EUROPEAN COMMISSION

Community Research

DOPAS

(Contract Number: FP7 - 323273)

Deliverable n°6.3.1

Consensus memorandum for D3.30 Expert Elicitation

EE documentation from Expert Group EE meeting inputs and outcomes concerning Work package 3 final deliverable's Expert Elicitation

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Date of issue of this report: **31 August 2016**

Start date of project: 01/09/2012 Duration: 48 Months

Project co-funded by the European Commission under the Euratom Research and Training Programme on Nuclear Energy within the Seventh Framework Programme		
Dissemination Level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the partners of the DOPAS Project	
CO	Confidential, only for partners of the DOPAS Project	

EURATOM

Scope	Deliverable n°6.3.1 (WP6)	Version:	1.0
Type/No.	Public Memoradum	Total pages	44+App.
		Appendixes	8
Title	EE documentation from Expert Group EE meeting inputs and outcomes concerning Work package 3 final deliverable's Expert Elicitation	Articles	11

ABSTRACT:
This memorandum summarises the quality assurance outcomes of the expert elicitation that was carried out for the DOPAS Work package 3 final report draft D3.30 dated 29 February 2016. The elicitation was carried out during 5 April 2016 to 15 July 2016. The final deliverable was produced in 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 WP3 elicitation experts Frédéric Bernier, Fernando Huertas Ilera, Antti Ikonen, Arjen Poley and Jan-Marie Potier by 14 July 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 WP3 final report D3.30 - Consensus meeting on 15 June 2016

Date	Wednesday 15 June 2016 from 8:30-19:00 hrs
Place	ECN Amsterdam office, Radarweg 60, 1043 NT Amsterdam (Sloterdijk), The Netherlands, Radarsaal nr.2.
Present	Frédéric Bernier, FANC (PA expert) Jean-Michel Bosgiraud, Andra (WP3 leader, observer) Fernando Huertas Ilera (Domain expert) Antti Ikonen, Saanio & Riekkola Engineering (Domain expert) Marjatta Palmu, Posiva Oy (EE facilitator) Arjen D. Poley, NRG (PA expert) Jan-Marie Potier, Advisor (Domain expert)

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 Work 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.

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.

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 WP 3 "*Design and technical construction feasibility of the plugs and seals*", the development, design and implementation process description was produced as the starting point in addition to the design basis development workflow description already produced in D2.4 - *WP2 Final Report*. 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 WP3 EE Consensus Meeting memorandum present the outputs of the expert elicitation carried out on the DOPAS WP3 final draft deliverable D3.30 "WP3 Final Summary Report - *Summary of, and Lessons Learned from, Design and Construction of the DOPAS Experiments. Design Basis for DOPAS Plugs and Seals*".

1.2 About DOPAS Work package 3

The DOPAS WP 3 had the following objectives according to the project's description of work.

- To (further) develop a comprehensive design basis for the in-situ demonstration experiments planned in the France (FSS), Czech Republic (EPSP), and Finland (POPLU);
- To carry out large/full-scale tests (EPSP, FSS) in underground rock laboratories or mock-up drifts, and URCF ONKALO (POPLU), proving that the stated reference design, which is used as subsystem justification in the license applications for the final repositories, fulfils the requirements and can be implemented on an industrial scale;
- To monitor full-scale demonstration (DOMPLU) at Äspö HRL and

- To address seal plug materials with respect to long-term behaviour[1], providing experimental data needed for numerical simulations in order to demonstrate material suitability.

The objectives were further refined for the experts in the background material provided for them to address the work done on the development, design and implementation of the three full-scale plug/seal structures and the work methods (compaction) and materials developed for the ELSA experiment.

WP3 plan includes the production of a total of thirty-two different deliverables including D3.30 Final Summary Report. The following deliverables had been published by the time the elicitation was started:

- *DOPAS D3.8 Test report on FSS cast in-box concrete (incorporating the low-pH concrete formula report D3.4 and the laboratory performance report D3.6 of this material);*
- *DOPAS D3.9 Test report on FSS test panel for shotcrete (incorporating the on FSS metric core emplacement test report D3.7);*
- *DOPAS D3.10 Drift model FSS construction report;*
- *DOPAS D3.11 Report on FSS cast concrete plug construction;*
- *DOPAS D3.16 Testing plan for EPSP laboratory experiment;*
- *DOPAS D3.17 Interim results of EPSP laboratory testing;*
- *DOPAS D3.22 DOMPLU experiment* and
- *DOPAS D3.26 URCF RSC work memorandum (POPLU).*

These reports were also distributed as a background material to the experts for the elicitation of D3.30 together with the D2.4 *WP2 Final Report*, revised version.

An additional draft of the EPSP experiment report planned for publication was also distributed:

- *DOPAS D3.19 EPSP Functionalities demonstration.*

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 D3.30, the background information is available and referenced in other public deliverables of the DOPAS Project.

Since some reorganisation of tasks had been agreed between the WP3 and the WP4 (*Appraisal of plug and seals system's function*) during the course of the DOPAS Project, not all monitoring and test plan descriptions were included in the WP3 materials with the exception of

[1] meaning post-closure period (including the stipulated assessment period depending on the lifetime) of the repository. The absolute time is dependent on the national legislation and repository concept.

the DOMPLU experiment (and complemented in the D4.3 report). The monitoring and test plan descriptions for the other three full-scale plug/seal experiments were included into the deliverables of WP4 - mainly in the detailed and public experiment summary reports of WP4 (D4.5, D4.7 and D4.8).

The 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;
- The D4.4 *Integrated report* that was originally foreseen for publication (in December 2015) prior the D3.30 report and only one of the two planned experiment summary reports delivered under WP4 was available as background information for the experts working with D3.30 report elicitation. This was a partial result of the reorganisation of the work between the two Work packages 3 and 4;
- Due to the work in progress regarding part of the background reports in both WP3 and WP4, the report did not have a clear referencing baseline to all of the relevant background reports and the information provided in the D3.30 was based on the common data freeze date in December 2015 that was agreed by the consortium;
- WP3 is an intermediate work package focussing on the design and implementation of the experiments. This work is then followed by the assessment in WP4 and WP5 on how well the experiments succeeded in reaching their objectives. Therefore, the expert judgments on the design and construction needed to be based on the information available at the selected time and stage of the experiments without the related performance outcome information;
- It was especially challenging to address the objective of making judgments about the "completeness" of the D3.30 as a stand-alone report but having still a summarizing and not a too detailed content for the potential reader due to the above reasons.

1.3 Target of WP3 elicitation

The WP3 D3.30 target of elicitation was defined as:

"Is the D3.30 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?

The elicitation's focus is to assess the completeness of the constructed experiments in relation to the objectives set for them as described in the report. In addition, the elicitation should identify potential uncertainties, ambiguities/deviations and controversies in and between plug/seal experiment/s' input data, the design, test/monitoring plan, and construction implementation that could prevent reaching the desired initial state of the plug/s (and seals, where applicable) in the repository.

Further the elicitation aims to look at

- the application and implementation of the requirements and design bases developed for the experiments in the design/s (incl. materials used) produced for the experiment/s
- the construction solutions used to carry out the design/s including the needed components and their role in the technical performance of the plug, the construction supporting activities (like ground improvement, grouting) and test plan / monitoring solutions
- the appropriateness of the report 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 initial state in respect to the report content and 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)
- 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 WR2008-66, 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 early April 2016 to June-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 5 April 2016, the experts' review results were produced by end of April and the consensus meeting was held on 15 June 2016 with the draft minutes out on 7 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 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.

Mr. Frédéric Bernier, Performance Assessment/Safety Assessment Expert, works at the Belgian regulator FANC (Federal Agency for Nuclear Control since 2007 in charge of geological disposal. He has worked at the Belgian research organisation SCK.CEN since 1992. First he worked with thermo-hydro-mechanical aspects in disposal, in the Belgian HADES underground laboratory since its construction e.g. as the manager of the PRACLAY heater test and in shaft sealing in-situ experiment, and then as scientific manager of EURIDICE consortium. He has also coordinated and worked with several Euratom projects related to the use of clay materials for disposal and participated in international working groups (at IAEA), steering committees and peer reviews e.g. of the Finnish Radiation and Nuclear Safety Authority STUK.

Mr. Fernando Huertas Ilera, Domain Expert, has a M. Sc. in Engineering Geology and has worked in nuclear waste management since 1980. He worked for Law Engineering Testing Company in the United States prior joining the Spanish waste management company ENRESA in 1986. There he worked in a managing position until his retirement in 2009. Mr. Huertas has worked with the development and design of disposal and the engineered barrier systems in salt, clay and granitic host rock environments in a multitude of different design and experimental projects. The latest projects prior his retirement included the FEBEX experiments and the Euratom ESDRED project (Engineering Studies and Demonstration of REpository Designs).

Mr. Antti Ikonen, M.Sc., Domain Expert, is director of Nuclear Waste Management (NWM) Services at Saanio & Riekkola Consulting Engineers and works also as a project manager in several NWM projects. Mr. Ikonen has more than 20 years of experience and wide range of knowledge in NWM from L-ILW to high level waste (HLW) and spent fuel disposal facilities both in consulting and in Posiva, a Finnish waste management company, where he was in charge of the feasibility and initialization of underground rock characterisation facility (URCF) ONKALO project. He has participated in all stages of Posiva's waste programme from site investigations and site selection process through environmental impact assessment and decision making process in the design, building and commissioning stages.

Mr. Arjen Poley M.Sc., Performance Assessment/Safety Assessment Expert, is the team manager in Decommissioning and Waste Management at NRG, the Dutch Nuclear Research and Consultancy Group since 2006. Before, he has worked with risk assessment of nuclear power plants in the 1980s, in waste management e.g. in the Asse mine (Germany) safety case work for ten years and in various European waste management projects, including ESDRED, dealing with salt and clay disposal concepts. He was for the first time engaged with the compaction of salt based materials in 1996 in the BAMBUS project (FP5). He has worked in developing and supporting the Dutch national waste management programme OPERA (studying both clay and salt disposal concepts) since 2006. Mr. Poley has been a participant in the review of several research works and reports for the European Commission, OECD/NEA and the IAEA.

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 WP3 EE process
2. Working during the day - Discussions and proposed modifications
3. General findings and improvement suggestions to the WP3 D3.30, the way forward
    3.1 General findings and their handling

3.2 Findings related to individual experiments
3.2 Improvements to the report
4. Discussion about the technology readiness of the experiments (TRL)
5. Refinement of the contextual and structural descriptions
6. Timing of approval of consensus meeting memorandum
7. EE process - experts' experiences from the process and feedback
Closing

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

These 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 point 3 on the consensus meeting agenda.

As a result a total of around 100 comments were received from the five experts, several of the comments were overlapping. A part of the comments related to the need to ensure that the topic in question was covered in the other consecutive DOPAS Work package summary reports (see Chapter 7). The 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 findings	103	The overall general comments included both favourable and improvement comments about the report itself. These will be included into the text D3.30 and into the conclusions of the experiments to the degree they have not yet included in the report. Further these general findings will be used in the final project summary report D6.4 with the referencing to their original source when applicable.
Experiment specific findings	95	The specific experiment findings complementing the above will be addressed in connection with the experiment descriptions in D3.30.
Improvement recommendations for D3.30 both included in the general findings and in their	59	The general findings included improvements that are intended to put the report and the described experiments into their relevant contexts and to highlight a need for clarity and referencing in the text

Types of inputs	**Number of comments**	**Additional information and the handling of comments**
recap in the consensus meeting		to other DOPAS work to assist the reader in achieving the overall picture of the scope of and the work done in WP3. These improvements also address any potential misunderstandings and contradictions in the experts' comments caused by the report text, and include highlighting omissions that still need to be included so that a reader can have a sufficiently full picture of the work and about its basis. Also direct recommendations to correct factual errors are included. The overall improvements are detailed in subchapter 4.2.
Experiment related findings that are generally more specific or editing related:		T = indicates the total number of comments and I = indicated the comments in the total number recommending improvements to the report/reporting. The experiment specific expert findings and recommendations are covered in Chapter 5 and the specific improvements to experiment related text complementing the Chapter 4.2 improvements are included in Chapter 5 subchapters for each experiment separately:
FSS	T = 24 I =17	in Ch. 5.1
EPSP	T = 19 I = 16	in Ch. 5.2
DOMPLU	T = 15 I =9	in Ch. 5.3
POPLU	T = 21 I = 9	in Ch. 5.4
ELSA	T = 16 I = 12	in Ch. 5.5
Controversial findings between experts	2	Two areas were discussed where the original findings of the different experts were not in alignment. Common solutions for these were agreed as explained below. These areas were: 1. Modifying report structures vs. adding

