EUROPEAN COMMISSION

Community Research

ESDRED

(Contract Number: FI6W-CT-2004-508851)

PROJECT RESULTS LEAFLET

Engineering Studies and Demonstration of Repository Designs

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RE	Restricted to a group specified by the partners of the ESDRED project	
CO	Confidential, only for partners of the ESDRED project	

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Author: **WOLF K SEIDLER**

Introduction

The permanent disposal of highly active and long-lived radioactive waste is an important issue for most of the member states of the European Union; in fact it is a challenge facing all of the nuclear power producing countries around the world. In 2003 a number of European National Waste Management Agencies and R & D organisations decided to embark on a common project aimed at advancing the level of available practical technology in the field of radioactive waste management. A proposal was submitted to the European Commission and a Contract was signed with the EC in early January of 2004. The work began on February1, 2004 and was completed in January 2009.

The technical work carried out within ESDRED is all about the development of new technology and is therefore focused on four basic technical themes:

- Buffer Construction Technology
- Waste Canister Transfer and Emplacement Technology
- Heavy load Emplacement Technology
- Temporary Sealing Technology Based on Low pH Cements/Concrete

The work completed within ESDRED has been an important step towards establishing a sound technical basis for demonstrating the feasibility of safely disposing spent fuel and other high-level and long-lived radioactive wastes in deep geological formations, up to hundreds of metres below surface. The results of the work have helped to fill certain technological gaps that previously existed. In the future waste management agencies will have more technological options to choose from. By demonstrating the results of the work and by sharing the acquired knowledge widely the ESDRED partners have also enhanced the process of Confidence Building and they have helped to underpin the development of a common European view on the main issues related to the management and disposal of radioactive waste. This booklet provides a brief overview of the objectives and results achieved.

Nature and Scope of the Project

The Integrated Project known as ESDRED (Engineering Studies and Demonstrations of Repository Designs) has been a joint research and development effort by major national radioactive waste management agencies (or subsidiaries of those agencies) and by research organisations. ESDRED was co-ordinated by the French National Radioactive Waste Management Agency (ANDRA) and was part of the European Union's 6th Euratom Framework Programme for Nuclear Research and Training. The five year Project started with a total budget of EURO 18.4 million, of which 7.3 million was provided by the EU's Framework Programme. Many of the participants elected to do more, or more elaborate, work than originally envisaged so that a conservative estimate of the total final expenditure (including other increased costs) is 23 million €.

The technical work carried out within ESDRED focused on eight main activities related to the construction, operation and closure of an underground deep geological repository namely:

- the design, fabrication and installation of pre-fabricated engineered barriers in horizontal waste disposal drifts (also sometimes called tunnels, galleries or cells),
- the design of unconsolidated buffer materials for backfilling annular gaps (large and small) between waste canisters and disposal drifts, including equipment selection and demonstration of the placement process,
- the design and in situ testing of post sealing non-intrusive monitoring techniques,
- the design and testing (laboratory and in situ) of self-sealing bentonite/sand barriers suitable for application where gas generation is likely,
- the design, fabrication and demonstration of equipment intended for the transport and emplacement of waste canisters weighing less than 6 tonnes, in both horizontal and vertical disposal drifts/tunnels/boreholes,
- the design, fabrication and demonstration of equipment intended for the emplacement of heavy loads (up to 45 tonnes), such as spent fuel canisters in horizontal disposal drifts,
- the development of low pH cements to be incorporated in shotcrete which is then used to construct plugs and to construct rock support linings,
- a desk top study related to the retrieval of emplaced waste canisters was also carried out.

The concepts as envisaged at the start of the work are shown in Figures 1 and 2 below.

