance sections of the report? On what grounds?

### **Universal applicability of the results in repository and other implementation**

DU1 And what parts of these experiment implementation experiences could be universally applied to all types of plugs'/seals' development and construction work? What parts cannot be applied? And on which grounds?

DU2 What type of broader application potential do you identify for the results and the work presented in D4.4 in your technical field of expertise beyond the plugs/seals subsystem?

DU3 To what extent could the construction, materials and instrumentation development work done in these experiment works be used for other repository components than plugs (and seals)?

**Other review comments related to the D4.4 (e.g. other information to be included to the report concerning terminology, theories, referencing to other work related to plugs and seals)**

**What is your assessment of the technology readiness level (TRL<sup>3</sup>) of the plugs/seals based on the D4.4 report?**

### **Feedback on the EE process and the form:**

This is a pilot process. What are your proposals for changes or additions concerning the questions and visual appearance of this form, needed for improving the usability of the form as a tool in the formal expert elicitation process of this type of full-scale demonstration project?

<sup>3</sup> see attachment in background materials about the TRL levels





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## APPENDIX 2

DOPAS Expert Elicitation for WP4  
PA/SA Expert (Form 2)

20 May 2016

V2

### PERFORMANCE ASSESSOR'S (/SAFETY ANALYST'S) ELICITATION FORM (DOPAS EE WP4)

The outcome of the work in DOPAS WP4 is reported in the final report D4.4. This report is currently at the draft stage. After the elicitation, the D4.4 will further undergo RWM's internal quality assurance prior publication. This report is strongly linked with the work carried out in WP3. The D4.4 report also summarizes previous work with the **intent to integrate** the DOPAS work. In your elicitation keep in mind the main objectives of the Work Package 4 as described in the DOPAS project's WP4 description.

#### Elicitation Task/Topic under elicitation (WP4)

Is the D4.4 report **complete and consistent regarding the objectives set for the work and is it "fit for use"** i.e. representing an acceptable level of quality as a work package deliverable (not too much and not too little) and how well does the D4.4 achieve its task to integrate the Research and Technology Development (RTD) and Demonstration work done in DOPAS at the time of the writing of the report?

The elicitation's focus is to assess the completeness and (technical) performance of the constructed experiments in relation to the objectives set for them as described in the report and in the project's work plan.

In addition, the elicitation should identify potential uncertainties, ambiguities/deviations/unjustified conclusions, and controversies in and between plug/seal<sup>1</sup> experiment/s' inputs and test and technical feasibility output data and other outcomes and between the original design basis, the design itself and each experiment as implemented. This means an assessment of the alignment of the construction and test plan implementation and results with the design basis and design is expected. Further, the realised test/monitoring plan and the output data received from the plan and the interpretation or the plans for the interpretation of the results needs to be addressed as stated in the above. The reasons for deviations need to be transparently explained and an assessment made whether these could prevent the component (plug/seal) or subsystem (closure) from reaching the desired initial state or from performing according to the expectations (in the repository). Further the elicitation aims to look at

- the practical application and feasibility of the implemented technical design of the experiments as described in WP3 and as summarized in D4.4 and complemented with the experiment specific reports under WP4;
- contrasting the achieved performance results of the experiments vis á vis the original requirements and objectives set for them (the soundness of the compliance evaluation);
- the construction solutions' feasibility, including available dismantling results and lessons learned related to the desired performance of the experiments; and
- the appropriateness of the report's integration of the tasks carried out, its conclusions and suggestions for use of the results from the above; and the lessons learned from the experiences related to desired outcomes, the capability of the plug/seal to reach their technical performance and desired/expected initial state.

The assessment is carried out in respect to the original objectives, to the report content and to experts' previous experiences.

Name of expert responding

<sup>1</sup> address the seals only to the degree they have been addressed in the compliance evaluation section of the report D4.4





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Explain your expertise<sup>\*)</sup> in regard to the target under elicitation:

<sup>\*)</sup> personal involvement in the input data/test plan production, implementation and/or results assessment related to practical technical and long-term safety related requirement setting, performance assessment<sup>2</sup> of design bases and in the monitoring and interpretation of performance related inputs and outputs from geological disposal related experiments and/or in the assessment of technical feasibility of safety important structures/components in disposal.