Types of inputs	**Number of comments**	**Additional information and the handling of comments**
		sufficient cross-referencing vs. adding clarifying text into the report; 2. The systematic application of the D2.4 workflow process to the WP3 work. This is discussed also in subchapter 4.1.
Structure of report		The handling of the report structure as noted above: Recommendations were given to revise the report structures of D2.4, D3.30 and D4.4. This was discussed and the conclusion was to complement the report information, but not to change the structure itself also because the D2.4 has already been finalized in the project.
Application of D2.4 design basis development workflow		The D2.4 workflow was developed as an outcome of the DOPAS Project and at the same time the individual experiment designs were developed based on the different waste management programme's individual approaches. Thus the WP3 work was carried out simultaneously and the application was not timely in the DOPAS Project.
Omissions from the D3.30		The detailed test plan descriptions and their justifications for FSS, EPSP and POPLU had been shifted to WP4 and D4.4 resulting from the reorganisation of the work between WP3 and WP4. Any minor needs for complementing the report are addressed in the specific improvement comments in the sections of subchapter 4.2.
Terminology and abbreviation comments	3	Reference to IAEA glossary (2013) is needed; Specifics: e.g. plug/seal definitions are needed; List of abbreviations requires complementing for completeness.
Areas of similar change comments by the experts	3	All of the experts commented on the difficulties to compare the experiments with each other due to the different stages in which the experiments were in. This was clarified by providing the experiments the relevant context using the design basis

Types of inputs	Number of comments	Additional information and the handling of comments
		development workflow. Further the ELSA experiment description requires clarification for understanding the full scope of the work within DOPAS. The traceability and justification for the selection of the requirements required clarifications. This is achieved by more (detailed) referencing to other DOPAS work and improves the transparency.
Improvement by using the GEOSAF concepts of the safety envelope and design target as additional tools for DOPAS Project	1	The GEOSAF IAEA TECDOC 2015 work was recognised as a tool to come up with the approval criteria for the experiment results in the basic design stage. This concept would enable the comparison of the design targets to the as-built of the experiments especially in WP4. For conceptual design, the concept is useful with the aim to define the safety envelope (and potential design targets) for the individual reference plugs/seals and their components. The concept as discussed in the elicitation meeting is presented in Appendix 3.
Table for tracing the safety functions of the design and their components one by one	1	A suggestion was given for an additional table to address the designs by each component and safety function. Another suggestion was given in the meeting to move some D4.4 tables to D3.30, but this was not considered feasible at this time of the DOPAS Project. Thus improved cross-referencing was considered the appropriate solution. A suggestion for a simplified table to address the choice of the design components was agreed.
Development, Design and Implementation process structure	1	A simplified work process structure that was produced for the WP3 EE kick-off meeting was modified already in this meeting and approved after the meeting as a part of the kick-off meeting notes. This structural description is presented in Appendix 4.
Description of the experiments related	2 descriptions	For the WP4, a consecutive description of the work was produced including all the

Types of inputs	Number of comments	Additional information and the handling of comments
to WP3 and WP4 input and outputs for performance assessment	were worked during the meeting	tests and experiments and their assessment. This was presented at the D3.30 elicitation to clarify the context of the WP3 further. In the preparation process, the facilitator noted that an additional description to include the WP3 tests carried out was needed for a comprehensive picture. Both of these descriptions were discussed and further modified in the WP3 EE consensus meeting and included in Appendices 5 and 6. WP5 elicitation produced complementary information on the scope of ELSA experiment in DOPAS Project. Appendix 7 includes a draft for clarifying the ELSA experiment. Also this information is included into the consensus memorandum even though this information was not handled in the meeting.
Factual corrections and editing comments	various minor comments	These are mentioned in connection with the individual experiments and also handled directly by the main author of the D3.30 report based on editing comments made directly to the D3.30 final draft.
To be considered in future WP reports	13	Listed in Chapter 7.
Proposal for work outside the DOPAS scope	1	To study the potential use shotcrete in POPLU and DOMPLU as plug construction material based on the EPSP experiences and also on other existing state-of-the-art.

4 Main comments and outcome of their handling as input to D3.30 draft 1 v.4

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

The experts found the D3.30 report in general to cover the contents of the work carried out in the WP3 and the main WP3 the objectives of the work have been achieved. The information is comprehensive and detailed enough to identify a number of positive achievements contributing to the design basis validation.

The work described in the report improves or strengthens the reference designs/design basis taking advantage of the lessons learned, which are well covered in the report. The more advanced and more detailed the designs are, the better fitted they are for input for the safety case/s and less uncertainty is related to the designs.

The experts' reminded about the overall DOPAS work context limitation that each plug or seal is treated as an independent (stand-alone) component a) which in itself is a complex entity consisting of several components and b) which in the real repository setting is part of wider complex engineered barrier subsystems and of the overall repository system with many interactions and couplings. The direct interaction to the adjacent host rock, and its safety function and quality have been discussed in D2.4 (*Factors affecting design basis*) indirectly by addressing the required host rock characteristics and the factors influencing e.g. the safety-critical functions.

For the D3.30 reporting a set of key requirements were chosen to be included from the WP2 into the D3.30 descriptions of the experiments. Major safety functions have been described in the D2.4 and the detailed requirements in D2.1 deliverables of WP2. The transparency of their referencing requires improvements in the D3.30 as the long-term requirements have not been addressed as key requirements in D3.30 report.

It was noted that the work presented in the WP3 does not systematically follow the workflow developed in D2.4. In the discussions it was clarified that this workflow is an outcome of the DOPAS Project work and therefore its systematic application was not possible as the WP3 work was carried out simultaneously with the development of the generic design basis development workflow. Regarding the use of this workflow in the future it needs to be noted that each step is multifaceted incorporating many tasks. Therefore moving to the next step in the workflow requires the formal validation of the previous results according to the developed quality plan.

The workflow was identified as a useful tool in the future design basis development of the plugs and seals. The systematic application of the workflow process as a part of the management system and uncertainty management in the future contributes to assuring the quality of the input for the safety case. This was considered an important lesson from the work by the experts.

In addition to the workflow, 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 was discussed and recommended for future use (see Appendix 3).

Due to internal reorganisation of the work, the monitoring strategies and test plan justifications and information (with the exception of DOMPLU experiment) are included in the WP4 reporting dealing with the performance assessment of the experiments and their results.

All aspects of material selection were found to be covered and the materials have fulfilled and successfully reached their set objectives. The materials selection was successful in the experiments and the analysis of how the lessons learned influence the future industrial context of the repository is useful together with the most of the material related conclusions in D3.30.

In the D3.30, the work related to the materials developed and selected for the experiments is addressed from the relative short-term perspective as the scope of this work package addresses only the design and construction of the four full-scale experiments. The choices in design and materials have mainly been based on the attaining the initial state of the experiments and intended performance during the experiments' run-time. Areas of materials development where also the long-term is considered relate to the tests for dry density and swelling pressure of bentonite (in FSS, EPSP and DOMPLU) and to the use of low-pH concretes (in FSS, EPSP, DOMPLU and POPLU).

With an exception, the ELSA experiment's material development addresses also the longer-term material behaviour, but this research was still "work-in-progress" by the time of producing the D3.30 report and is partly covered in WP5 reporting.

Particular attention has been paid to the emplacement of the materials to avoid quality related uncertainties resulting from the construction. The drivers for the selection and use of construction methods are well and transparently explained in the report. Equally, the work safety and logistics concerns have been addressed in the report but working procedures need to be further developed to ensure workers' safety. Attention needs to be paid on the impact on the concrete mix quality and performance due to the long transporting distances of concrete mixes.

The conclusion by the experts is that technology is ready and available to carry out some realistic construction tests of the whole plug and seal systems with in-situ tests and monitoring. One would expect that the solutions developed during these DOPAS experiments might have a better chance of ending-up in the industrial-scale production schedule than any other developments that someone might come up with, even if those were to turn out to be better in the end. A follow-up and benchmarking of others' solution developments by comparing all the solutions that have resulted also from other experiments and their use as a basis for further development, too, is recommended in the future instead of satisfying with the DOPAS experiment results that look at the moment favourable.

However, even though the WP3 full-scale demonstration tests (mainly FSS, DOMPLU and POPLU) were not intended to serve safety assessment directly; their focus is on feasibility of construction; they are able to provide input about the initial state for simulations. The major inputs for performance and safety assessment are included in the scope of the consecutive WP4 work in DOPAS Project.

A variety of constraining factors has been identified and taken into account in the work and challenges related to the work in WP3 have been covered comprehensively in the report's Chapter 7.

The importance of including also lessons learned about when the progress was not as planned was emphasized by the experts and noted the WP4 reporting is also a suitable report to include these experiences.

When looking at the project objectives and using the D2.4 information as a basis and assessing the experiments in relation to the technology readiness, the overall conclusion is: although significant progress has been made, there are still more development steps needed to reach the reference design/s. Some of these developments are reported in following DOPAS Work package reports.

This chapter's following subsections and the Chapter 5 address the more detailed improvements that the experts recommend to be made into the D3.30 report.

4.2 Specific improvements to the report content

4.2.1 Clarifying each **experiment's context in relation to their stage in the design basis development** workflow of D2.4 and the justifications for the selected key requirements

The experts noted that as the different experiments in the DOPAS Project are in different stages of the design basis development, the relevant context of the experiments needs to be given in the report in a clear way to enable better comparison of the experiment results:

- The full-scale experiments FSS, DOMPLU and POPLU are part of the Basic Design Basis development stage as described in the D2.4 workflow for design basis development. For these experiments, the reference design or alternative experiment design requirements have been developed and described in WP2 and the design in WP3 is based on these requirements.
- In contrast to the French, Swedish and Finnish experiments, the EPSP and the ELSA experiments are still at the Conceptual

Design Basis stage targeting to develop the more detailed requirements for their future reference plugs or seals.

The difference in the maturity of the experiments was also noted in the technology readiness level (TRL) assessment made by the experts (in Appendix 8).

To clarify the context and to link the WP2 and WP3 reporting about the safety functions and requirements, it is recommended that the experiment relevant safety functions are described shortly in the existing experiment text with an explicit cross-referencing to D2.4 report and potentially other WP2 reports (D2.1). This is needed for traceability and for finding all of the relevant requirements for each of the three full-scale demonstrations. It is acknowledged that not all the detailed requirements can be addressed in the D3.30 text, but the traceability needs to be ensured with the detailed referencing to WP2 reports.

In this way it is also possible for the reader to differentiate between some requirements that are not originally included into the WP2 requirements but have come up during the work in WP3 (see the experiment specific improvement recommendations for such details).

The justification for the selected "Key requirements" for each experiment is also needed (see also section 4.2.7).

4.2.2 **Existing state-of-the-art** as the starting point of the DOPAS experiment design and construction

Work related to the development of materials and construction of such experiments has been carried out already for decades in the geological disposal community even though not in this scale. However, in the report no referencing is made to the previous experimental work carried out. This relevant referencing is needed as the DOPAS work did not start from a clean slate. For example, the work carried out in the FP6 ESDRED project is one of the reference works on which the DOPAS work is partly building on.

The DOPAS experiments with their set requirements (as described in D2.1) and size of their scale are first-of-their-kind and thus the examples from other industries like mining are not necessarily providing the applicable state-of-the-art in meeting the requirements for these experiments. Experiences in conventional technology from other industries can and have been applied e.g. in the EPSP experiment in the use of shotcreting.

4.2.3 Quality **management system and management of uncertainties** in the experiment contexts

The compliance of the design features with the requirements and the design basis shall be thoroughly assessed and formally established through an internal project review process – this is a requirement that should be specified in the project/experiment's quality management system. All experiments are required to have such a 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 D3.30 results.

Linked with the management system, also the management of uncertainties is not reported or it is not included in this work. See also comments in Ch. 5.3 related to DOMPLU experiment's objective on uncertainty reduction.

In a similar manner, the safety margins are not clear for the experiments. The concepts of safety envelope and design targets (*ref. to GEOSAF final draft IAEA TECDOC 2015* and an extract of the text below for information) and their definition in advance of the experimental work for the basic design basis development increases confidence also in the case that the parameter values change during or as a result of the experiment. This was concluded by the experts to be a lesson learned for and from the DOPAS work.

"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.

This is part of the work that serves as an input to the WP4 reporting and is expected to be found in the D4.4 report.

4.2.4 Comments to improve the **D3.30 report structure** to facilitate the comparison of approaches

The five experiments of DOPAS Project are each treated differently in their relevant part of the D3.30 report. Each experiment description in the D3.30 is recommended to follow a similar structure. This makes the comparison of the results from different experiments easier for the reader.

A suggestion was also made to modify the structures of D2.4, D3.30 and potentially the D4.4 to be consistent with each others, but since the D2.4 report has already been published and D4.4 structure is outside the scope of the WP3 elicitation and is well structured, this proposal was dropped. Time permitting; either the section 5 structure of D2.4 or the D4.4 structure could act as a model for restructuring also the D3.30 experiment descriptions.

4.2.5 **Terminology and abbreviations**

Glossaries

There was a comment made to the lack of definitions of the main key terminology in D3.30 deliverable regarding e.g. "Plug" and "Seal". This is recommended to be included the glossary of specific terminology applied in the report.