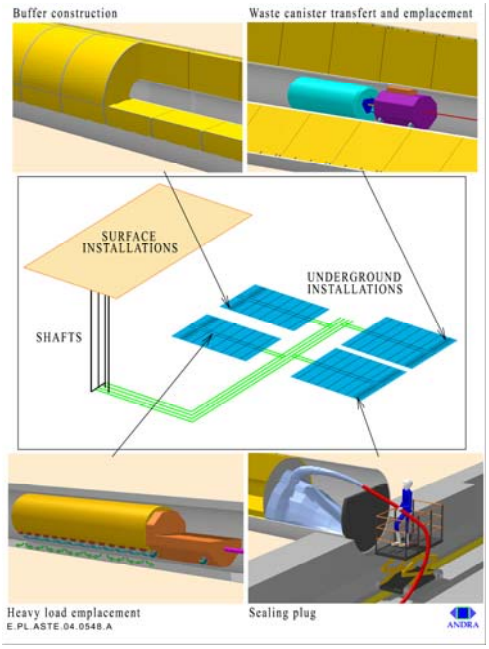

Figure 1: ***Basic Input Concepts***

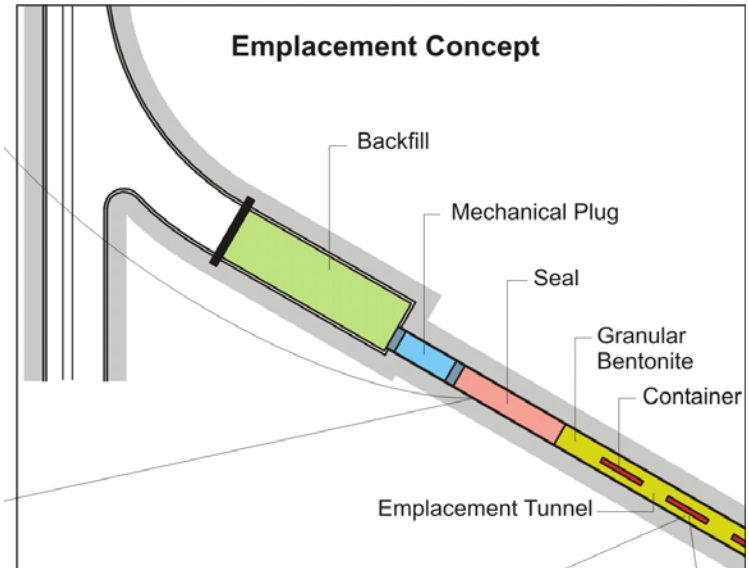

Figure 2: ***Details of a Generic Emplacement Concept (horizontal disposal) with its Various Elements***

RESULTS

ESDRED set out to demonstrate that certain feasible techniques are available for the implementation of deep geological disposal. The actual work was organised within 4 separate Technical Modules each with a Module Leader. Each Module was made up of a number of different Work Packages. From 3 to 7 of the 13 partners were involved with each of the Modules. There were also 3 non-Technical Modules, one of which dealt with "Training and Communication" for which the results are also summarised herein. The main accomplishments are provided below:

Module 1 - Buffer Construction Technology

Within this Module certain participants were able to successfully design the necessary formulation and thereafter produce 4 tonne bentonite rings to be used as an engineered barrier.

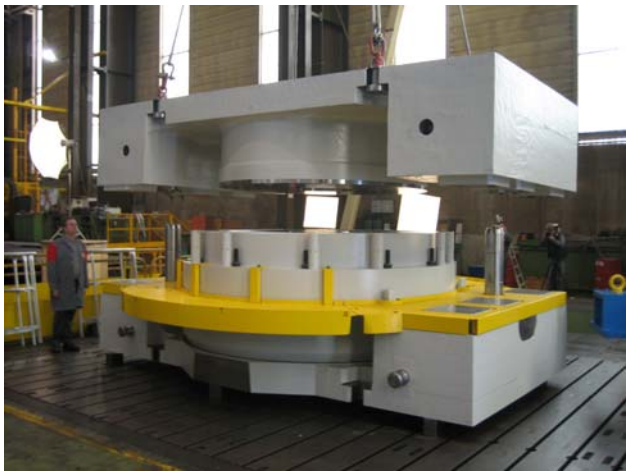

Figure 3: ***100 Tonne Mould for Pressing Sand/bentonite Rings***

Figure 4: ***Four Tonne, 2.25m Diameter Sand/bentonite Ring after 45 000 tonnes of Pressure & Stripping from Mould***

Other participants demonstrated backfilling of the annular gap between a waste canister and the disposal drift wall using a variety of wet and dry products. Still others developed the product and the technique for backfilling disposal drifts with bentonite pellets. The evolution over time and the performance of bentonite based seals, particularly in relation to gas permeability, was also assessed and is in fact on-going beyond ESDRED. Finally non- intrusive monitoring techniques based on cross-hole seismic tomography were also developed and demonstrated. This work is also continuing beyond ESDRED.