**PA1. Appropriateness and completeness of the conceptual models underlying the testing and assessment and of analysis methodology and in addition the approach (for designs, test plans, and their implementation) used for producing, assessing the compliance and reporting the results of the WP4 for making conclusions about the performance of the tests and of the experiments undertaken? Appropriateness and completeness of the outcomes/results received to be able to make conclusions about the successful or technically feasible implementation of the plug experiments<sup>3</sup>?**

a) How appropriate and transparent are the conceptual models, the selected approval criteria, and methods and in addition the approaches used for the plug experiments from the performance or compliance assessment point of view taking into account that the implementation in WP3 applies the requirements and design basis identified as input data for the design, testing and construction of the plugs and seals experiments and that the WP4 testing and results follow from the plans and the implementation of the related test plans?

b) What are the main uncertainties related to the application of the models and concepts, the testing methodologies and the used approaches in making the evaluation about the impact of the test outcomes on the function/safety functions of the plugs, plug components or component materials?

c) What type of uncertainties, omissions or risks can you identify regarding the data sources (resulting from the models used) and the outcomes from the experiments and the tests carried out or from their interpretation in reaching compliance with the set requirements and eventually the desired/expected initial states for the plugs?

d) What type of expert input and related uncertainties do you identify in the used approval criteria for outcome parameters of the tests and of the experiments? Are the uncertainties transparent in the reporting?

e) Is the results data use in performance or safety assessment (PA/SA) directly possible or do the results present an intermediate outcome in the data production chain for compliance assessment of the design basis? If the result data cannot be directly applied to PA/SA, what would need to be done to make use of the results for this purpose? (see also PA2 c.)

f) What type of uncertainties in terms of the plug performance in relation to the expected DOPAS experiment outcomes do you identify in the testing, data and analysis of the results in D4.4?

<sup>2</sup> Performance assessment in this context does not have the same meaning as in DOPAS WP5/PAMINA project where an indicator of performance is e.g. dose. Performance assessment in WP3-4 looks at whether the plug or a component or a method meets the overall function it is intended to do or if it meets a specific safety function. In some of the DOPAS concepts the plug itself does not have a direct safety function (see D2.4 report for details).

<sup>3</sup> the ELSA project is not included as a part of the WP4, but assessment about the applicability of the WP4 results for the ELSA project can be made





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Please consider this only in the context when assessment of long-term safety features are included for the experiment, its component or materials or highlight those uncertainties that could influence the long-term safety, too.

**PA2. Role of the expert input and output in the data use and interpretation of the results from the experiments: about the initial state for the performance assessment and for the safety case (consider this also in the context of the reference design, not only in the experiment design context, if possible).**

a) What are the main uncertainties and possible biases related to the collection and interpretation of data resulting from the experiments? Does the D.4.4 provide evidence of the relevance, accuracy and quality and quality assurance of collected experiment results?

b) What type of role and influence does expert input have in the analysis and assessment process where the DOPAS requirements and design bases have been applied and tested to the experiment design instead of the reference design? How did the results achieved and reported in D4.4 change the underlying assumptions related to the experiment design vs. reference design. Are the conclusions in the D4.4 about this warranted and justified based on your experience?

c) What type of uncertainties in terms of the plug performance and long-term safety features do you identify related to the fact that the experiment design bases and experiment designs differ (to some degree) from the reference designs for the plugs? Please consider this only in the context when assessment of long-term safety features is included for the experiment, its component or materials.

d) What kind of assessment about the completeness of the experiment design in respect to the overall objectives of demonstrating compliance of the design basis with a) the reference designs and b) with the experiment designs now after the test results from the experiments are available, can be made about the work reported in D4.4? Is your assessment in alignment with the D4.4 assessment conclusions?

**PA3. Preliminary assessment of the adequacy of and uncertainties in the design solutions made including materials, testing plan and implementation of monitoring system and construction methods including location and other "tools" used for coming up with the experiment objectives and/or plug or seal initial state. Adequacy of the above for use or application in safety case / performance assessment?**

a) What is your opinion on the adequacy and suitability of the applied design/s including used materials and different components of the design for the desired performance of the plugs/seals at the initial state and potentially in the long-term<sup>4</sup>? Are the choices made in the design and implementation grounded from these perspectives? How about the justifications for the choices based on the assessment of the test results (in D4.4).

b) Is there (sufficient) evidence and what type of evidence in the D4.4 of the adequate design and installation of monitoring systems, appropriate selection of monitoring devices and robustness and quality of collected experiment results? What is the impact on the results affected by the (large) numbers of monitoring sensors?

<sup>4</sup> the lifetime for the plugs in crystalline rock is couple of hundred years, in clay several hundreds to million years and in salt million years plus