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.

Related to the instrumentation of the plugs, it would be useful to explain the term "lead-through holes" or "lead-through" and also the need for the adjacent instrumentation tunnel/location for the instrumentation for the experiment and to use the same terminology throughout the D3.30 report.

In general, in the DOPAS Project it has been agreed that reference to IAEA glossary (2013) 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.

Complementing the list of abbreviations

The list of abbreviations covers only a limited part of the abbreviations stated and used in D3.30. All abbreviations need to be included into this listing.

4.2.6 Input related to the WP3 **structural and test context descriptions**

Simplified structure of lessons learned from the work in WP3 for development, design and implementation of plugs and seals.

A description was produced by the facilitator for the experts as generic description of the development work, design and implementation of the plugs and seals using the input given as an input from the WP2. The description was discussed and modified in the WP3 elicitation kick-off meeting and sent to the experts for comments together with the notes of the kick-off meeting. The context of the structure was further clarified by adding a text and the description is presented in Appendix 4.

Description of **Testing in WP3 - WP4 prior analysing performance results**

The first version of a description presenting the different tests carried out in the DOPAS Project prior the performance assessment of the results was discussed in the consensus meeting. This draft description included both the full-scale experiments and the individual tests related to plugs' and seals' working methods and materials. Several change proposals were made to this description and the changed description was sent for comments and review to the experts as a part of the consensus meeting memorandum draft. The final description is presented in Appendix 5.

Description of the **Structure of work in WP4 prior integration of outcomes and conclusions**

A version of the description presenting the work and tests planned to be carried out in the DOPAS Project's WP4 was also discussed and revised in the WP3 consensus meeting to further clarify the context of the WP3 in the chain of the DOPAS activities. Changes were made to this description, too, and this changed description was sent for comments and review to the experts as a part of the consensus meeting memorandum draft. The final description is presented in Appendix 6.

4.2.7 Referencing needs to explain the **purpose/function of the plugs**

The report D3.30 states:”…*summary of lessons learned from the detailed design and construction of the experiments. These include the full-scale demonstrators, laboratory work and upscaling, and the learning provided by the practical experience in constructing the experiments*”. In this respect the experts concluded that **the D3.30 report does not provide much information on the role/ purpose of each plug/seal component.** Such a description is instead included in D2.4 and referencing to this report is needed for transparency.

4.2.8 Approach to address the function and safety function of the **plug designs** and the components of the designs.

Following from the above findings (in 4.2.7 and also in 4.2.1), the lack of clarity whether the plug designs in D3.30 meet the requirements stated for them in the D2.4 a suggestion was made by the expert to address this in a table format. The suggestion for a clear and systematic summary for compliance assessment is included below as a table:

Summary tables as proposed hereafter could be quite useful for readability:

Experiment name							
Context	Design stage:						
	Iterative step within the design stage:						
	Current conceptual design	Safety functions	Design basis (requirements)	Current Basic design (if any)	Working assumptions	Experimental objectives	Experimental design basis
Component 1							
Component 1							
Component 1							
……							

It was noted that the report D3.30 text is unclear about who has been responsible for translating the WP2 input data to the experimental designs and what type of reviews have been carried out on this work of translating the requirements into design.

In the WP4 D4.4 report, where the compliance assessment and performance assessment is made, the reporting uses tables for compliance assessment that address the individual design basis specifications derived from either the requirements management system or functional analysis, give justification (or function of) for the specification, and then describe the compliance assessment (in several cases the quality assurance) approach, and potentially feedback back to the design basis. In the discussions, a suggestion was first made to move these tables to D3.30 and complement them with an additional information column as in the figure above, but as the performance assessment belongs to the scope of the WP4, this idea was dropped.

Instead it was suggested to simplify the table and to include it into the D3.30 depending on the design basis development stage as summary of the functions and safety functions of each component in the experiment designs as follows:

For the experiments in Basic Design stage:

	Experiment name: FSS/DOMPLU/POPLU				
Context		Design stage: Basic design			
		Iterative step within the design stage: Experimental design			
	Current reference design	Function/ Experimental objective	Safety function/s	Working assumptions	Only used in Experimental design
Component 1					
Component 1					

For the experiments in Conceptual Design stage:

	Experiment name: EPSP/ELSA				
Context		Design stage: Conceptual design			
		Iterative step within the design stage: Development of preliminary design requirements for basic design			
	Experimental design basis for conceptual design alternative	Function/ Experimental objective	Safety function/s	Working assumptions	Only used in Experimental design
Component 1					
Component 1					
Component 1					
……					

Regarding the functions and safety functions of the experiments, the risks related to the hydraulic limitation (containment term was originally used, but limitation was deemed a better definition for the safety function related to the water tightness of the plugs and seals) are dealt with in the components of the FSS and ELSA experiments. For the other experiments, the backfill is responsible for this safety function. Despite of this, also the plugs in the other experiments should function in limiting the water leakages (and this should be noted in the tables above as a function for the experiment and its individual components).

For the D3.30 experiments, the load bearing capacity / mechanical integrity was the second safety function assigned to the plugs and seals that have a safety function. Also the other plugs that do not have a safety function are required to bear the loading resulting from the groundwater pressure and swelling pressure of the backfill with sufficient safety margins.

The objective set for proving that the stated reference design fulfils the requirements for the final repository is an ambitious objective from the outset and since the experiment designs are not yet the final designs, such judgments on the adequacy of the reference design/s are difficult to make at this stage of the development. The further developments towards this objective have been made during the experiments as stated in subchapter 4.1.

4.2.9 **Construction and operations** related findings and recommendations

One area of influence that is not included and not mentioned in the design of the experimental designs is the presence of radiological hazard in the actual repository context in the future. It is absent from the experiments in DOPAS Project, but it may have an impact on the use of the methods now selected as at least some of the plugs are in the vicinity of the waste package disposal operations. It is worth to include this aspect into the conclusions of D3.30 report.

The constraining factors are likely to increase and/or change in the future as the repository layout and the designs are more developed including more detailed definitions of the operational conditions, requirements, and logistic issues. The nuclear safety authorities' increasing oversight role and requirements now and in the future need to be addressed, too.

The quality assurance and control procedures are likely to improve the robustness of construction in the repository (like in POPLU also FSS some reference). Detailed quality plans for the plug emplacement shall be produced and there through they are foreseen to reduce uncertainty in the construction process. The future industrial activities need to be carried out with the same care as in the experiments and the use of other than manual methods can either increase or reduce the uncertainties by either producing e.g. more voids not properly filled or resulting in more homogeneous emplacement methods.

The work safety and related constraints were covered in few of the experiments (e.g. the choice of POPLU slot excavation; dust in bentonite emplacement in FSS and actual requirements for underground ventilation). These also make a lesson for the other future experiments that needs to be addressed. In the actual repository, the working environment and the conditions can be limited in a way that the experiment specific conditions in the DOPAS Project cannot be replicated in the actual repository.

The need for transparency in communication with the contractors and the cooperation in the development of the working methods and related work descriptions is needed to ensure compliance of the construction to the designs. In the design, one needs to recognise that the design is always idealised and that reality is translated to the design implementation by setting up requirements with workable tolerances. In this context the definition of the safety envelope and design target value ranges (ref. GEOSAF) assist in ensuring the compliance of the as-built to the design, too.

One area that has not been addressed in connection with the experiments is the need of resources (personnel, costs) and competences to implement the experiments and the plugs and seals in the future in industrial scale.

4.2.10 Identified **uncertainties** and other experts' inputs

The experts identified several uncertainties related to the experiment outcomes and to the future plugs and seals. Some of these uncertainties are addressed in the previous comments, some are addressed in connection with the experiment specific comments, and the rest of these uncertainties are listed in this section. These uncertainties are potentially already included into the reporting of the WP4 and WP5 reporting, and thus this listing serves as a check list for these two work package reports.

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 realise. The missed water bearing structures may lead to hydraulic bypass of the plug and eventually to faster than intended radionuclide transport through the host rock. There is a need to 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 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[2] 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

[2] Low-level waste

filling of voids and requirement for a smooth surface are limitations of the construction technique causing procedural uncertainty. This can be addressed with strict quality control during the construction.

4.2.11 Editing, technical corrections and detailed clarifications to D3.30

Editing comments are handled as edits into the final report not requiring further discussions. These comments have been provided to the author in a separate file.

Main corrections needed in the D3.30 report relate:

- to checking the units and parameter values related to the densities of the bentonite and using the same units for all the experiments (kg/m^3) in D3.30 and also in the other reports (D4.4 and D5.10 mainly), at least for FSS and EPSP values, and
- to clarify the evaluation basis of the global multicriteria analysis carried out for the FSS experiment (in Figure 2.7 and potentially also Figure 2.5). The name of the analysis is global **multicriteria** analysis (MCA).

Resolution of some report figures - the FSS figure 2.9 (the dimensions), EPSP figures 3.2, 3.5 and 3.7, and ELSA figures 6.3, 6.8, 6.13, 6.16, 6.17, 6.20 - need improvement of their resolution for legibility.

The terminology in figure 3.7 also needs unification with the rest of the terminology used in the D3.30 (lead-throughs). This can be partly dealt with adding clarifications to the legends of the figures.

For POPLU figures 5.6, 5.8 and 5.9, the explanation of the abbreviations on the modelling figures is missing (lithology and structures).

The type of sealing elements for which the compaction experiments are done need to be added to the legends of the figures 6.4 and 6.5 for clarity.

Several areas in the report were identified to lack transparency of choices made. This transparency about the choices made is also required for the application of the alternatives in the safety case. These areas have been highlighted in the report and delivered separately to the main author.

5 Comments related to the individual experiments

5.1 FSS

FSS experiment has been a strong driver for further optimisation of costs, operations and schedule at Andra. The objective related to the industrial feasibility for the FSS experiments have been reached and this has been acknowledged by the French safety authority ASN. The feasibility demonstration included the constructing the seal in full-scale, emplacement of the bentonite and development of low pH concrete materials in industrial scale, and specification and testing of the operational requirements for the clay core emplacement.

Regarding the materials developed, the choices have been well grounded, however referencing to state-of-the-art prior FSS is missing:

- low-pH self Compacting Concrete (SCC) has been developed and tested;
- shotcrete mix has been developed and tested with recommendation on appropriate range of values to work with.

FSS as a mock-up worked in line with the state-of-the-art, the experiences could be extrapolated to a test under natural conditions, and it will help in such preparation of the experiment: confidence has been built on the important part of the structure and some of the information can be used in the safety case (especially from operational point of view). This work is complemented with the REM[3] metric scale test reported in WP4-WP5 reports as the time period for the FSS test does not provide the full saturation of the bentonite swelling core.

Future uncertainties relate to the question of up-scaling and extrapolations of these experiments to real repository conditions e.g. regarding the behaviour of this design component from stability and support needs' point of view. The removal of the liner in the repository (being outside the experiment scope) was already addressed in the discussion, but also other mock-up requirements might not be the same as for the Cigéo reference design.

Neither the description of the development work of FSS test plans for large full-scale tests including instrumentation for monitoring the behaviour of materials nor the referencing to it is included into D3.30 experiment description. Also the approval of the results is not addressed in D3.30. This topic will be handled in the D4.4 report and the referencing to the other reports needs to be included into D3.30. It is essential to mention that the monitoring of FSS is dedicated only for the test run-time of the experiment until its dismantling.

For the future Andra is studying other means of monitoring the seal, e.g. with non-destructive monitoring techniques, but as this is not within the scope of the DOPAS Project it is not discussed in this reporting.

Also quality control, change and impact assessment means still need to be developed during and after the construction. They are needed for managing the risks due to the change in specifications as a part of the current management system and the implementation of such means is

[3] resaturation experiment

recommended, since the reporting does not include information about the existence of (or a reference to) such system for the work.

One larger concern relates to the size of the component and hydraulic cut off i.e. the "keys" into the rock that are proposed for cutting the EDZ. This is a regulatory request, but the actual need of the cut was questioned based on for example the results from Mont Terri EB-experiment. This discussion point does not result in changes to the D3.30.

Future work potentially needed includes additional work on the construction of bentonite backfilling spaces with techniques that ensure that the required porosity and/or dry density is attained (the issue is regarding any voids not properly filled locally) and another development need is to address the safe removal of the concrete liner and the local dismantling challenge that will be faced in the underground conditions (as already mentioned).

