Work package number	**2**	**Lead beneficiary**				**RWM**		
Work package title	**Collection and compilation of existing data and available models**							
Participant number	1	2	3	4	5	6	**7**	9
Short name of participant	SKB	SURAO	Posiva	ANDRA	NAGRA	ENRESA	RWM	UPC
Person months per participant:	3	1	1	2.3	1	0	2.6	3
Participant number	10	11	12	13	14	15	16	17
Short name of participant	GRS	CTU	CU	CEA	VTT	ULg	BGR	KIT INE
Person months per participant:	1.5	7.5	1.9	5.13	2	2	1.75	1.9
Participant number	18	19	20	21	22	23	24	25
Short name of participant	LEI	CIEMAT	CT	EPFL	ICL	Quin-tessa	NERC /BGS)	JYU
Person months per participant:	0	5.4	1.5	2	2	6.2	1.6	1
Start month	1			**End month**	48			

Objectives

Quantitative models of bentonite mechanical evolution that are currently available are not fully able to represent all the complexities of the evolution of an emplaced bentonite in a repository context. A substantial effort is therefore needed of improve both the conceptual approaches and the numerical solutions in the current models. The updated/newly developed models need to be tested and verified using available data. There are some areas where fundamental data and the understanding of materials are incomplete; an efficient experimental programme is needed to support model development and testing (WP4).

A substantial database of knowledge on issues potentially relevant to bentonite mechanical evolution is available from earlier and ongoing laboratory and Underground Research Laboratory (URL) experiments, complemented in some cases by modelling studies. However, many such experiments / studies were not primarily focussed of the mechanical evolution of repository bentonite barrier material, and therefore a large part of the existing database needs to be re-evaluated to extract important information directly relevant to bentonite mechanical evolution, to compile the qualitative and quantitative observations and to develop the conceptual understanding. This will be done as a joint effort between WMOs, experimentalists and modellers, all with previous experience in the field, in this Beacon work package.

The key objective of Beacon WP2 is therefore to collect such relevant information as produced from past and ongoing projects that provide knowledge relevant to understanding bentonite mechanical evolution in a repository context, and to process it to a level where it can be useful as input to the other Beacon work packages.

Description of work

There are three whole work package deliverables from WP2, with all participants requested to contribute on a timescale such that a report can be delivered at Month 6 and one towards project end. It is not anticipated that any other deliverables from WP2 will be necessary.

Input will be via completion of e.g. data sheets / questionnaire; the aim being that these can be readily collated by Quintessa, in an editorial role, into two reports that collate data and understanding at Month 6 (for use by WPs 3 and 5 in particular as the project proceeds), and towards project end (as a

mechanism of recording new understanding derived on the basis of work undertaken in the project).

To initiate the production of the Month 6 deliverable, WP2 will arrange and host a workshop (D2.1) (M1) in Kaunas, Lithuania, to establish a network of specialists in support of the project, and further to initiate a process leading to successful dissemination of the results within WP7.

This workshop will be held towards the very beginning of the project (and will include the whole project kick-off); one of the primary objectives will be the presentation and discussion of relevant extant information that is available from national and international projects relating to bentonite mechanical evolution. The workshop will therefore form an effective training mechanism to ensure transfer of knowledge and collaboration between the project participants and furthermore transfer of knowledge outside the project to the wider scientific community. The location of the workshop to Kaunas in Lithuania also aims at sparking and strengthening the involvement of, and transfer of knowledge to, less advanced programs (LAPs).

The workshop will advertised as a special conference dealing with the mechanical evolution of bentonite and participation and presentations from organizations outside of Beacon will be encouraged.

The purpose of the WP2 deliverables – particularly D2.2 – is to extract important information regarding processes affecting bentonite as relevant to an evolving repository, to compile all available qualitative and quantitative observations, and to develop the conceptual understanding. This information will be particularly relevant to WP3 and WP5 of BEACON. Completion of WP2 deliverables will be done as a joint effort between WMOs, experimentalists and modellers, all with previous experience in the field.

This timescale is tight but necessary, given that this WP2 deliverable will be a key input to WP3 and WP5 work; a delay in WP2 delivery D2.2 is therefore intolerable, as it will detrimentally impact other aspects of the project.

A participant cannot pick and choose which report they contribute to; input to both reports is required.