- c) Which monitoring data has been highlighted as relevant essential to provide confidence in the plugs/seals performances in the final repository? What is the rationale behind? Do you agree with this selection and rationale? Why/Why not?
- d) What steps would need to be complemented in the descriptions of D4.4 to present a useful process for demonstrating consistency with the state of the art of such repository components in respect to their design, testing and construction? Do you see them adequate to achieve the expected or set objectives for assessing the plugs experiments and/or the objectives set for them? On what grounds?
- e) What type of constraining factors have been taken into account and which approaches or methods have been used to tackle the constraints in the assessment and evaluations made? Are these adequate when keeping the set objectives of the experiment/s in mind?
- f) Do you feel any additional doubt concerning the adequacy of the produced experiment itself or its outcomes for carrying out a performance assessment or using the outcomes for a safety case based on the D4.4 analysis? (see PA1 e.) Are there difficulties in handling the identified uncertainties in performance assessment or in the assessment of other compliance with the requirements? If so, about what and why, what are the reasons?
- g) What type of uncertainties or reductions in quality of outputs can be identified from the presented D4.4 solutions with regard to the technical performance 1) within the time frame of DOPAS project, 2) with regard to the expected performance at initial state or 3) with regards to the long-term safety related performance? Please take into account the different objectives and lifetimes of the various individual experiments in their respective repository concept or otherwise as e.g. some experiments represent only technical feasibility testing.
- h) What is the influence of the results from the WP4 testing and assessments and how can they be used to improve the state-of-the art of performance assessment processes and results, and the overall understanding of the initial state<sup>5</sup> of the full-scale plug or plug/seal components?
- i) Is there any possible bias for performance assessment and technical feasibility in the transposing of the testing results methods and experience gained from an experimental pilot project to an industrial-scale operation? If so, how to prevent them?
- j) What are the conditions in the repository environment to be expected underground, which may have a more severe influence compared to those prevailing on the experimental test site from the performance and long-term safety point of view? How could they possibly influence the plug/seal performances at different stages of this subsystem evolution?
- k) Could any identified inadequacies in the implementation (construction of plug/seal) influence the desired performance (or the performance assessment results) and the compliance with the desired initial state of the plug/seal (as defined in the safety case)? If so, in which ways?
- PA4. Rationale for lessons learned, conclusions, and suggestions from the experiment implementation from both technical and long term performance point of view.**
- a) What judgment would you make on the conclusions and lessons learned from the technical

<sup>5</sup> the state in which the plug (or its component) is after the last man-made action targeted to the plug and its near-field





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performance, test results, and long-term performance point of view related to the design, materials used, monitoring parameters chosen and results achieved? What uncertainties do you identify at this state of the process related to them?

b) How have the lessons learned and the results from the DOPAS project learned to date contributed to the ability of plugs and seals designs to meet safety functions specified in disposal concepts? (DOPAS contribution to the current body of knowledge?)

#### **Challenges in producing the report itself and its completeness**

PC1 Have there been identified difficulties / what were the difficulties possibly encountered in producing the report and its results what were / might have been the reasons for the difficulties? Are these transparent in the D4.4?

PC2 Is the information provided in the report adequate for any future plug and seal system developer to benefit from the lessons learned and experience gained by the DOPAS project partners throughout the development process? What is especially transferable to a seal system developer?

PC3 Does the report contain relevant recommendations on the organisation, resources and competencies needed to plan for, design and implement and test a plugging/sealing system and its performance?

PC4 What areas do you see that need complementing in the design, material development, instrumentation/monitoring/test planning, results collection and interpretation, quality aspects, and construction sections of the report? On what grounds?

#### **Universal applicability of the results in repository implementation**

PU1 And what parts of the experiment implementation experiences could be universally applied to all types of plugs/seals' development, testing, and construction work? What parts cannot be applied? And on which grounds?

PU2 What type of broader application potential do you identify for the results and the work presented in D4.4 in your field of expertise (PA/SA) beyond the plugs/seals subsystem?

PU3 To what extent could the testing and assessment work done in these experiment works be used for other repository components than plugs and seals (from the performance and safety assessment perspective)?

PU4 Could possible inadequacies in the work process influence the desired performance (or the performance assessment results) and the compliance assessment with the set requirements for state of the plug/seal (as defined in the safety case)? If so, in which ways?

PU5 What type of uncertainties do you see remaining related to the chosen test parameters and technical feasibility and other selected approval criteria as an input in the analysis for making the report's conclusions? How has this been tackled in the reported work?

#### **Rationale and way of thinking underlying your preliminary assessment (previous)**



PR1 What are the assumptions and grounds<sup>6</sup> underlying your assessment?

PR2 Did you experience difficulties in making your assessment? If so, what kind of difficulties and for why? What were the reasons?

PR3 Do you feel any doubt concerning the adequacy of your assessment? If so, about what and for what reasons?