In addition to the FSS reporting the following details were noted:

- The requirement for the concrete temperature (50°C) was not a requirement given in D2.4, but a decision made by Andra for the input for design and work specifications given to the contractor. The explanation about this is missing from the D3.30 reporting.
- The concrete pH value requirements were changed from the original pH 10.5-11 @28 days to pH 10.5-11 @90 days. The justification and discussion of the change is not mentioned in D3.30. The concern of the reader is that is the material still inside the safety envelope/design target or is it a part of the iteration work resulting in a future change of the original requirement according to the D2.4 workflow on design basis development. This clarification needs to be added to the report.
- In a similar way, the original target swelling pressure of 7 MPa was reduced to 5 MPa for WH2 without a justification given in the D3.30. This should be addressed in a similar way in the D3.30 report as the above change on the pH values.
- Bentonite density values need to be checked and corrected.
- Multicriteria analyses (tables 2.3 and 2.4 and figures 2.5 and 2.7) presented mix both safety attributes and circumstances into the same analysis. Also some of the produced result values require checking and correction.
- The number of different mixes discussed on page 9 is not fully traceable to the background reports e.g. the number and type of mixes in the background reports are different from the ones presented in the D3.30. The naming of the mixes require a unified presentation and the reference made as ”B40 CEM III/A

42.5 Héming" should be corrected to "B50 CEM III/A 42.5 Héming" (in section 2.2.1 – step 1, third bullet).

5.2 EPSP

The work on developing the Czech reference design basis in the conceptual design stage is driven by national strategy and existing experiences on the selection and use of plug materials to gain the skills and experiences in carrying out this type of in-situ tests. As discussed earlier, it is important to mention the stage of the development work in connection of the experiment description in D3.30 to clarify the difference in the maturity of this experiment compared e.g. with the DOMPLU and POPLU experiments and their design basis.

Concerning the materials used in the experiment the following materials were tested and used for defining the material requirements for the future:

For the plug materials Czech origin bentonite B-75 material was tested and used. Due to the conceptual design development stage bentonite requirements did not exist for inclusion to the WP2 work. This explanation is needed as a part of the D3.30 reporting as the requirements were developed during the EPSP experiment and later as part of the Czech experimental work. The reporting on the conclusions on composition of mix tests is quite detailed but despite of this not fully traceable due to lack of the background report from 2013 in its summary format. It would require clarification in the text related to B75_2013 (pp. 31-33). Also the value of the dry density requires checking in terms of correctness of the magnitude. The suggestion is to potentially move the test table 3.3 and part of the text into the EPSP experiment summary report and reference in D3.30 to this report for details. The experts judged that since the conditions of the tests do not represent a natural case, these results for the achievable bulk dry density might not give a realistic value and resulting from it nor the swelling pressure. Thus a question on the representativeness in general of the B75_2013 results was made. The actual density results from the experiment are expected to be found in the experiment summary report and in D4.4 report.

Further the concrete parts of the plugs were constructed by using a glass-fibre reinforced shotcrete, the mechanical strength of EPSP concrete was tested and the targeted concrete characteristics were achieved. The results on the higher compressive strength compared with the results of the FSS experiment mixes were worth noting despite the fact that the use of glass fibre in shotcrete can be questionable in the actual repository conditions.

The descriptions related to the shotcrete material selection are quite detailed and could be included in the experiment summary report (D4.7) instead of the D3.30 with the traceable referencing to the D4.7 report.

One question raised by the experts was: Is there any other function for the use of glass fibres beyond preventing micro-cracking during concrete curing e.g. a structural function? For defining the functions, the tables recommended for use in section 4.2.8 are useful. Otherwise the function/s of the fibres needs to be stated in the report as fibres are conventionally used for several functions in shotcreting.

The monitoring strategies and instrumentation details with their sensor quantities, types and other applications are not included and should be available in the D4.4 report and referenced in D3.30 report text.

In addition to the materials tested, bentonite emplacement techniques tested and selected for the EPSP experiment.

In the experiment, the preliminary design requirements were identified but significant amount of work would be required to validate the plug concept as now implemented in the future as the work was in conceptual design stage. As such experiment does not provide input for safety case being such an early stage of development. There is no timetable set for the dismantling of the experiment during the DOPAS Project.

Several limitations related to the plug design as a potential reference design for a repository exist already starting from the location and material selections (e.g. resin, glass fibres) made. The sealing of the host rock with resin for geotechnical location improvement is one of these. This approach was adopted due to predetermined geotechnical conditions and not resulting from the (to-be standard) approach of using predefined siting criteria for the plug location selection. The choices in terms of materials and techniques used are not acceptable in a reference design and its implementation need to be highlighted in the conclusions of the EPSP experiments in D3.30 and in the experiment summary report D4.7.

Further it was noted that the previous European Commission project work needs to be referenced as part of the state-of-the-art e.g. for the shotcrete development work. A suggestion was also made to reduce the number of photographs (in Figure 3.8), but this conclusion was that they are useful for the future as a part of the documentation of the experiment.

5.3 DOMPLU

Concerning the description of the DOMPLU experiments, the objectives were fully achieved and accurately incorporated and no ambiguities were identified. The input data has been properly used. The construction of the full-scale dome plug system was successfully completed, including the installation of sensors to monitor the development, and distribution of the swelling pressure in the backfill and bentonite seal, and the behaviour of the concrete dome.

The specific design modifications of the reference design basis to the experiment design were identified. Such modifications included the use of unreinforced low-pH concrete instead of reinforced low-pH concrete for the concrete dome and the use of 50 mm plastic drainage tubes as grouting tubes. Plug as a single component in the subsystem appears to be designed and constructed according to the state-of-the-art in all regards.

Requirements on excavation and construction methods were validated, although some of them can still be improved. Some modifications (e.g. work safety related) for enhancing the construction procedures of the reference design are to follow in the future. The conclusion seems to be that stated reference design, which is used as subsystem justification in the license applications for the final repositories, fulfils the requirements and can be implemented on an industrial scale. However, this can be seen in the results of the WP4 and confirmed only in the D4.4 report outcome descriptions.

Following areas in the D3.30 DOMPLU text need complementary information according to the experts:

- Uncertainty reduction is stated as an objective for DOMPLU and this requires that the uncertainties are to be defined in the process with a potential quantification and the results in terms of uncertainty reduction included into the reporting. The reporting is most likely done in D4.4 report, but referencing to it is needed in D3.30.
- Justification for use of SCC in reference design needs to be added to both the DOMPLU and POPLU experiment part of the report D3.30 or be referenced e.g. to the relevant experiment summary reports D4.3 and D4.5.
- The instrumentation plans for DOMPLU and POPLU are described in detail; however the monitoring strategies and references to monitoring requirements are not included (to be found in D4.4? or in the experiment summary reports with a reference).
- A quality error related to the DOMPLU location i.e. water bearing structures in the plug area occurred. Its impact needs to be evaluated in WP4 and in the D3.30 an explanation needs to be given how this error was corrected during the construction of the plug. This type of error handling should be included in the specifications of the design and design basis as a new requirement (as stated in the report).
- In the DOMPLU plug, an additional small gravel pocket is included related to the ground water pressurisation, but this additional

component's function is not explained in the relevant report text (see also the section 4.2.8 tables).

- A question was placed concerning the high air content in the concrete. Was the reason for the lower amount of shrinkage potentially due to higher air content in the material?
- The plug has to withstand 7 MPa pressure at the level of the experiment (combined hydraulic pressure and backfill bentonite swelling pressure). This was not tested now. The ability to reach the final total pressure with a sealing component whose swelling pressure might not exceed 2 MPa is seen as a difficulty in the experiment (a limiting or a risk factor of the experiment, to be addressed in D4.4?).
- The DOMPLU backfill materials specifications are not included in the D3.30. Explicit referencing to the source of information is needed.

Terminology used to be edited in both DOMPLU and POPLU for clarity: The disposal tunnels have horseshoe shaped tunnel **cross-section**.

5.4 POPLU

Constructability of a full-scale deposition tunnel plug was successfully demonstrated in POPLU. The main goal of this alternative to Posiva's reference design (DOMPLU) was to optimize design and construction. The plug was designed and constructed in accordance with the available engineering practices.

Wedge-shaped design has fewer components and could potentially be simpler than the DOMPLU reference design and easier to construct providing it meets the reference design requirements. The results of the test will be included in D4.4. The detailed structural design for this type of deposition tunnel plug has been developed and justified accordingly in D3.30.

The low-pH concrete materials that were developed in the laboratory within DOPAS proved to be excellent in meeting the material requirements when applied at full-scale in the POPLU experiment.

An alternative slot excavation technique was selected and tested; its pros and cons were discussed including design tolerances and the need for machinery improvement and work safety. The work safety policy of zero accidents and related guidelines were behind the alternative method selection.

Significant numbers of relevant experiences are mentioned in D3.30 that can be directly applied to future demonstration or repository design work.

Instrumentation and monitoring system was successfully developed and installed for monitoring the performance of deposition tunnel. For improvements related to the D3.30 text on the monitoring and instrumentation plan, see the comment in the DOMPLU subchapter 5.4.

The pressurisation programme of the POPLU experiment was updated (highest test pressure level lowered) based on the experiences and results from the DOMPLU experiment.

The expected behaviour of the different plug components during the experiment was discussed. The experts questioned the water tightness of the POPLU plug due to the lack of the sealing element in the experimental design.

In the future, the casting in one part is considered as a potential for optimization in actual operations. The experts concluded that despite the POPLU not representing the real case (lack of backfill or sealing element), it could provide a good alternative to DOMPLU, if proven acceptable.

Practical challenges associated with installation of deposition tunnel plugs prior to repository operation were identified in the report. The experts agreed with the POPLU lessons learned that were presented in D3.30.

A few loose ends in the POPLU chapter deserve to be tightened-up for a safety case supporting experiment so close to the actual start of repository development.

On page p. 77 choice of mix **"felt"** –need to be reformulated as it is an ambiguous expression. Regarding terminology see subchapter 5.4.

Report statement on the approval and approved materials is misleading and the statement *"all materials need to be previously approved by Posiva safety experts"* requires correction to the text as this led the experts to have an impression of the experiment not complying with the internal procedure of materials' selection, which is not the case. A change proposal for the text was given to the main author.

The potential for quality errors (deviations from design) need to be addressed also in the case of POPLU to be prepared for construction contingencies by contingency planning, also the experts emphasized the importance of defence in depth.

5.5 ELSA

The context and description of the ELSA related work requires rewriting and clarification of the work undertaken in terms of the scope and about interaction between DOPAS related work in WP3 and the German project work. An introductory sector into Ch. 6 giving a description of drivers for the ELSA work in reference to the various sealing elements presented in Figure 6.1, the timeline for when and what work was carried out in DOPAS (like the tables 2.1, 3.1, 4.1 and 5.1 provided for the other experiments on the D3.30 report pages 8, 29, 52, and 76) is needed to give the reader more orientation and highlight the focus of the work. A clarification of the ELSA work is drafted in Appendix 7 resulting from the WP5 elicitation process for assistance and also the section 2.5.5 in the D2.4 report provides further objectives of the work.

ELSA related lessons learned section is missing and needed related to the description of ELSA tests in D3.30. It was also noted that some of the experiment test results were not yet available, which does not enable reporting their experiences (e.g. the main reference *Kudla et al. 2016* related to the work was not available at all).

Since the ELSA experiment tests like the EPSP experiment are both in the early stage of design basis development and address the conceptual design basis stage, the experimental design basis is not available and thus not provided in the D2.4. More explanation about the role of the seal and its components helps the reader in this context and the table recommended in section 4.2.8 helps further in understanding the work done in DOPAS Project.

The work focuses on laboratory scale mock-ups on the various sealing elements, their work methods (compaction methods for the long-term sealing element), and material properties and both mechanical and chemical material interactions. For example a summary table listing the individual experimental work and the purposes of the individual tests and mock-ups would further assist the reader. Several materials tests and techniques method test to improve short and long-term sealing elements for the shaft have been done and this work is consistent with existing knowledge and provides experiences to be used in the future developments.

The most unclear text relates to the description of the in-situ tests using crushed salt stone and clay mixtures: their context in the whole is not at all clear to the readers (p. 106-108 in D3.30). Clarification can be improved also by adding additional explanatory text to the legends of the figures (e.g. Figures 6.4-6.5). Explaining in the D3.30 also how the individual experiments complement each other is recommended.

At this stage of the development, the uncertainty level is high. Identified uncertainties relate e.g. to the compaction force needed and to the use of bitumen in the seal element.

The installation of bitumen in the seal resulted in several questions in the elicitation (e.g. organics and fire safety) and for a need for justification in terms of acceptability for a reference design. This needs a clarifying explanation in the D3.30 report acknowledging also that the safety functions for the shaft sealing have not yet been defined in the German ELSA project.

In the future an adaptation of the used equipment for working in the shaft environment is also required.

6 State-of-the-art at the end of WP3 work and the future opportunities

6.1 Assessment of the technological readiness level (TRL) at the end of WP3

The experts made individual assessments on the experiments' technological readiness levels based on the D3.30 reporting. Majority of the assessments were made on the scaling used by DOE[4] and provided to the experts in the background materials for the elicitation. The outcome of the joint discussion of the assessment as a preliminary hypothesis is presented in the Appendix 8.