Tasks in WP2:

Task 2.1 Workshop to present and discuss relevant national and international extant information relating to bentonite mechanical evolution. (M1)

Task 2.2 Identification of relevant data/models, improvement of understanding of main processes associated to bentonite component evolution taking into account possible heterogeneities.

This will act as a source of information on which to base subsequent project WP3 and WP5 activities. The task will generate a report, D2.1. (M1-M6)

Task 2.3 Identification of captured knowledge (M6-M46)

SKB

The objective is to collect the current information available from the Swedish Radioactive Waste program. This refers to results from laboratory and field scale tests, modelling exercises and outcomes from safety assessments and design analyses.

Description of work to be performed: collection, documentation and analysis/assessment of the current information available from the Swedish Radioactive Waste program. This refers to results from laboratory and field scale tests, modelling exercises and outcomes from safety assessments and design analyses.

SURAO, CTU and CU

CTUs overall objective in WP2 is the gathering of relevant data from previous experiments supporting development and validation of homogenisation models with a dataset for mathematical model development and validation as a main outcome.

Description of work to be performed:

- Selection of relevant experiments and laboratory results
- Gathering of relevant data from past and ongoing experiments
- Data clean-up, conversion into dataset for further use in other WPs

The models developed in WP3/5 need extensive experimental dataset for their development and verification. Data from previous experiments exist. Relevant experiments will be selected, experimental data gathered, converted, cleaned up and prepared for further use in other WPs.

CUs overall objective of WP2 is the gathering of existing data on the selected bentonites needed for calibration of the models developed in WP3 with a dataset for constitutive model calibration and validation as the mail outcome.

Description of work to be performed:

- The task will be to gather relevant data from past and ongoing laboratory experiments. In particular, emphasis will be given on gathering of data on swelling properties and hydraulic conductivity of the bentonite. The study will focus on the bentonites from the Czech Republic (predominantly Ca-Mg bentonites from localities Rokle and Černý vrch).
- Data will be evaluated in the form needed for calibration of the models developed in WP3.

SURAO will contribute with experience and support to CU and CTU in their tasks.

Posiva, VTT and JYU's overall objectives for WP2 are to:

a) justify the choice(s) of conceptual model(s) to be used in WP3-5 (esp. in the targeted "industrial standard operational procedure to assess homogenisation of materials differences")

b) discuss and specify the needs for missing experimental data and forthcoming tests of WP4, by reviewing national experience and internationally applicable experimental studies of bentonite compatibility at medium and large scale.

c) discuss and specify the needs for development of more accurate mathematical models and their implementations, based on review of national and internal experiences.

The expected outcome of the above will be justification for the selection of methods in the forthcoming work and more detailed working plans for the next phases. Work to undertaken is:

Review of both Finnish and International literature and know-how on:

i) existing conceptual models,

ii) existing experimental results, and

iii) existing mathematical models.

The work here will be done based on the needs defined in Tasks 1.1 and 1.2. Results from this WP will form the basis for WP3-5.

ANDRA's work will involve the Identification of relevant data/models, and the improvement of understanding of main processes associated to bentonite component evolution taking into account possible heterogeneities.

Description of work to be performed: Andra has developed for the 20 years, several programs to characterize and understand bentonite component behaviour. Those programs included lab tests, field tests and modelling activities at several scales (from µm to real objects). The work in WP2 will concern an analysis of existing data in Andra which could be relevant for this project. Some specific tests will be described in details (data/ geometry/boundary conditions/results) and propose as benchmark within the WP5. Ongoing experiments will be described also to be used as predictive test cases for WP5 for example NSC, REM and BHN.

- NSC: A 5 meter long bentonite plug has been installed in 2013 in a gallery with a diameter of 4,6 meter (scale ½ compared to seals design in repository). The bentonite plug is made with bricks composed with 40% MX80 and 60% sand. Pure MX80 powder has been used to fill voids at the interface with the host rock. Forced Hydration started in January 2014 at several injections points. The objective is to evaluate hydraulic performance of the seal including the interface with the host rock and the damaged zone. The composition of the bentonite mixture has been chosen to obtain fast water saturation. In this experiment 420 sensors have been installed to measure pore pressure, relative humidity, total pressure, temperature, strain.
- BHN: The objective of the BHN experiment (naturally hydrated bentonite) is to monitor the

natural saturation of an argillaceous core in direct contact with Callovo-Oxfordian clay. The core is 3 m long into a horizontal borehole 75 cm in diameter at 7 meters depth. To monitor its natural saturation, instrumentation has been installed inside and around the periphery of the core. The core is composed with a mixture of bentonite pellets 32 mm in diameter (approximately 70% of the mixture), and bentonite powder or crushed pellets (approximately 30% of the mixture). The installation and hydration started in 2014.