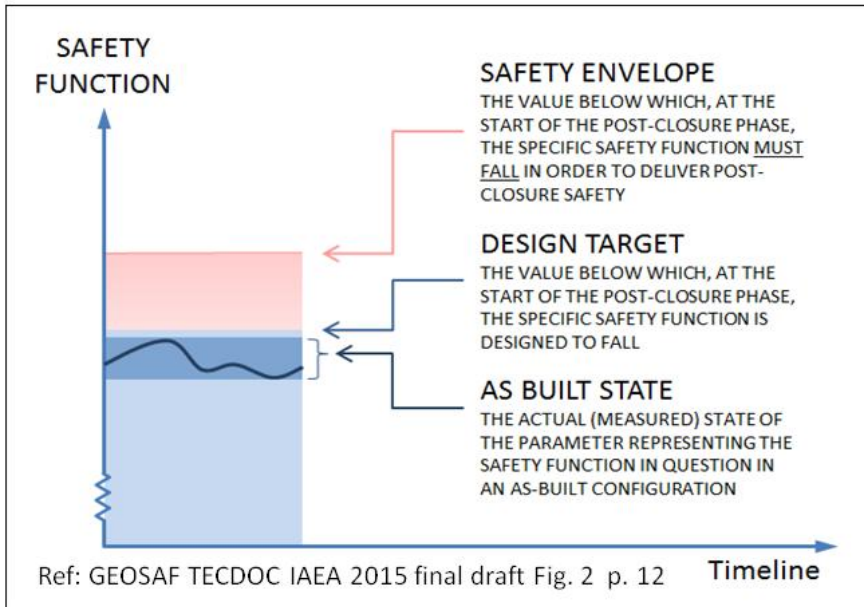
**Other review comments related to the D4.4 (e.g. other information to be included to the report concerning terminology, theories, referencing to other work related to plugs and seals**

**What is your assessment of the technology readiness level (TRL<sup>7</sup>) of the plugs/seals based on the D4.4 report?**

**Feedback on the EE process and the form:**

This is a pilot process. What are your proposals for changes or additions concerning the questions and visual appearance of this form, needed for improving the usability of the form as a tool in the formal expert elicitation process of this type of full-scale demonstration project?

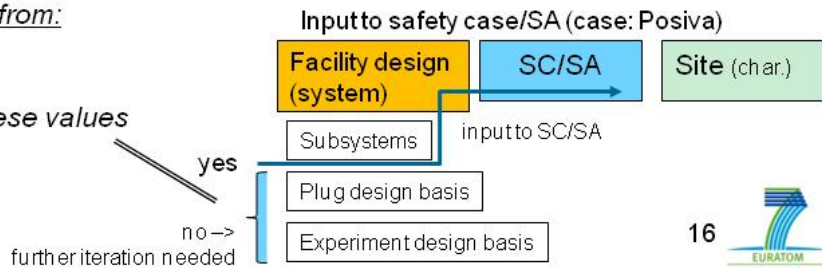




Appendix 3

15.6.2016

Approval criteria derived from:  
 defined safety envelope  
 defined design target  
 ⇒ is the as-built within these values  
 ⇒ initial state achieved





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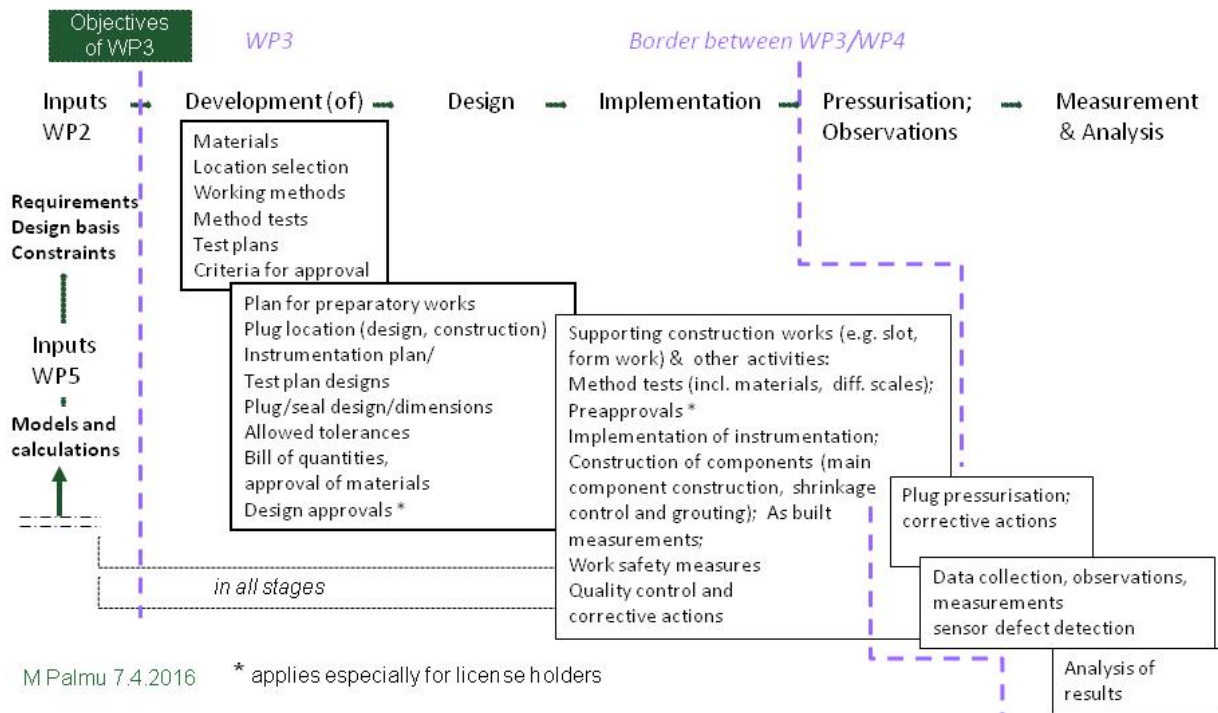
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## Appendix 4