The various reports produced, most of which are available to the public, will enable interested parties:

- To design a sand/bentonite mixture which, when compressed into a ring, has physio-chemical characteristics suitable for use as an engineered barrier around waste canisters,
- To design a method suitable for placing granular bentonite around waste canisters as a buffer material while obtaining the desired in situ density and other characteristics
- To design and fabricate a mould for producing large EBS rings as well as all the related stripping and handling equipment,

- To formulate various wet and dry materials for use as a backfill and to evaluate the related placement options,
- To formulate a borehole seal made of moderately compacted sand/bentonite mixtures and to have an understanding of the gas/water permeability of such a seal over time,
- To evaluate whether non-intrusive monitoring based on cross-hole seismic tomography is suitable to a particular application and to understand the scope and limits of the technique.

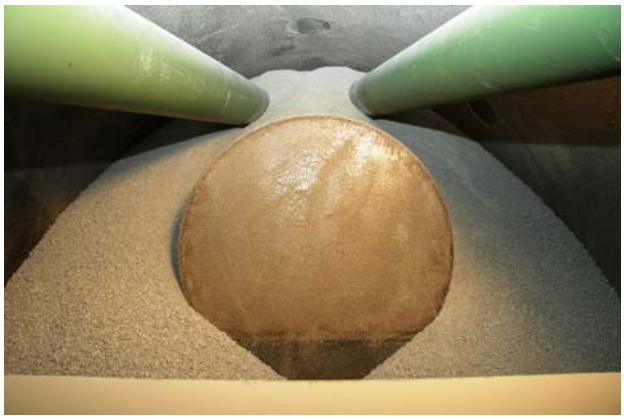

Figure 5: ***Double Auger (green) Placement of Bentonite Pellets around a Canister***

Figure 6: ***Reduced-scale Mock-up for Grout Backfill Testing, after Slice-cut (Nov. 2006)***

Figure 7: ***Granular Materials Backfill Test Configuration (June-Oct. 2006)***

Rock support tests, borehole seal tests and non-intrusive monitoring tests were all conducted underground however the fabrication of EBS rings and the backfilling tests (with the exception of the O/N Praclay Plug Construction) were conducted on surface, but at full scale.

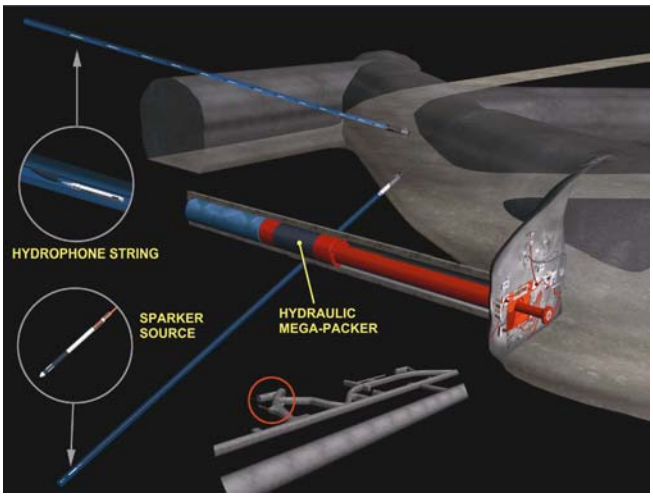

Figure 8: ***Installation at Mt. Terri Underground Laboratory Switzerland***

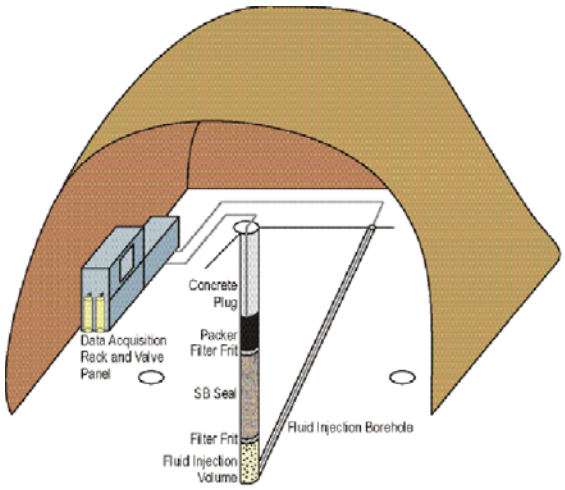

Figure 9: ***Design of the Self Sealing Clay/Sand Barrier Experiment (SB) at Mt Terri***

Module 2 - Waste Canister Transfer and Emplacement Technology

In this Module the two main participants were able to design, fabricate and demonstrate the equipment needed for the **Transfer and Emplacement of Waste Canisters** weighing between 2 and 5.2 tonnes. The equipment is designed for emplacement in both horizontal and vertical disposal boreholes with very small annular clearances between the canister and the wall of the disposal boreholes. A desk study related to retrievability was also produced.