- REM: The REM (Metric Scale Resaturation) experiment has been designed to study the water saturation of the bentonite mixture of 32 mm pellets and crushed pellets. The originality of this mock up is its scale. The cylindrical cell where the bentonite mixture is placed has a one meter height and one meter diameter. REM experiment is complementary to FSS; the Full Scale Seal (FSS) experiment, which is part of DOPAS project. The objective of FSS was to demonstrate the construction feasibility of a seal and REM is dedicated to study the behaviour of the bentonite during water saturation phase. The hydration started in 2014.

The last task will be about techniques of measure to detect initial heterogeneities in bentonite component after the installation.

NAGRA and EPFL are aiming for a better understanding of the role of chemo-osmotic effects on the swelling behaviour of active clays. The main expected outcome of WP2 is a comprehensive and critical review of existing data on swelling clays to serve as a basis for a new definition of an effective stress which includes chemo-osmotic effects. Description of their work to be performed in WP2:

Constitutive models, based on the effective stress approach, offer certain advantages when modelling geomaterials experiencing variations in their degree of saturation. The main advantages come from the direct link of the mechanical behaviour with the water retention behaviour and the smooth transition from the unsaturated to the saturated state. Nevertheless, those models have somehow limited ability in reproducing the behaviour of very active clays especially at the highest degrees of saturation. This is mainly due to the fact that the unsaturated state is mainly expressed through the matric suction (difference of the pressure of air and pressure of water) while the chemo-osmotic mechanisms are not taken into account. This limitation can reduce the possibility to proper analyse homogenisation phenomena during hydration of the barrier.

This work will focus on the collection and analysis of available experimental data performed with a clear definition of the chemo-osmotic conditions, in order to constitute a sounded database for developing an improved effective-stress-based constitutive model for bentonite-based materials (in WP3).

RWM's work in WP2 will concern an analysis of existing data that could be relevant for this project; this will cover information known by RWM, and information available to other project participants. Benchmarks for use in WP5 will be determined, primarily derived on the basis of available data.

Work will also consider techniques to measure / detect initial heterogeneities in GDF bentonite components after their installation, including their evolution in time and space.

UPC will perform a critical review of existing information on bentonite homogenisation and long term behaviour focusing on phenomenological description and modelling requirements.

The main expected outcome is a better understanding of the processes underlying long term bentonite behaviour and homogenisation and the development of improved guidelines for model development

Work to be performed:

- Review of the outcome of the long term cell experiments from CIEMAT

- Review of the results of the homogenisation tests carried out by Clay Technology

- Review of the observations of some large scale in situ tests. The tests will be selected from those where a direct observation of the final state of the barrier is available through dismantling (e.g. CRT, Febex, EB, Prototype).

GRS, BGR and KIT INE will undertake a compilation of existing data from experiments that provide the required information (e.g. long-term data performed at different compaction densities and experimental setup sizes in the cm – m scale and its effect on long-term swelling pressure distribution

and also clay mass losses). Beside the re-evaluation of already-existing data, in the course of the project continuously- generated data will be implemented, and/or definition of needs regarding additional experiments identified.

CEA's objective is to re-analyse laboratory scale experimental results (obtained for ANDRA or other WMOs) in order to extract information relevant for the problem of the re-homogenization of heterogeneous bentonite structures.

The work to be performed covers the re-analysis of past experiments relevant for the BEACON project, e.g. large REV hydration experiments, gas transfer/crack healing experiments, and *post-mortem* analyses (dry density, water content) of samples from older programmes. Work includes the selection of relevant experiments, necessary analysis or post-processing, and the communication of experimental results.

ULg will gather existing data on the selected bentonites needed for calibration of the models developed in WP3/5 with a dataset for constitutive model calibration and validation as the mail outcome.