### Simplified structure of lessons learned from work done in WP3



Applicable for basic design phase experiments extracted from DOMPLU, POPLU, FSS

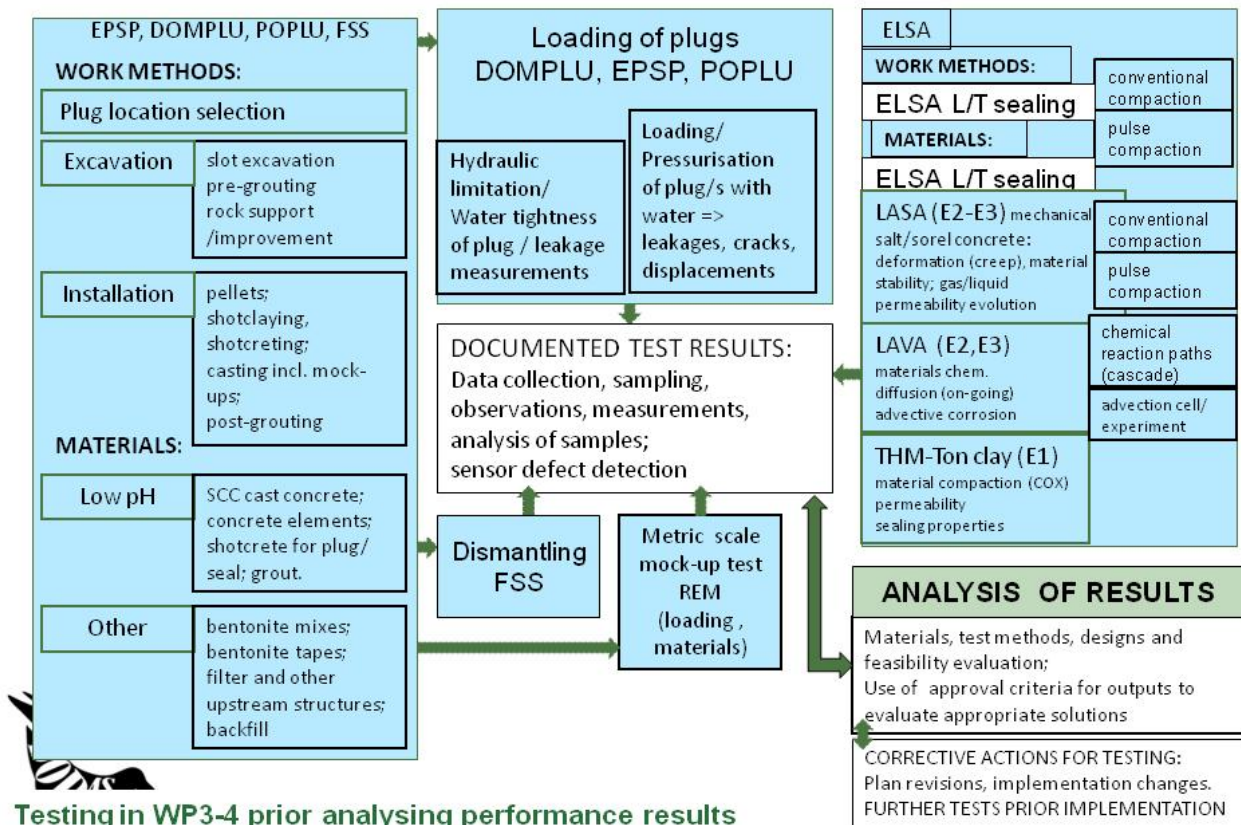