Resulting from the assessment, the TRL level of DOMPLU and POPLU would fall between 5 and 6, the TRL levels for ELSA and EPSP around 2 and a bit above, and for the FSS the views were divided between TRL levels 3 and 5. However, an agreement was reached about the relative maturity of the individual experiments in relation to each other.

6.2 Future development needs and opportunities

The D3.30 conclusions address several development needs for the plugs. Further needs and opportunities are included also in D4.4 report.

According to the experts, future steps of development include work for the development of the industrial scale design and construction operations. It was concluded that the design requirements developed allow room for construction optimisation. Part of the optimization includes the total number of plugs in terms of their respective numbers and types, their localisation, performance monitoring, and lifetime contingency planning when taking into account their unit and total cost.

Optimization potential exists also in other areas of the plug development.

A suggestion was made in the elicitation to consider the use of shotcreting for plug construction also in the other crystalline repository concepts at SKB and Posiva providing the capability of the material and working methods meet the requirements for hydraulic limitation and mechanical integrity. The suggestion is based on the material test results from the EPSP experiment. This suggestion falls outside the scope of the DOPAS Project.

[4] in DOE (2011). Technology Readiness Assessment Guide. DOE G 413.3-4A, pp. 9-11 (this is an updated version of the March 2008 version of the guide that was used in the pilot elicitation of DOPAS).

6.3 Applicability of the results to other plugs and seals or repository components

The experts were asked for their assessment on the potential applicability of the work and results presented in D3.30 for other plugs and seals or even for other repository components.

The experts noted that

- Similar methodology and approach (the D2.4 work flow) could be applied to all repository components design basis development or for the development of future experiment design bases;
- General project management approaches like enough time to design, transparent communication, and early involvement of various stakeholders like authorities and contractors, paying attention to work safety issues, to work environment (dust), logistics and procurement with sufficient redundancy can be applied as the lessons learned from the work;
- The consortium members could also make an assessment on how they have benefitted from working together and from sharing the information about their experiments. How may their own approach to designing, constructing, and testing their plug/seal have been positively influenced by other approaches?
- POPLU, DOMPLU and EPSP can learn from each other;
- FSS materials and to some degree the construction techniques deployed could be applicable for similar design concepts in clay;
- The modelling approaches could possibly be reused with different parameter values;
- FSS experiences can strengthen the safety concepts in crystalline rock using bentonite (better material understanding);
- DOMPLU design could be simplified for industrial application;
- The application to other plugs/seals in different environments is limited since each context has their specificities and it is difficult to extrapolate the results and assess their applicability to contexts which are not precisely known;
- Based on the work now carried out, a question for assessment remains is full-scale testing in the future needed for all components or pieces of equipment.

One conclusion by the experts was that even though the work provides approaches and other output that can be beneficial for the future work on developing plugs and seals and potentially also other repository components, it should be noted that trying to develop and apply the outcomes as a universal recipe can be dangerous as much of the work carried out has demonstrated its context dependency.

7 Recommendations and expectations on content to be included in the following Work package reports

During the elicitation, some comments were made to revise the structures of the WP2, WP3 and WP4 reports. Also suggestions were made to move parts of the D4.4 tables into the D3.30. However, it was stated that the timing of the project was such that such changes were not feasible as the D2.4 report had already been finalised in the project. The D4.4 structure was also outside the scope of this elicitation.

For the record, some confusion was found in the D2.4 descriptions related to boundaries of the conceptual and basic design basis development stages as the experts noted that the ELSA and EPSP are included as a part of the basic design development. Similarly, the boundaries of the basic design requirements and experiment design requirements were not fully clear in the text. Preliminary design basis is adopted to an experiment design basis and into the experiment design for the FSS, DOMPLU and POPLU experiments. Part of this work was done during the work carried out in WP3 e.g. the concrete temperature limit for FSS.

There is a need to include short description of contexts of the experiments (conceptual/basic) into the D4.4 as stated in 4.2.1. Also the introduction about the scope of the ELSA experiment is needed (see Appendix 7).

Using the GEOSAF framework of defining the safety envelope and the design targets in advance provides the approval criteria for the experiments' performance assessment in the D4.4, too (Appendix 3). The coupling of the experiment results to the total repository system safety requirements needs also consideration in the future and in the conclusions and in the remaining open issues at the end of DOPAS Project (e.g. in D6.4).

A discussion on the influence of the differences in the boundary conditions of the experiment and reference designs is needed as a part of the D4.4 report conclusions. Also the discussion should address the potential risks and biases from when the experiment results are up-scaled and used to define the final plugs/seals.

A discussion question remains on how does the actual siting of the plugs/seals in the various environments influences the loads the structures need to withstand and how it influences their performance? This relates also the materials selected and used and their application also in industrial scale. This discussion belongs to the scope of the D4.4 conclusions.

For the experiments, not all information was available on their performance by the time the date for submitting the input information for D3.30 was set. Thus for example some experiment data is left open like: Was the targeted density of emplace bentonite pellets achieved in the EPSP experiment with the origin materials? A reader expects to find this in the D4.4 reporting.

Due to the division of work little information on the production of the test (instrumentation) plans in respect to the selection of the types and number of instruments and potential uncertainties is included in the D3.30 and it is expected that this information will be found in to D4.4, but simultaneously also referenced in the D3.30 report. Topics of interest for the reader in the D4.4 regarding the instrumentation and monitoring are: who is responsible for the monitoring strategies and plans and who uses and analyses the results from the test plans. Potentially several user groups are foreseen for the results. Also the use of monitoring in the experiments and not using such extensive plug/seal monitoring in the actual repository is expected to be discussed in the D4.4 report in the conclusions.

As stated by the experts in Ch. 4.1, the results of the full scale experiments in WP3 cannot directly be used in Performance or Safety Assessment (as defined in WP5, D5.10): these results will only become available in the work described in WP4 D4.4 except for the initial state as discussed earlier.

The results of the laboratory experiments concerning hydraulic conductivity and permeability, as well as their development over time as a function of circumstances can certainly be used in PA/SA: they provide central and distributions data to be used in the appropriate models.

The final report D6.4 needs to focus on the full picture of the DOPAS Project work, as the D3.30 is limited in its scope of work and thus its "completeness" is also limited to its scope.

Aiming for universal lessons learned from such experiments can be dangerous. This was highlighted by the experts that the intent to try to develop a universal “recipe” for the repository and its development is limited in geological disposal due to the different and specific context related constraints. The approaches developed (e.g. the D2.4 workflow) can be modified for the specific work undertaken e.g. in the less advanced disposal programmes. This conclusion is recommended to be included into the D6.4 conclusions, too.

A further recommendation is to add information about the extent of the needed resources and competences for the plugs and seals development and for the potential industrial scale implementation. Preliminary information could be collected from the work input reported to the

European Commission in the official project reports on the needed quantities and skills applied and included into the conclusions of D6.4. This is also partly included in the remaining issues and challenges of the D4.4 report, too.

8 Good practices

The systematic application of the identified outcome of the D2.4 in the form of the design basis development workflow provides a good basis for the quality management system of the following work stages combined with the safety envelopes and design targets for the compliance assessment.

The report conclusions provide several useful learning points from the experiments for use in the other experiments and also in the future experiments carried out by other organisations when keeping in mind that taking the outcomes and work of the DOPAS Project as "universal recipes" can be a dangerous short cut as the context and constraints and national strategies influence the experiment choices in a significant manner.

9 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 is dependent on 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.

10 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 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.

10.1 Feedback from the experts on the process and tools

In terms of lessons learned, it would be interesting to hear from the DOPAS Project partners how much they have benefited from cooperating and working together under the same umbrella on these complex issues. It would be worthwhile to know the DOPAS partners' views on the key technical lessons learned from one another during the course of the project by exchanging information and sharing results and which may have influenced their own experiment. This important added value of DOPAS Project when supported by concrete examples would be worth being reported to the EC in the final project report as part of the conclusions.

The previous experiences of the experts were from elicitations, where a direct question was asked from them. In this respect the ambiguity about what was expected from the individual experts was higher in terms of their input and the assessment answers given. Also some questions seemed similar to the experts on the forms. The PA/SA expert's form (Appendix 1) was perceived more ambiguous in its questions compared with the Domain expert's form (Appendix 2).

Concerning the elicitation forms, there was a request to the facilitator to provide information on how to reply to the questions "correctly". The meaning of "uncertainty" in the questionnaire context was somewhat confusing as it has a specific function in performance assessment and in the experiment context it was used more as in non-specialised language. Thus a performance assessor would expect that the "uncertainties" are identified in the work done in the project itself instead of the expert being asked about them.

The timing of the EE: It would have been beneficial to have it earlier in the process to provide input earlier (when remained open). Overlapping of the elicitations resulted because it was not possible to find an earlier common date for the consensus meeting.

Suggestion was made to have all reports elicited in one elicitation (was discussed in the original WP6 plan, decided that it is not feasible in the project) for the overview.

10.2 The facilitator's underlying views on the forms and process

The forms are intended to speed up the process. The use of the form enables a faster tracking 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. The use of wording "uncertainties" relates in this context to content in the report that leaves the expert in doubt about e.g. the factual correctness of the information presented in the report. However, also during the process the length of the questionnaires has increased, which needs to be addressed in the future, if such a process is applied.

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 it 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 meetings 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.

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

Descriptions:
4. Development, design and implementation process - WP3 simplified structure of lessons learned
5. Testing in WP3-WP4
6. Structure of work in WP4

Other materials:
7. Draft of ELSA context and work carried out for improvement
8. Technology readiness assessment (WP3)

APPENDIX 1

DOPAS Expert Elicitation for WP3 — 8 March 2016
Domain Expert (Form 1)

DOMAIN EXPERT'S ELICITATION FORM
(DOPAS EE WP3)

The outcome of the work in DOPAS WP3 is reported in the final report D3.30. This report is currently at the final draft stage. After the elicitation, the D3.30 will further undergo Andra's internal quality assurance prior publication.

Elicitation Task/Topic under elicitation (WP3)

Is the D3.30 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?

The elicitation's focus is to assess the completeness of the constructed experiments in relation to the objectives set for them as described in the report. In addition, the elicitation should identify potential uncertainties, ambiguities/deviations and controversies in and between plug/seal experiment/s' input data, the design, test/monitoring plan, and construction implementation that could prevent reaching the desired initial state of the plug/s (and seals, where applicable) in the repository. Further the elicitation aims to look at

- the application and implementation of the requirements and design bases developed for the experiments in the design/s (incl. materials used) produced for the experiment/s
- the construction solutions used to carry out the design/s including the needed components and their role in the technical performance of the plug, the construction supporting activities (like ground improvement, grouting) and test plan / monitoring solutions
- the appropriateness of the report 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 initial state.

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

Name of expert replying

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

*) I.e. your personal involvement in input data production like defining design bases/ designing underground structures or planning instrumentation/monitoring systems, carrying out related material testing, implementing or supervising such structures or test plans, relevant experience in the area in general including previous engagement in similar activities.

DE1. Assess the role of expert judgment used in the production of the design and construction for the DOPAS experiments plugs or seals from 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 been used for the production of the plug/seal design and construction in the experiment /s (as described in D3.30) and potentially for the repository reference design development? Is this flow of inputs visible for the reader of the report?

b) Who has transferred the input data into the design including the material choices made as a part of the design?

c) Do you identify any omissions or uncertainties related to the application of the requirements or design basis in the design?

d) What influence does it have that the DOPAS requirements and design bases were applied to the experiment design instead of reference design?

e) What type of uncertainties and differences can be potentially identified in the expected initial state of the plugs/seals resulting from the implementation of the experiment compared with the implementation of a final repository design?

DE2. Rationale underlying the experiments' material selections and potential uncertainties
a) How have the criteria for the material choices been selected? Are these criteria and the related choices transparent and well grounded in the report or do they include direct or embedded expert judgments?

b) What is your assessment on the soundness of methodologies used for testing and selecting materials and components for the experiment design?

c) Is the role / purpose of each plug/seal component included as a part of the design explained in a transparent way in the report (or in related background references?)

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 used. What uncertainties do you identify at this stage of the process related to the materials used?

DE3. Rationale underlying the production of the test plan/s for instrumentation and monitoring and the types and quantities of instruments and potential uncertainties
a) For what purpose is the test plan produced and by whom? What type of input has been used for preparing the test plan? How have the measured or observed parameters been chosen? On what grounds?

b) Who is the main customer using the outputs of the test plan?

c) What are the uncertainties related to the desired initial state taking into consideration the potential outputs (and parameters) to be received from the test plan implementation (from the instrumentation)?

DE4. Rationale for selecting the construction methods for the experiments and potential

uncertainties

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

b) Are there any potential limitations in using the selected methods in a repository environment?

c) What type of uncertainties or limitations in relation to meeting the requirements can result from these selected construction methods?