CIEMAT will re-evaluate the data base on bentonite physical state (dry density and water content) of the FEBEX and EB in situ tests. Work to be undertaken includes:

- Comparison of the state of the FEBEX barrier after 5 and 18 years of operation;

- Analysis of the microstructural changes (pore size distribution) of the FEBEX barrier after 18 years of operation;

- Analysis of the microstructural changes (pore size distribution) of the EB barrier after 10.5 years of operation.

The main expected outcome is a conceptual understanding of the evolution of bentonite fabric and microstructure upon hydration (and heating) and of the factors affecting it.

Clay Technology (CT) has the overall objective in WP2 of the compilation and documentation of the current status of hydro-mechanical material models for bentonite, together with available data from laboratory and field tests.

The main expected outcome is the compilation of: i) data from water saturated test, i.e. homogenisation tests, oedometer tests, triaxial and uniaxial compression test, and creep tests; and ii) information on material model, i.e. porous elastic and plastic cap model (Abaqus), BBM (Code_Bright), and HM model based on a swelling pressure/suction relation with hysteresis.

Description of work to be performed:

ClayTech will collect and compile both existing data and available hydro-mechanical material models of relevance for THM calculations of bentonite in general, and for homogenisation calculations in particular. This type of data compilation is preferably focused on processes with water-saturated conditions, since these are simpler and more fundamental than unsaturated conditions. Data from the following tests will be compiled: homogenisation tests (e.g. SKB TR-12-02; SKB TR-14-25), oedometer tests (e.g. SKB TR-95-20), triaxial and uniaxial compression test (e.g SKB TR-10-32; SKB TR-10-41) and creep tests (e.g. SKB TR-95-20). Information on the following material models will be compiled: porous elastic and plastic cap model (SKB TR-95-20), HM model based on a swelling pressure/suction relation with hysteresis, and BBM (strategy for parameter value adoption in SKB TR-10-44).

ICL will collect the current information available from the ongoing work being undertaken for RWM, and related precedent UK and international studies. This refers to results from laboratory and field scale tests, modelling exercises and outcomes from safety assessments and design analyses. Documentation and analysis/assessment of information will be undertaken. ICL's overall objective for WP2 is to critically assess the available data from other existing experimental studies on bentonite homogenisation, for the purpose of modelling requirements that ICL will progress under WP3 and WP5.

Quintessa will use literature data to build up two datasets against which models can be tested. The first dataset will consist of swelling data from a range of experiments. The second dataset will consist of

water retention data, swelling pressure data and consolidation curves for a range of bentonites. These data will be made available for all the modelling teams and are expected to be used widely in WP3 to constrain swelling models.

Two datasets have been identified as important for further constraining models of bentonite swelling and homogenisation. The first is swelling data at different suctions for unconfined swelling to improve the conceptual understanding and numerical representation of the swelling process. The second is stress (both swelling and consolidation) and suction data for bentonite samples. Current work has identified a link between the mechanical and hydraulic expressions of stress in the sample, and further data would be used to confirm whether this link is seen on a wider range of samples.

For both datasets, the data will be taken from both peer reviewed papers and contractor reports, alongside any unpublished data that may be available through the BEACON consortium. The datasets will cover a range of experiments and different types of bentonite to detect general trends, to improve confidence in the applicability of models across a range of repository conditions. Simple qualitative and quantitative comparisons will be made of the data that are collated. Quintessa will additionally have the responsibility of collating all other participants' WP2 input (collected via a questionnaire / completion of data sheets) into a report that will then be used by WP3/5 in the latter (post the opening year) part of the project's schedule.

NERC (via its component org BGS) will collect the current information available from the ongoing work being undertaken for SKB, and related precedent studies. This refers to results from laboratory and field scale tests, modelling exercises and outcomes from safety assessments and design analyses. Documentation and analysis/assessment of information will be undertaken.

MKG will follow the work in the work package and coordinate interaction with WP6.

Deliverables

D2.1 (Month 1): Workshop to present and discuss relevant national and international extant information relating to bentonite mechanical evolution.

D2.2 (Month 6): Report on identification of relevant data/models, improvement of understanding of main processes associated to bentonite component evolution taking into account possible heterogeneities. (Contributions from all WP2 participants, edited by Quintessa)

This will act as a source of information on which to base subsequent project WP3 and WP5 activities.

D2.3 (Month 46): Report on captured knowledge bentonite mechanical evolution gained over the duration of the BEACON project. (Contributions from all WP2 participants, edited by Quintessa).