## Appendix 5-1

### DEVELOPMENT, DESIGN, IMPLEMENTATION, AND ASSESSMENT

M Palmu & al. 29.6.2016

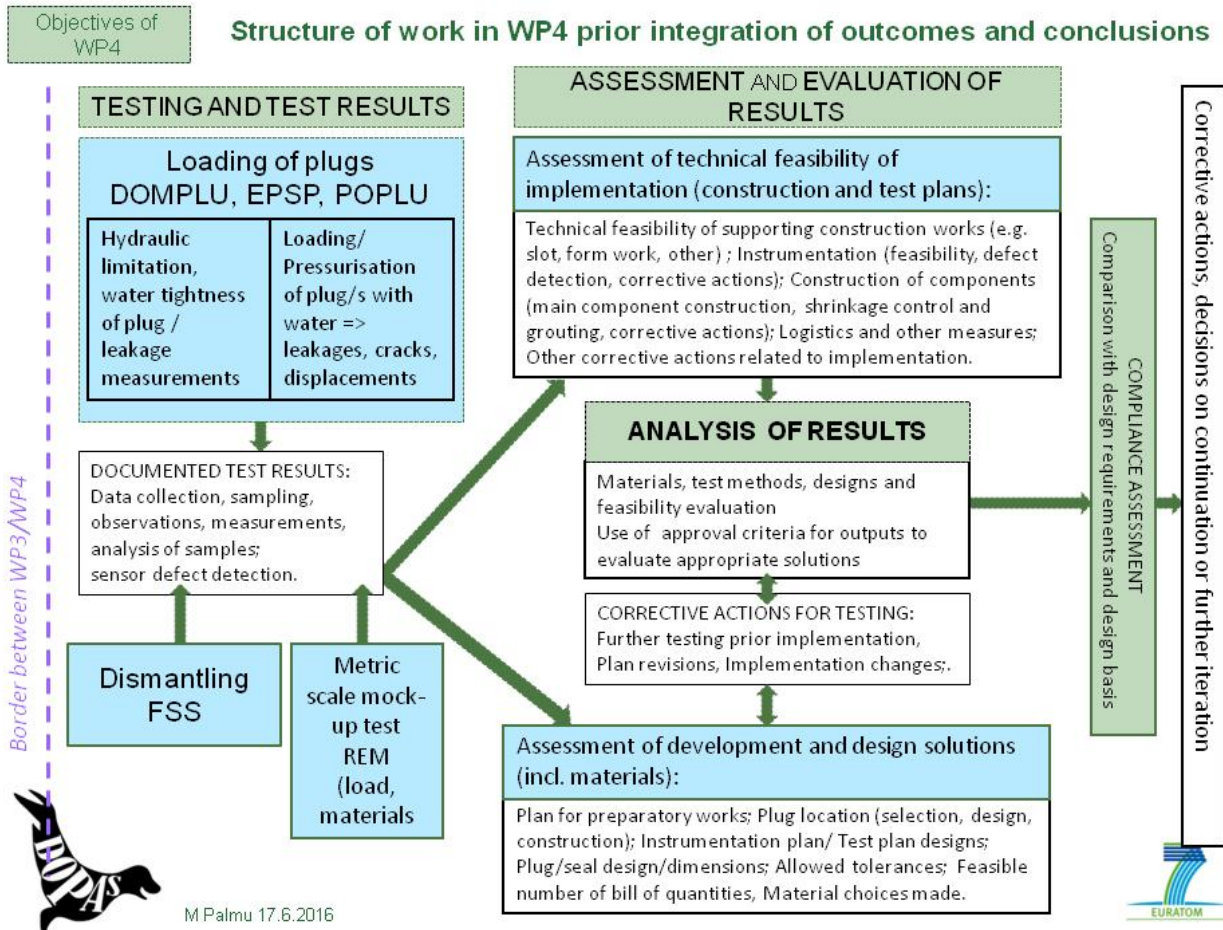
#### TESTING AND MOCK-UPS, TEST RESULTS (INCL. SELECTION)