DE5. Adequacy of and uncertainties about the work carried out (in designing, planning the instrumentation, and constructing the experiment/s including the location selection/s) to achieve the expected outcomes/objectives for plugs/seals (initial state)?

a) Does the work carried out and described in D3.30 demonstrate consistency with the state of the art in relation to the input data (requirements and reference design basis for plugs, seals and other closure components) in general?

b) Do you feel any doubt concerning the adequacy of the produced and used experiment design/s, construction methods and test plans? 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? Are these adequate when keeping the set objectives of the experiment/s in mind?

d) Could the identified inadequacies in the implementation 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?

Challenges in producing the report itself and its completeness

- 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?
- What areas do you see that need complementing in the design, material development, instrumentation/monitoring planning, and construction sections of the report? On what grounds?

Universal applicability of the results in repository implementation

- And what parts of the 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?
- To what extend could the development work done in these experiment works be used for other repository components than plugs and seals?

Other review comments related to the D3.30 (e.g. other information to be included to the report concerning terminology, theories, referencing to other work related to plugs and seals)

DOPAS Expert Elicitation for WP3 Domain Expert (Form 1)

8 March 2016

What is you assessment of the technology readiness level (TRL[1]) of the plugs/seals based on the D3.30 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 2

DOPAS Expert Elicitation for WP3 9 March 2016
PA/SA Expert (Form 2)

PERFORMANCE ASSESSOR'S (/SAFETY ANALYST'S) ELICITATION FORM
(DOPAS EE WP3)

The outcome of the work in DOPAS WP3 is reported in the final report D3.30. This report is currently at the final draft stage. After the elicitation, the D3.30 will further undergo Andra's internal quality assurance prior publication.

Topic under elicitation

Is the D3.30 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?

The elicitation's focus is to assess the completeness of the constructed experiments in relation to the objectives set for them as described in the report. In addition, the elicitation should identify potential uncertainties, ambiguities/deviations and controversies in and between plug/seal experiment/s' input data, the design, test/monitoring plan, and construction implementation that could prevent reaching the desired initial state of the plug/s (and seals, where applicable) in the repository. Further the elicitation aims to look at

- the application and implementation of the requirements and design bases developed for the experiments in the design/s (incl. materials used) produced for the experiment/s
- the construction solutions used to carry out the design/s including the needed components and their role in the technical performance of the plug, the construction supporting activities (like ground improvement, grouting) and test plan / monitoring solutions
- the appropriateness of the report 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 initial state.

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

Name of expert responding

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

*) personal involvement in the input data production and assessment related to practical technical and long-term safety related requirement setting, performance assessment[1] of design bases and/or implementation underground structures directly or as external reviewer or your relevant experience in the area in general including previous engagement in (in either performance assessment or safety analysis/safety cases)

[1] 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).
The results of the monitoring of the experiments belong to the scope of WP4 and are not included in the scope of WP3, which contains the test planning.

PA/SA Expert (Form 2)

PA1. Appropriateness and completeness of the methodology and approach (for designs, test plans, and implementation) used for producing the results of the WP3 in terms of moving from requirements and design basis to design and implementation of a plug or a seal?
a) How comprehensive and transparent are the methods and approaches used for the plug/seals' experiments from the performance or compliance assessment point of view taking into account that WP3 applies the requirements and design basis identified as input data for the design, testing and construction of the plugs and seals experiments?

b) What are the main uncertainties related to the application methodologies and approaches used in including the input data into the design and implementation?

c) What type of uncertainties, omissions or risks can you identify regarding the expected outcomes of the experiments in reaching the desired initial states for the plugs and seals?

d) What type of uncertainties in terms of the plug/seal 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/seals?

PA2. Role of the expert input data in the production of experiment solutions 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) Can the results from WP3 be directly used in performance or safety assessment or are they an intermediate result in the data production chain for coming up with further experiment stages?

b) What type of role and influence does expert input have in the application process where the DOPAS requirements and design bases have been applied to the experiment design instead of the reference design?

c) What is 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.

PA3. Preliminary assessment of the adequacy of and uncertainties in the design solutions including materials, testing plan and implementation of construction methods including location and 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?

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[2]? Are the choices made in the design and implementation grounded from these perspectives?

b) Do the various steps described in D3.30 present a useful way to design, test and construct an experiment for demonstrating consistency with the state of the art of such repository components? Do you see them adequate to achieve the expected or set objectives for the plugs/seals experiments? On what grounds?

[2] 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) What type of constraining factors have been taken into account and which approaches or methods have been used to tackle the constraints? Are these adequate when keeping the set objectives of the experiment/s in mind?

d) Do you feel any 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? 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?

e) Do you foresee any inadequacies[3] in the way the design bases identified in D2.4 have been used/have not been used in the design and test plan for the experiments?

f) What type of uncertainties or reductions in quality of outputs can be identified from the D3.30 solutions with regard to the performance or long-term safety aspects of the plugs/seals? 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.

g) What possible or predicted influence does the use of the experiment design basis for the designs have on the performance assessment results and on the understanding of the initial state[4] of the full-scale plug/seal or plug/seal components? Please note that the monitoring results are not included into the scope of WP3 (belong to WP4).

h) Is there any possible bias in transposing the construction methods and experience gained from an experimental pilot project to an industrial-scale operation? If so, how to prevent them?

i) 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?

j) 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 jugdment would you make on the conclusions and lessons learned from the technical performance and long-term performance point of view related to the design, materials used, monitoring parameters chosen? What uncertainties do you identify at this state of the process related to them?

Challenges in producing the report itself and its completeness

- Have there been identified difficulties / what were the difficulties possibly encountered in

[3] e.g., ungrounded or undocumented choices, omissions, generalizations etc.
[4] the state in which the plug (or its component) is after the last man-made action targeted to the plug and its near-field

producing the report and its results what were / might have been the reasons for the difficulties?

- Is the information provided in the report adequate for any future plug/seal system developer to benefit from the lessons learned and experience gained by the DOPAS project partners throughout the development process?

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

- What areas do you see that need complementing in the design, material development, instrumentation/monitoring planning, and construction sections of the report? On what grounds?

Universal applicability of the results in repository implementation

- And what parts of the 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?

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

- Could possible inadequacies in the work process 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?

- What type of uncertainties do you see remaining related to the requirements selected as input, the design basis and its potential outcomes? How has this been tackled in the reported work?

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

- What are the assumptions and grounds[5] underlying your assessment?

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

- 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 D3.30 (e.g. other information to be included to the report concerning terminology, theories, referencing to other work related to plugs and seals

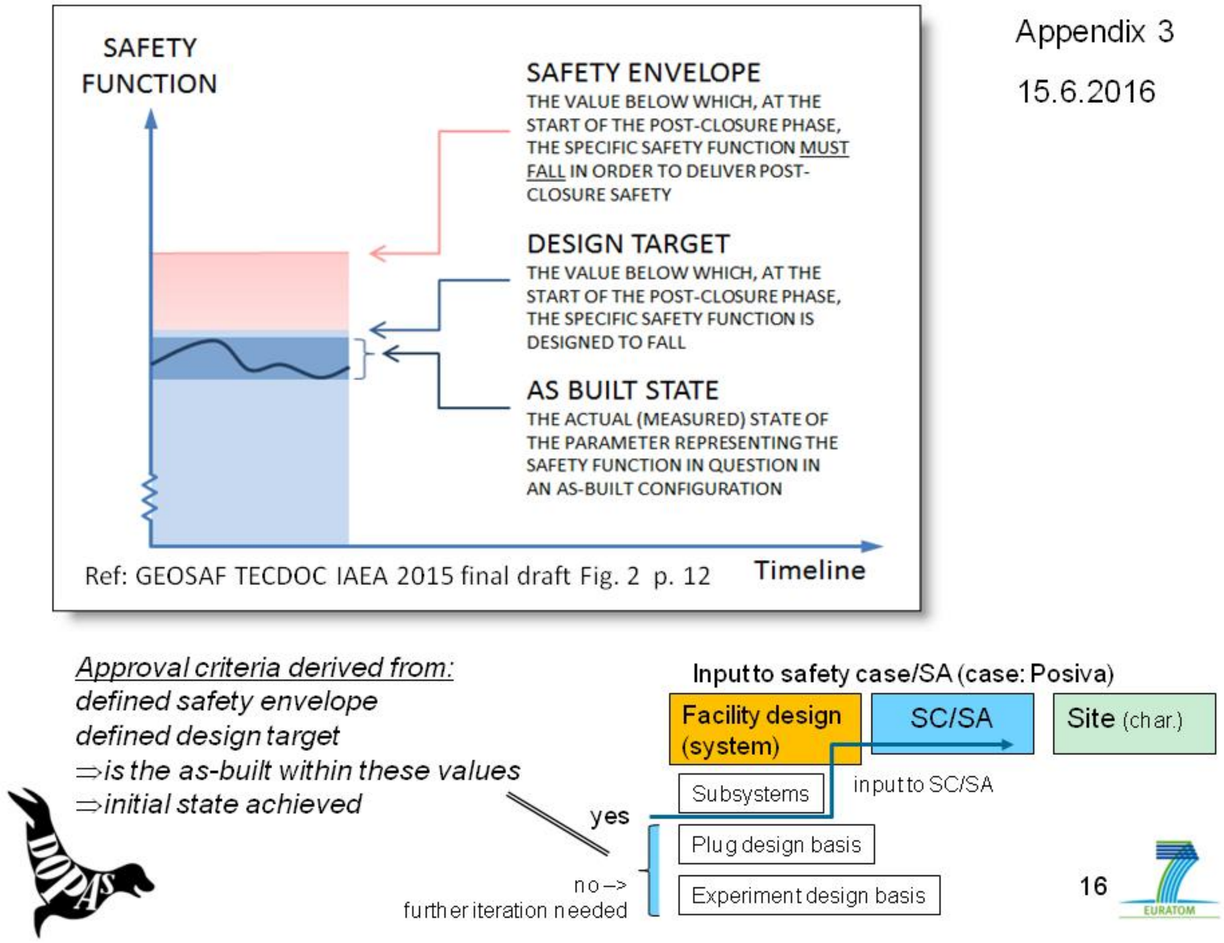
[5] e.g., literature, pilot modelling results, sensitivity analysis, use of conservatism, authorities' requirements

DOPAS Expert Elicitation for WP3 9 March 2016
PA/SA Expert (Form 2)

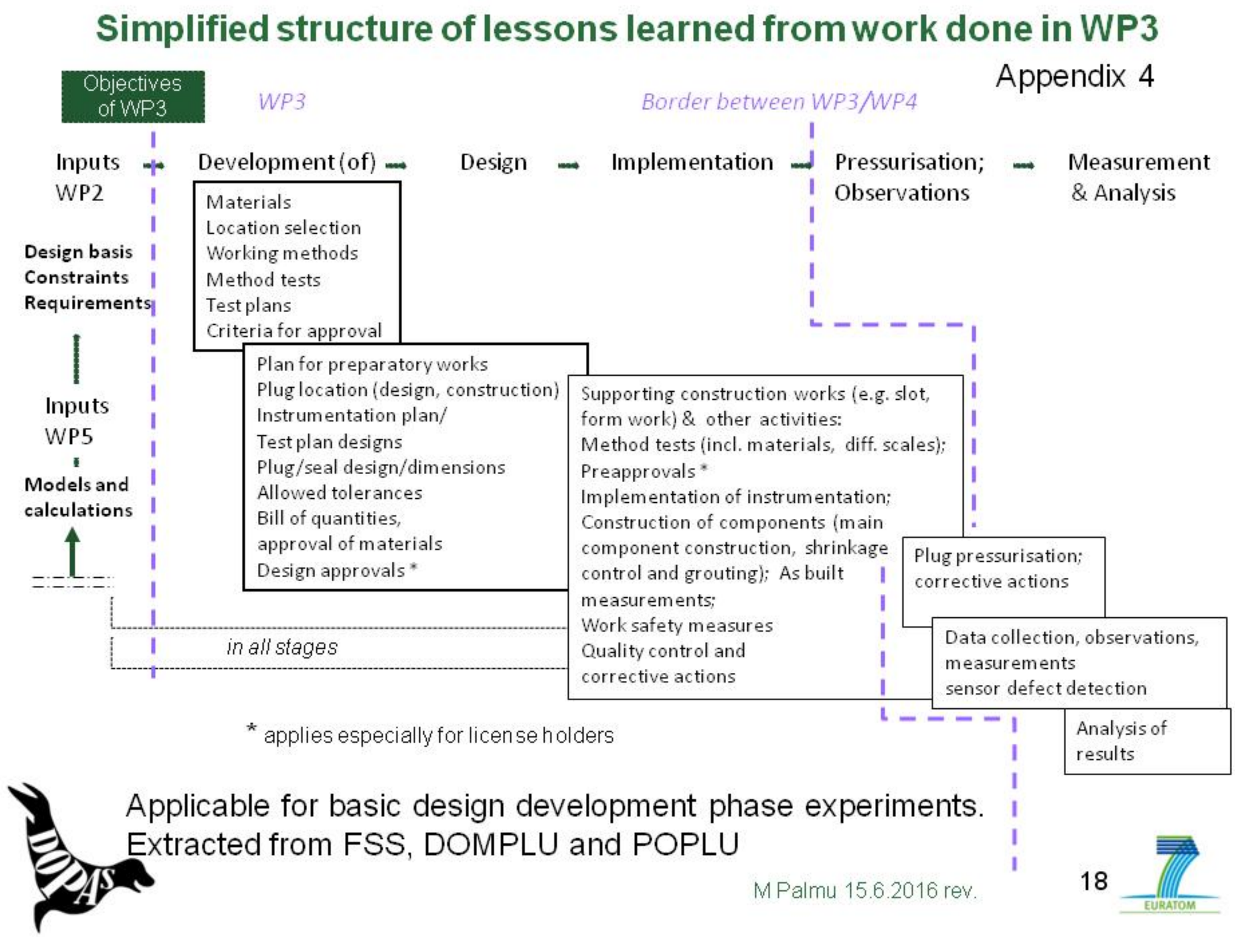
What is you assessment of the technology readiness level (TRL[6]) of the plugs/seals based on the D3.30 report?