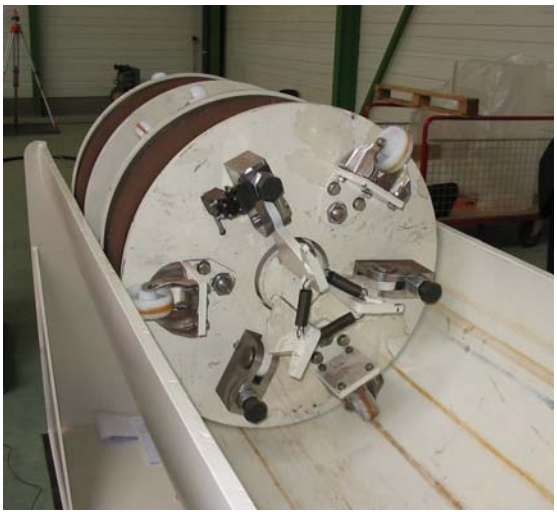

Figure 10: ***First Prototype Pushing Robot (Oct 05)***

Figure 11: ***Horizontal Emplacement Demonstrator (Sept 08)***

The horizontal emplacement equipment which was produced can be seen by the public at ANDRA's Technology Centre (CTe) in Saudron, near the Bure URL. Likewise the vertical emplacement equipment can, for the short term at least, still be seen at the Kraftwerk Robert Frank facility at Landesbergen Germany.

Both emplacement systems were demonstrated in surface facilities using inert waste canisters that were otherwise accurate geometrically and with regard to mass.

Figure 12: ***Vertical Emplacement Device***

Figure 13: ***Emplacement Device Manipulating Transfer Cask (Sept.08)***

Module 3 – Heavy Load Emplacement Technology

Heavy Load Emplacement Technology for horizontal disposal concepts was the only focus of this Module**.** The two participants active in this work each successfully produced a machine for emplacing 45 tonne waste canisters in bored disposal drifts while maintaining only a very small annular gap between the canister and the walls of the drift. One machine was based on water cushion technology while the other used air cushions. The latter machine was subsequently modified to demonstrate the emplacement of packages of 4 bentonite rings produced in Module 1, weighing 17 tonnes per package.

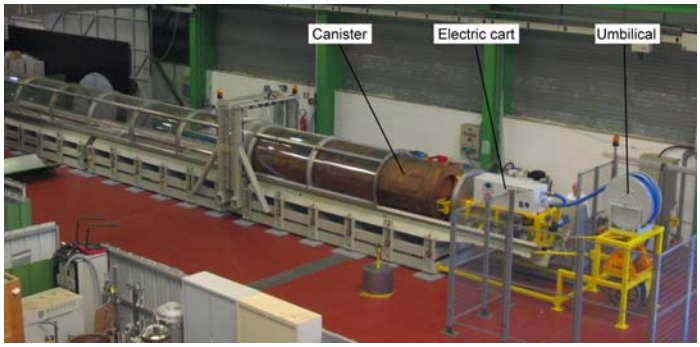

Figure 14: ***Demonstration of Emplacement of 43 Tonne Canister Using Air Cushion Emplacement Equipment***

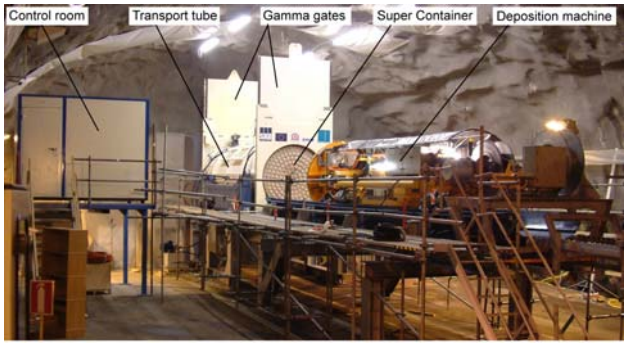

Figure 15: ***Water Cushion Emplacement Machine with 45 Tonne Super Container in Background***

The air cushion machine is on public display at ANDRA's Technology Centre in Saudron, near the Bure URL in France. At time of writing the water cushion machine is set up underground on the minus 220m level at the Äspö URL in Sweden. Design details, test results, as well as recommendations for future enhancements are available in the various project reports which have been designated for public access.