Testing in WP3-4 prior analysing performance results



### Appendix 5-2







### Appendix 6 1(2)

Figure 1 Schematic of DOE Technology Readiness Levels

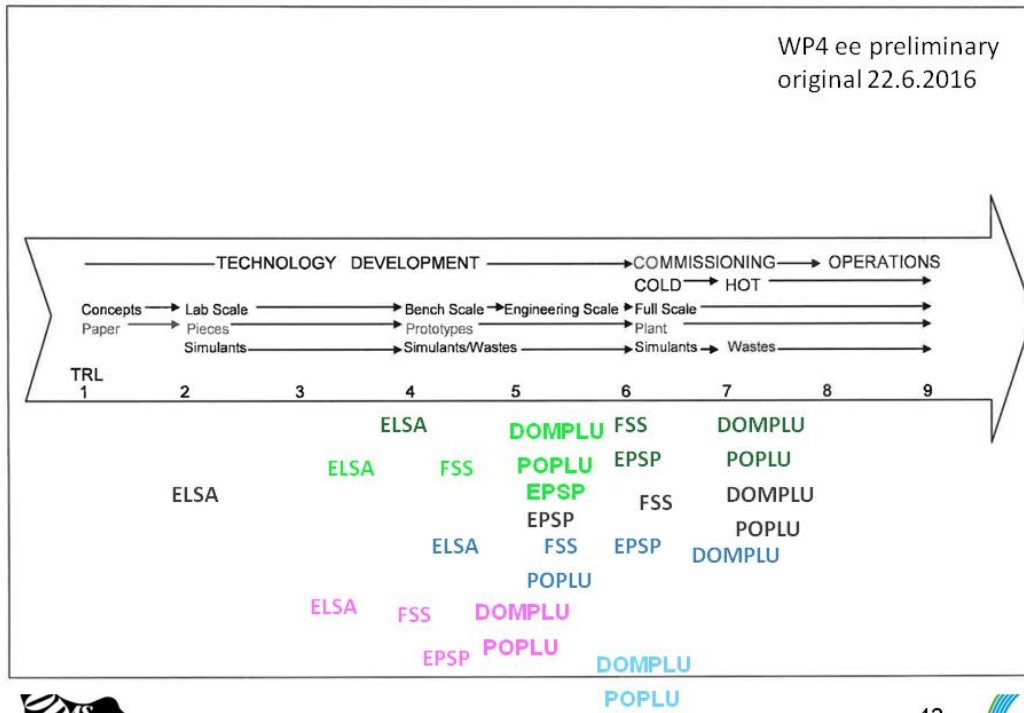
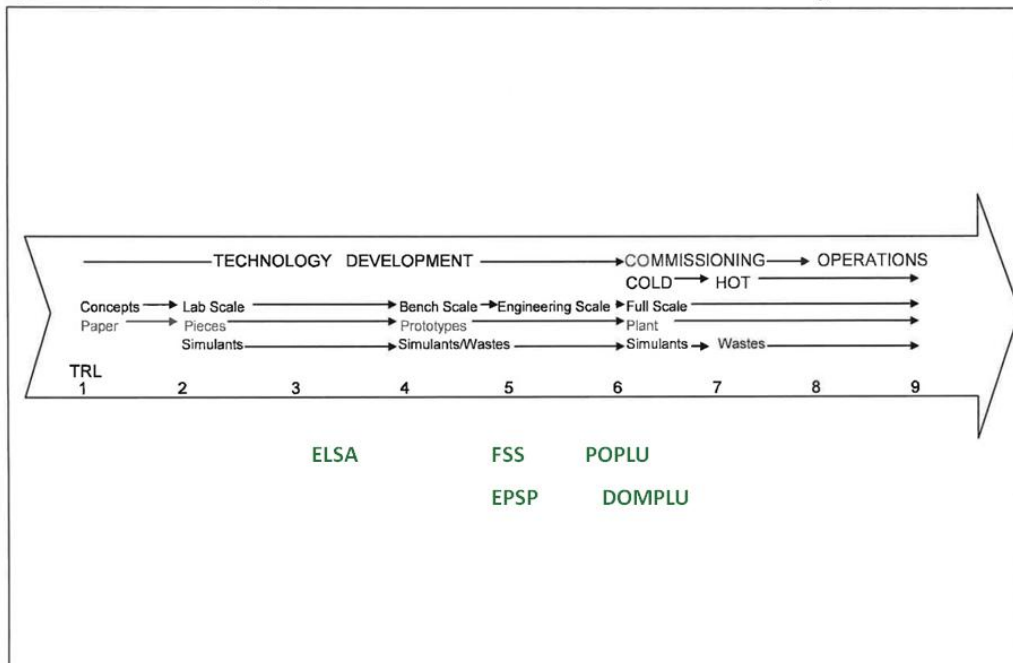


Figure 1 Schematic of DOE Technology Readiness Levels

WP4 average of assessments







**Appendix 6 2(2)**

**TRL levels shortened (source: DOE 2008)**

TRL level	Short description	TRL level	Short description
9	Actual system operated over the full range of expected conditions (hot commissioning).	4	Component and/or system validation in laboratory environment.
8	Actual system completed and qualified through test and demonstration.	3	Analytical and experimental critical function and/or characteristic proof of concept.
7	Full-scale, similar (prototypical) system demonstrated in relevant environment (cold commissioning).	2	Technology concept and/or application formulated.
6	Engineering /pilot scale, similar (prototypical) system validation in relevant environment.	1	Basic principles observed and reported.
5	Laboratory scale, similar system validation in relevant environment.		