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
SAFETY FUNCTION
SAFETY ENVELOPE
THE VALUE BELOW WHICH, AT THE START OF THE POST-CLOSURE PHASE, THE SPECIFIC SAFETY FUNCTION MUST FALL IN ORDER TO DELIVER POST-CLOSURE SAFETY
DESIGN TARGET
THE VALUE BELOW WHICH, AT THE START OF THE POST-CLOSURE PHASE, THE SPECIFIC SAFETY FUNCTION IS DESIGNED TO FALL
AS BUILT STATE
THE ACTUAL (MEASURED) STATE OF THE PARAMETER REPRESENTING THE SAFETY FUNCTION IN QUESTION IN AN AS-BUILT CONFIGURATION
Ref: GEOSAF TECDOC IAEA 2015 final draft Fig. 2 p. 12
Timeline
Approval criteria derived from:
defined safety envelope
defined design target
⇒is the as-built within these values
⇒initial state achieved
yes
no –> further iteration needed
Input to safety case/SA (case: Posiva)
Facility design (system)
SC/SA
Site (char.)
input to SC/SA
Subsystems
Plug design basis
Experiment design basis
16


Simplified structure of lessons learned from work done in WP3
Appendix 4
Objectives of WP3
WP3
Border between WP3/WP4
Inputs WP2
Development (of)
Design
Implementation
Pressurisation; Observations
Measurement & Analysis
Design basis
Constraints
Requirements
Materials
Location selection
Working methods
Method tests
Test plans
Criteria for approval
Plan for preparatory works
Plug location (design, construction)
Instrumentation plan/
Test plan designs
Plug/seal design/dimensions
Allowed tolerances
Bill of quantities,
approval of materials
Design approvals *
Supporting construction works (e.g. slot, form work) & other activities:
Method tests (incl. materials, diff. scales);
Preapprovals *
Implementation of instrumentation;
Construction of components (main component construction, shrinkage control and grouting); As built measurements;
Work safety measures
Quality control and corrective actions
Plug pressurisation; corrective actions
Data collection, observations, measurements
sensor defect detection
Analysis of results
Inputs WP5
Models and calculations
in all stages
* applies especially for license holders
Applicable for basic design development phase experiments.
Extracted from FSS, DOMPLU and POPLU
M Palmu 15.6.2016 rev.
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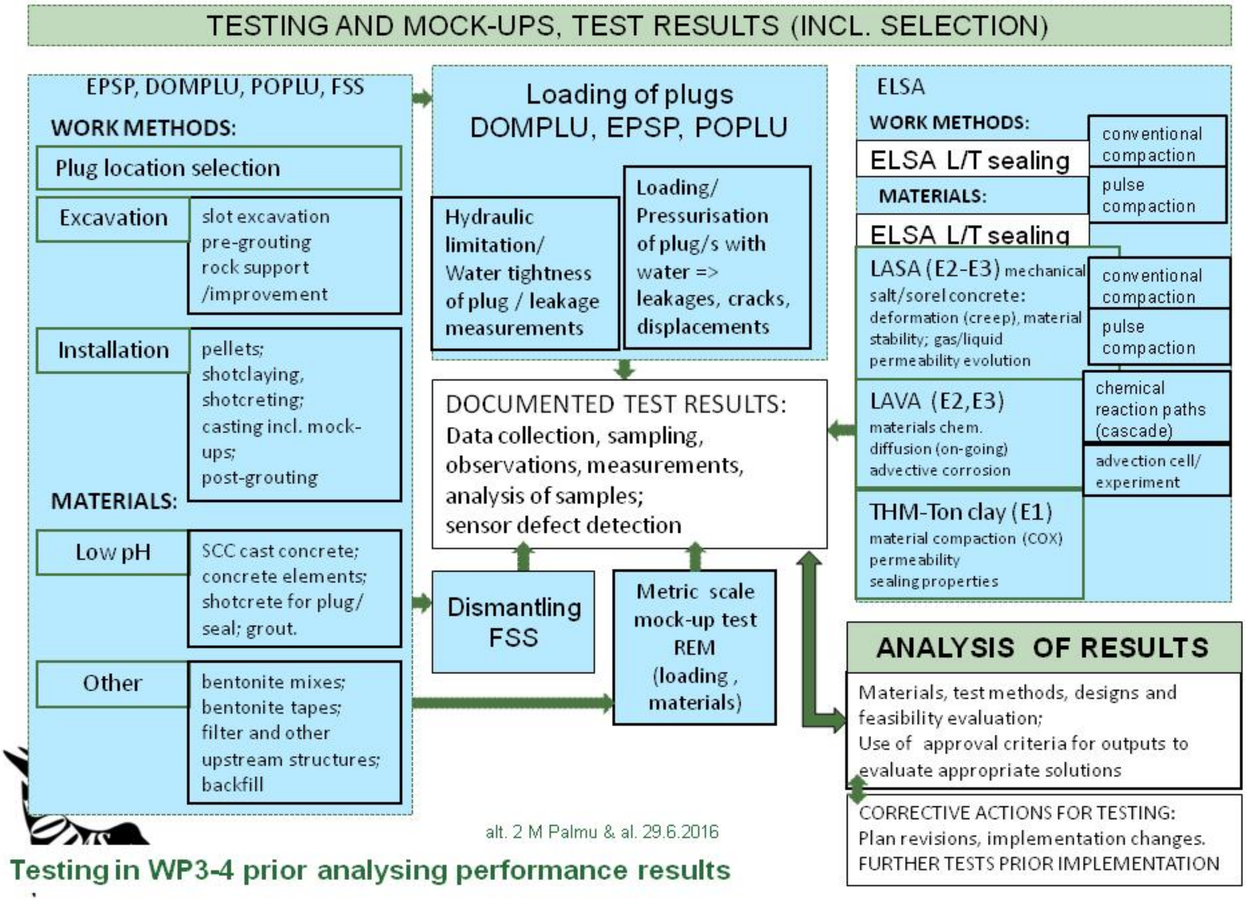
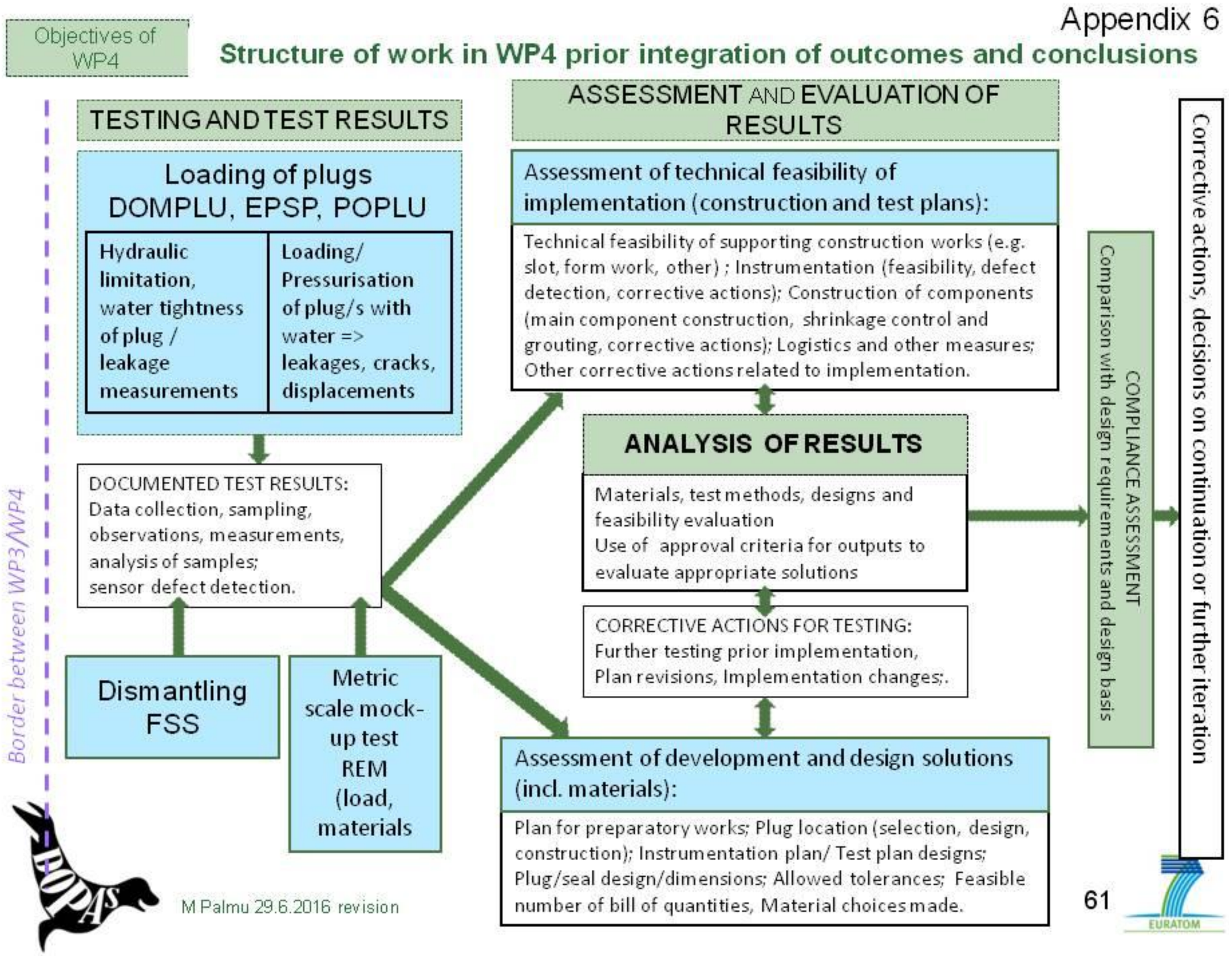
APPENDIX 5



TESTING AND MOCK-UPS, TEST RESULTS (INCL. SELECTION)
EPSP, DOMPLU, POPLU, FSS
WORK METHODS:
Plug location selection
Excavation
slot excavation
pre-grouting
rock support
/improvement
Installation
pellets;
shotclaying,
shotcreting;
casting incl. mock-ups;
post-grouting
MATERIALS:
Low pH
SCC cast concrete;
concrete elements;
shotcrete for plug/
seal; grout.
Other
bentonite mixes;
bentonite tapes;
filter and other
upstream structures;
backfill
Loading of plugs
DOMPLU, EPSP, POPLU
Hydraulic
limitation/
Water tightness
of plug / leakage
measurements
Loading/
Pressurisation
of plug/s with
water =>
leakages, cracks,
displacements
DOCUMENTED TEST RESULTS:
Data collection, sampling,
observations, measurements,
analysis of samples;
sensor defect detection
Dismantling
FSS
Metric scale
mock-up test
REM
(loading ,
materials)
ELSA
WORK METHODS:
ELSA L/T sealing
conventional
compaction
pulse
compaction
MATERIALS:
ELSA L/T sealing
LASA (E2-E3) mechanical
salt/sorel concrete:
deformation (creep), material
stability; gas/liquid
permeability evolution
conventional
compaction
pulse
compaction
LAVA (E2,E3)
materials chem.
diffusion (on-going)
advective corrosion
chemical
reaction paths
(cascade)
advection cell/
experiment
THM-Ton clay (E1)
material compaction (COX)
permeability
sealing properties
ANALYSIS OF RESULTS
Materials, test methods, designs and
feasibility evaluation;
Use of approval criteria for outputs to
evaluate appropriate solutions
CORRECTIVE ACTIONS FOR TESTING:
Plan revisions, implementation changes.
FURTHER TESTS PRIOR IMPLEMENTATION
alt. 2 M Palmu & al. 29.6.2016
Testing in WP3-4 prior analysing performance results