Figure 16: ***View Showing Emplacement Cart, Radiation Shield, Pushing Jack, Canister and Gripping Mechanism***

Figure 17: ***The Water Cushion Deposition Machine in the Demonstration Drift at Äspö***

Module 4 - Temporary Sealing Technology Based on Low pH Cements

The work in this Module consisted first of designing low pH cement formulations and then of preparing several concrete designs suitable for the construction of sealing plugs and for rock support. In both cases shotcreting was used as the construction method. A short plug and a long plug were subsequently constructed in situ underground in 2 different URL's. The short plug was loaded to failure (i.e. slippage) very quickly and monitored during the entire process. The full scale longer plug was loaded using the swelling pressure created by bentonite blocks which were artificially hydrated. This is a much slower loading process more closely related to what would happen in reality (albeit still on a much faster time scale). At time of writing the full scale long plug had not been loaded to failure. Final results will be reported as part of the MoDeRn project which is also being financed by the EC as part of the 7th Euratom Framework Programme for Nuclear Research and Training.

Fig 18 ***Long Plug in Background with Monitoring Equipment***

Fig 19 ***Short Plug Construction at Äspö***

A variety of project reports, available to the public, describe in detail the process used to develop low pH cements which would meet the project needs. Other reports describe the test plan and the execution related to the construction of the 2 plugs noted above. The short plug constructed at Äspö has been tested and demolished. However the full scale long plug at the Grimsel Test Site in Switzerland is still intact. The desired water saturation and the maximum swelling pressure are not expected to be reached until well after the end of the ESDRED Project. As the saturation of the bentonite is taking longer than expected the partners involved agreed to continue with the saturation of the bentonite blocks and the related data monitoring. The Grimsel Test Site is managed by NAGRA and can be visited at any time by making appropriate arrangements in advance. This plug has also been employed for a further programme of cross-hole seismic tomography and other types of wireless monitoring (TEM Project) organised by ESDRED partners outside of the ESDRED programme. It is also a part of the MoDeRn Monitoring Project noted above.

Module 5 – Training and Communication

ESDRED also focused on training and communication. The project the participants wrote articles, presented technical papers at international conferences, held workshops, developed and presented university lectures, and organised international events in Prague (Czech Republic), in Bure (France), in Landesbergen (Germany), etc.

The ESDRED partners developed and then presented 17 Masters level lectures to the students of the University Polytehnica of Bucharest, Romania. The concerned partners also organised 2 workshops focusing on the R&D related to low pH cements, which attracted an international audience & authors.

The *"International Technical Conference on Practical Aspects of Deep Radioactive Waste Disposal"* (June/08) was organised by ESDRED together with the Czech Technical University of Prague (CTU) and RAWRA the Czech national waste management agency and was held in the facilities of the CTU. Nineteen of the 37 papers and posters related directly to ESDRED, to the national agencies represented in ESDRED or to the contractors that had been engaged by the ESDRED participants. The results were immensely appreciated by the more than 120 participants hailing from 19 different countries. The proceedings have been posted on the ESDRED website and bear the following ISBN # 2-916162-05-4.

In October 2008 all of the ESDRED Module Leaders made important presentations at the EC's Euradwaste Conference in Luxembourg and during the field trip to Bure which included a demonstration of some of the equipment produced as part of the project. There was also a separate for journalists in Bure.

Most of the material prepared by the ESDRED partners for the public has been placed on the ESDRED web site described below. This includes technical papers, presentations to various groups, posters, videos, annual activity reports, summaries of the proceedings from 2 Low pH Workshops and the Proceedings from the International Conference held in Prague.

Prague, June 08

Bucharest, June 06

Landesbergen, September 08

ESDRED Web Site: Information for Stakeholders and the Public (**www.esdred.info**)

The ESDRED web site was set up during the first year of the Project and updated regularly thereafter. At present it represents a sort of history of the Project. As such it presents not only the objectives and contractual commitments of the partners but also the accomplishments.