**TRL levels as defined by European commission (H2020)**

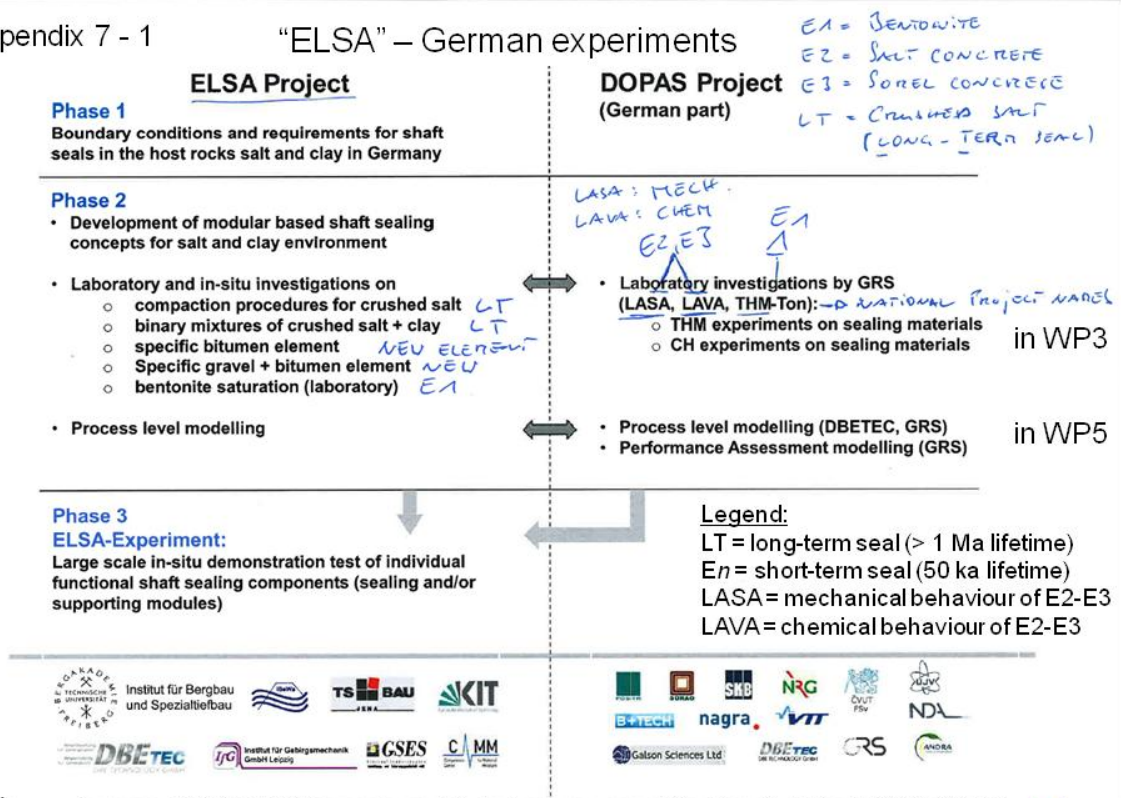
TRL level	Short description	TRL level	Short description
9	Full commercial application, technology available for consumers.	4	Small scale prototype built in a laboratory environment ("ugly" prototype).
8	First of a kind commercial system. Manufacturing issues solved.	3	Applied research. First laboratory tests completed; proof of concept.
7	Demonstration system operating in operational environment at pre-commercial scale.	2	Technology formulation. Concept and application have been formulated.
6	Prototype system tested in intended environment close to expected performance.	1	Basic research. Principles postulated and observed but no experimental proof available.
5	Large scale prototype tested in intended environment.	0	Idea. Unproven concept, no testing has been performed.



**Appendix 7**  
1(2)

Appendix 7 - 1

“ELSA” – German experiments



Source: DOPAS 2016 seminar, M. Jobmann, modified by A. Rübél (20.6.2016)

Context of ELSA (1/2) added 30.6.2016





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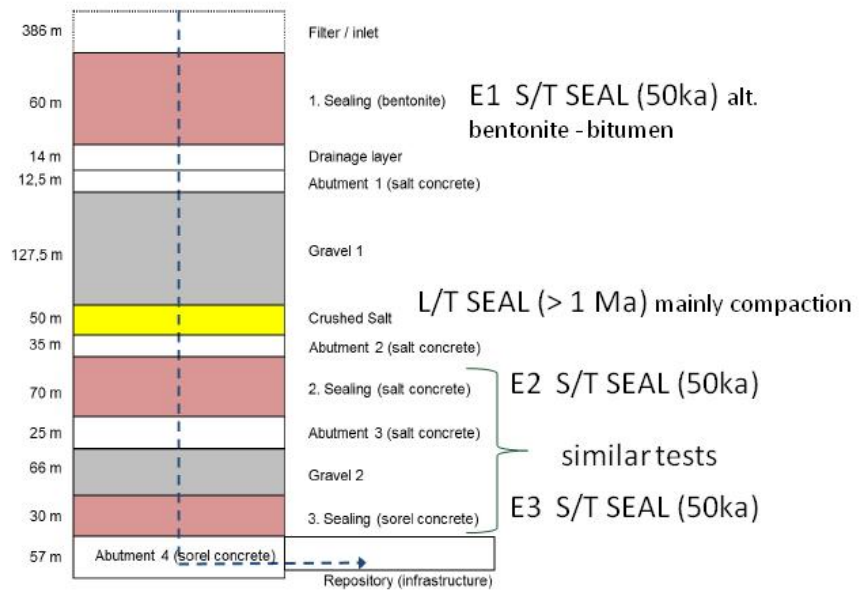
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## Appendix 7 2(2)

Appendix 7 - 2

# Schematic test model for the shaft sealing

Context of ELSA (2/2) added 30.6.2016



M. Palmu 29.6.2016

Source of test model: D5.10, p.125, see also Fig. 6.1 in D3.30  
See previous slide for details of seal types