Appendix 6
Objectives of WP4
Structure of work in WP4 prior integration of outcomes and conclusions
TESTING AND TEST RESULTS
ASSESSMENT AND EVALUATION OF RESULTS
Loading of plugs DOMPLU, EPSP, POPLU
Hydraulic limitation, water tightness of plug / leakage measurements
Loading/ Pressurisation of plug/s with water => leakages, cracks, displacements
DOCUMENTED TEST RESULTS: Data collection, sampling, observations, measurements, analysis of samples; sensor defect detection.
Dismantling FSS
Metric scale mock-up test REM (load, materials
Assessment of technical feasibility of implementation (construction and test plans):
Technical feasibility of supporting construction works (e.g. slot, form work, other) ; Instrumentation (feasibility, defect detection, corrective actions); Construction of components (main component construction, shrinkage control and grouting, corrective actions); Logistics and other measures; Other corrective actions related to implementation.
ANALYSIS OF RESULTS
Materials, test methods, designs and feasibility evaluation
Use of approval criteria for outputs to evaluate appropriate solutions
CORRECTIVE ACTIONS FOR TESTING: Further testing prior implementation, Plan revisions, Implementation changes;.
Assessment of development and design solutions (incl. materials):
Plan for preparatory works; Plug location (selection, design, construction); Instrumentation plan/ Test plan designs; Plug/seal design/dimensions; Allowed tolerances; Feasible number of bill of quantities, Material choices made.
COMPLIANCE ASSESSMENT
Comparison with design requirements and design basis
Corrective actions, decisions on continuation or further iteration
Border between WP3/WP4
M Palmu 29.6.2016 revision
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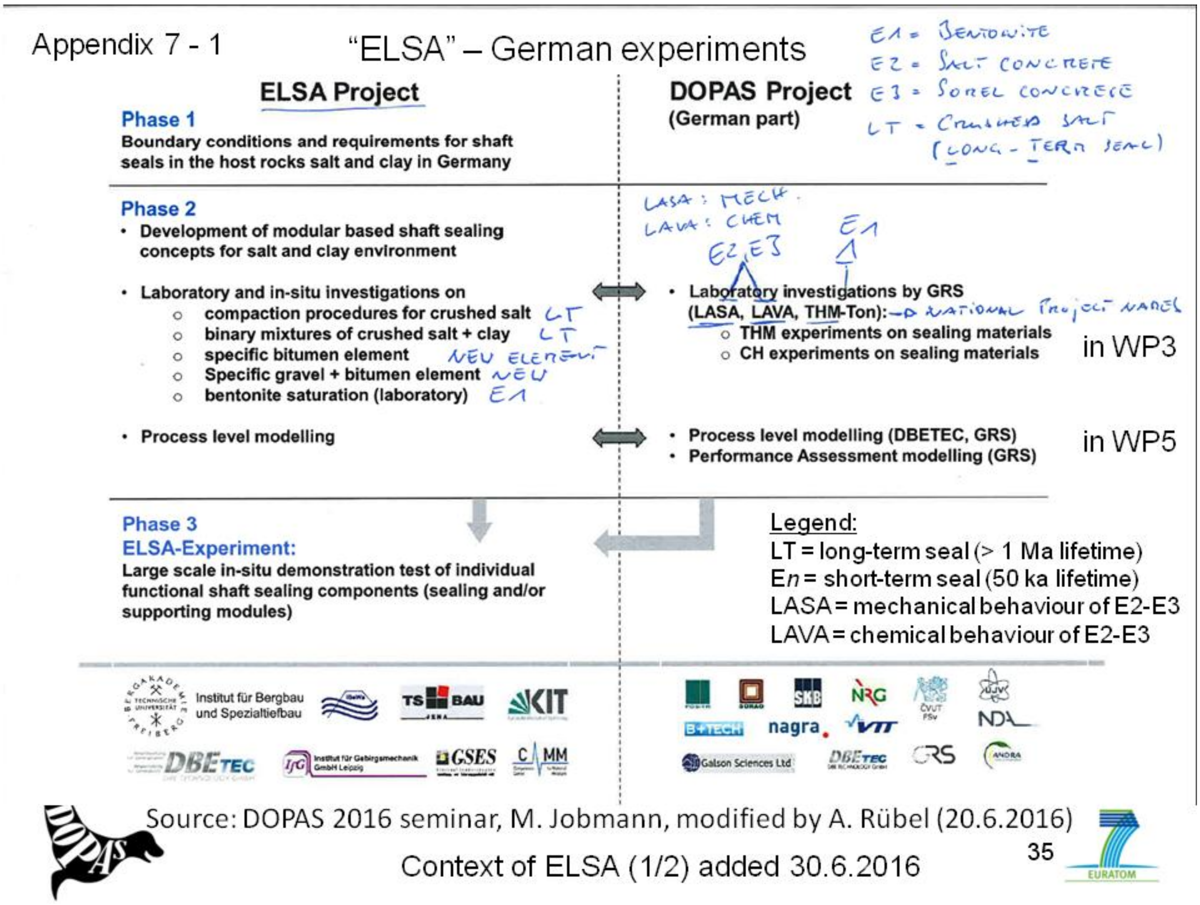
EURATOM


Appendix 7 - 1
"ELSA" – German experiments
E1 = Bentonite
E2 = Salt concrete
E3 = Sorel concrete
LT = Crushed salt (long-term seal)
ELSA Project
Phase 1
Boundary conditions and requirements for shaft seals in the host rocks salt and clay in Germany
DOPAS Project
(German part)
Phase 2
• Development of modular based shaft sealing concepts for salt and clay environment
• Laboratory and in-situ investigations on
○ compaction procedures for crushed salt LT
○ binary mixtures of crushed salt + clay LT
○ specific bitumen element NEW ELEMENT
○ Specific gravel + bitumen element NEW
○ bentonite saturation (laboratory) E1
• Process level modelling
LASA: MECH.
LAVA: CHEM
E2, E3
E1
• Laboratory investigations by GRS (LASA, LAVA, THM-Ton): → national project named
○ THM experiments on sealing materials
○ CH experiments on sealing materials
in WP3
• Process level modelling (DBETEC, GRS)
• Performance Assessment modelling (GRS)
in WP5
Phase 3
ELSA-Experiment:
Large scale in-situ demonstration test of individual functional shaft sealing components (sealing and/or supporting modules)
Legend:
LT = long-term seal (> 1 Ma lifetime)
En = short-term seal (50 ka lifetime)
LASA = mechanical behaviour of E2-E3
LAVA = chemical behaviour of E2-E3
Institut für Bergbau und Spezialtiefbau
DBETEC
GSES
nagra
Source: DOPAS 2016 seminar, M. Jobmann, modified by A. Rübel (20.6.2016)
Context of ELSA (1/2) added 30.6.2016
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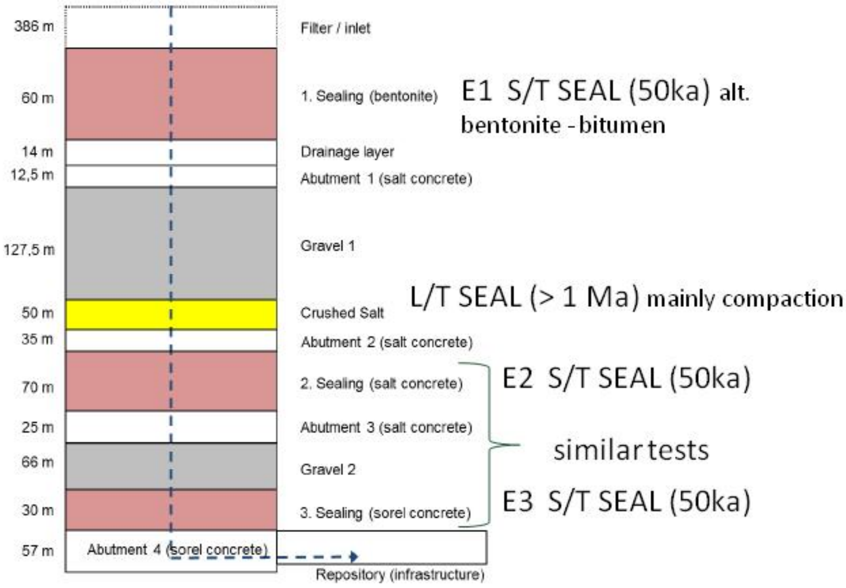
EURATOM

Appendix 7 - 2

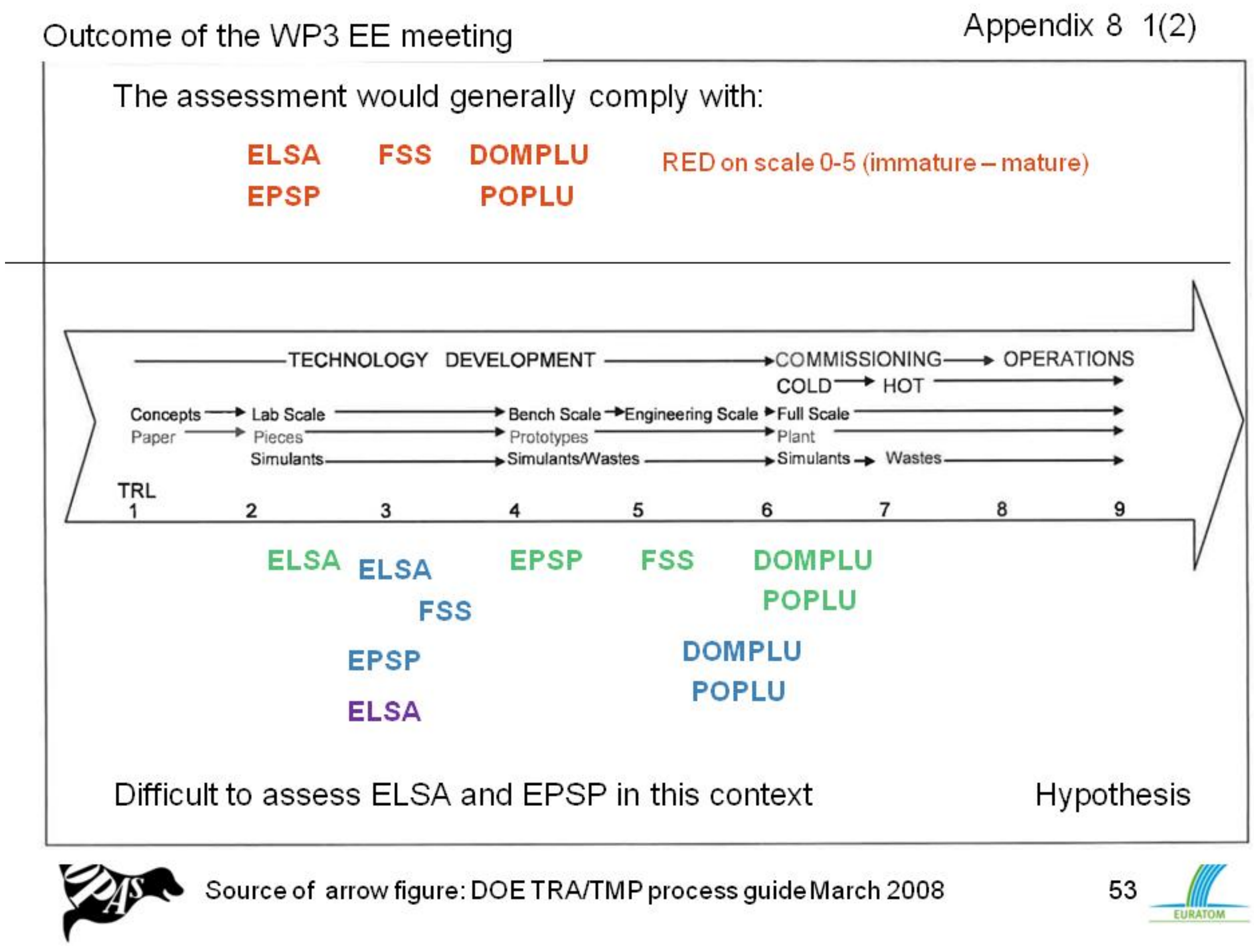
Schematic test model for the shaft sealing

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



Outcome of the WP3 EE meeting
Appendix 8 1(2)
The assessment would generally comply with:
ELSA FSS DOMPLU
EPSP POPLU
RED on scale 0-5 (immature – mature)
TECHNOLOGY DEVELOPMENT
COMMISSIONING
OPERATIONS
COLD
HOT
Concepts
Paper
Lab Scale
Pieces
Simulants
Bench Scale
Engineering Scale
Prototypes
Simulants/Wastes
Full Scale
Plant
Simulants
Wastes
TRL
1 2 3 4 5 6 7 8 9
ELSA ELSA EPSP FSS DOMPLU
POPLU
FSS
EPSP
DOMPLU
POPLU
ELSA
Difficult to assess ELSA and EPSP in this context
Hypothesis
Source of arrow figure: DOE TRA/TMP process guide March 2008
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EURATOM

TRL levels shortened (source: DOE 2008)

Appendix 8 2(2)

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

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EURATOM