The ESDRED website provides information at several levels of detail and is therefore adapted to the various audiences. Among other things the site provides access to technical papers, posters, videos, project presentations to various groups, press releases, proceedings from workshops and conferences, etc. It also includes a summary of the annual activities for each year of the Project as well as the seven main "*End of Project Reports/Documents*" listed below:

Reference	Title
Mod1-WP6-D6	Module 1 (Buffer Construction Technology) Final Technical Report
Mod2-WP7-D8	Module 2 (Waste Canister Transfer & Emplacement Technology) Final Technical Report
Mod3-WP5-D6	Module 3 (Heavy Load Emplacement Technology) Final Technical Report
Mod4-WP4-D9	Module 4 (Temporary Sealing Technology) Final Technical Report
Mod5-WP5-D11	Final Report on Communication Action Plan
Mod5-WP9-D12	Leaflet on Final ESDRED Results
Mod6-WP4-D6	Final Summary Report and Global Evaluation (Final ESDRED Project Report)

Many of the other reports produced by the ESDRED partners during the course of the work are also available to the public. A complete listing of these will be available on the European Commission's "CORDIS" web site (http://cordis.europa.eu/results/home_en.html) and is attached hereto as an appendix.

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ENRESA, Spain
NAGRA, Switzerland
NDA, United Kingdom
ONDRAF/NIRAS, Belgium
POSIVA, Finland
SKB, Sweden

Technological R&D organisations:
AITEMIN, Spain
CSIC, Spain
DBE TECHNOLOGY, Germany
ESV EURIDICE EIG , Belgium
GRS, Germany
NRG, The Netherlands

Project Coordinator:

- ANDRA (also leader of Modules 5, 6 & 7)

Technical Module Leaders:

- ONDRAF/NIRAS (Belgium) for Module # 1,
- DBE TECHNOLOGY (Germany) for Module # 2
- SKB (Sweden) for Module # 3
- ENRESA (Spain) for Module # 4

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Appendix: List of Public Reports

Deliverable		Available from	Available on ESDRED Web site
MODULE 1 - BUFFER CONSTRUCTION TECHNOLOGY			
Mod1-WP4-D4	D4 = Report in situ test configuration	ONDRAF/NIRAS	
Mod1-WP5-D5	D5 = Report testing non-intrusive monitoring systems	ONDRAF/NIRAS	
MODULE 2 - WASTE CANISTER TRANSFER & EMPLACEMENT TECHNOLOGY			
Mod2-WP1-D1	D1 = Set of input data and functional requirements	DBE TEC	
	Module 2 WP4, Internal Report on Retrievability (on Web Site)	DBE TEC	Yes
Mod2-WP6.2-D7	D7 = Report in situ (surface facilities)	DBE TEC	
MODULE 3 - HEAVY LOAD EMPLACEMENT TECHNOLOGY			
Mod3-WP1-D1.1	D1.1 = Set of input data and functional requirements	SKB	
Mod3-WP4-D5	D5 = Report of the emplacement/transportation test	SKB	
MODULE 4 - TEMPORARY SEALING TECHNOLOGY			
Mod4-WP3.2-D8.1	D8.1 = Report on plug test results	ENRESA	
Mod4-WP3.2-D8.2	D8.2 = Report on rock wall support demonstration	ENRESA	
Mod4-WP3.2-D8.3	D8.3 = Report on long plug demonstration	ENRESA	
MODULE 5.1 - TRAINING ACTIVITIES			
Mod5-WP2.1-D2	D2 = Support documents of first training workshop (on Web Site)	ANDRA	Yes
Mod5-WP2.2-D4	D4 = Support documents of second training workshop	ANDRA	Yes
MODULE 5.2 - COMMUNICATION ACTIVITIES			
Mod5-WP7-D10	D10 = Proceedings of International Event	ANDRA	Yes
Mod5-WP8-D5	D5 = Media press release	ANDRA	Yes
Mod5-WP9-D6	D6 = Leaflet related to Programme Presentation	ANDRA	Yes
Mod5-WP9-D12	D12 = Leaflet on Esdred results	ANDRA	Yes
Mod5-WP10-D9	D9 = Main conclusions of meetings with Cowam 2	ANDRA	
MODULE 6 - INTEGRATION ACTIVITIES			
Mod6-WP1.1-D1	D1 = Report on common set of input data and functional requirements	ANDRA	
Mod6-WP2-D3	D3 = Report on common features of Design Studies	ANDRA	