ENHANCED SEALING PROJECT (ESP): DESIGN, CONSTRUCTION AND MONITORING OF A FULL-SCALE SHAFT SEAL

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The Enhanced Sealing Project (ESP) consists of instrumenting and monitoring a full-scale shaft seal installed to permanently close the access shaft for Atomic Energy of Canada Limited's (AECL's) Underground Research Laboratory (URL) at the intersection of an ancient low dipping thrust fault (Figure 1). The URL was built to provide a facility where concepts for long-term management of Canada's nuclear fuel waste in a deep geological repository could be studied. Operated since the early 1980s, this facility provided much of the technical information used in developing the deep geological repository concept submitted by AECL to the Government of Canada in 1994 (AECL 1994) and continued to provide valuable technical data after that submission.

In 2003, a decision was made to discontinue operation of the URL and ultimately decommission and permanently close the underground portion of this facility. As part of the Nuclear Legacy Liability Program (NLLP) being funded by Natural Resources Canada (NRCan), facilities including the URL that are no longer part of AECL's mandate or operations are being decommissioned. Included in this work is the installation of seals at the intersection of the access shaft and ventilation raise with a deep fracture zone in order to limit the potential for mixing of deeper saline and shallower less saline groundwater. The funding available from NRCan was limited to the seal installation, with no mandate to provide any more than basic hydrological monitoring of the rock mass at a considerable distance (~ 50 to ~ 500 m) from these seals, and so the opportunity to monitor a full-scale shaft seal similar to one for a deep geological repository would have been lost.

The ESP arose from the recognition by a number of organizations (the Nuclear Waste Management Organization (NWMO – Canada), Agence Nationale pour la gestion des Dechets Radioactifs (ANDRA – France), Posiva Oy (Finland) and Svensk Kärnbränslehanertring AB (SKB – Sweden)) that the URL closure presented a unique opportunity to monitor the evolution of a full-scale repository-type shaft seal in a very well-characterized and otherwise undisturbed rock mass. As a result of this opportunity, these four organizations have partnered to support a package of work managed by AECL that will see the NRCan-funded construction of the shaft seal enhanced through the installation of a suite of monitoring instruments in the main shaft seal. However, the ventilation raise seal will not be instrumented. Each of the participants have provided technical input to the design of the seal and the sensor suite installed, providing this construction with a very well defined scope and focus, as well as an opportunity to test a variety of sensors under repository-like conditions. A challenge not previously dealt with in an underground laboratory is the issue of dealing with very long cable lengths (> 300 m) necessary to reach from the sensor installation point to a location where a logger can be installed and monitored. This has been dealt with by using a combination of three data logging techniques, including a watertight pressure-resistant logger, a sacrificial logger that is required to last only until water reaches it and selection of sensors that are capable of tolerating long cable lengths (e.g. fibre optics and vibrating wires).

The main shaft of the URL at the location of the seal is circular (~ 5 m diameter), having been excavated using careful drill and blast techniques. The seal itself consists of two keyed, conical sectioned, concrete sections 3-m-thick by 5- to 6-m diameter that confine a 6-m-thick swelling clay section (Figure 1). The lower concrete section, based approximately 279 m below the ground surface consists of reinforced low-heat, low-pH, high performance concrete that is intended to have minimal chemical influence on its surroundings. The clay segment of the seal consists of a mixture of Wyoming bentonite and sand-sized aggregate (40:60 mass ratio) that is densely compacted using conventional compaction techniques. This bentonite-sand material provides a substantial self-sealing capacity to the installation and will minimize mass transport into the fracture zone. The upper concrete segment consists of a further 3 m of monolithic concrete having the same composition as the lower segment. However, it does not contain any reinforcement. The concrete, clay and surrounding rock mass are being monitored via a suite of 60+ sensors that record temperature, strain, hydraulic and mechanical pressure as well as water content within the swelling clay portion of the seal.

The ventilation raise at the URL is structurally different than the main shaft in that it is 1.8 m in diameter and was excavated using raise-boring. As a result there is a different degree of excavation-induced disturbance of the rock adjacent to the excavation, although stress-induced damaged is evident in the region where the seal will be installed. The seal installed in the ventilation raise is also substantially different that installed in the main shaft. The ventilation raise seal will consist of 2-m-thick concrete segments confining a 5-m-thick assembly of precompacted clay-sand blocks (70% by mass of Kunigel VI bentonite and 30% sand). These blocks were surplus to the needs of the Tunnel Sealing Experiment conducted at the 420 m level of the URL during the period 1998-2005 and so were available for use. Their composition and properties are well characterized and they provide a means of evaluating the process of installing a substantial volume of clay blocks as part as a shaft seal.

Over the course of its operation, the ESP will provide a valuable resource for evaluation of repository seals, planning for future sealing studies and ultimately formal designs for repository application. The information gained will also provide information that will assist in development and testing of numerical models for use in evaluating repository seal evolution.

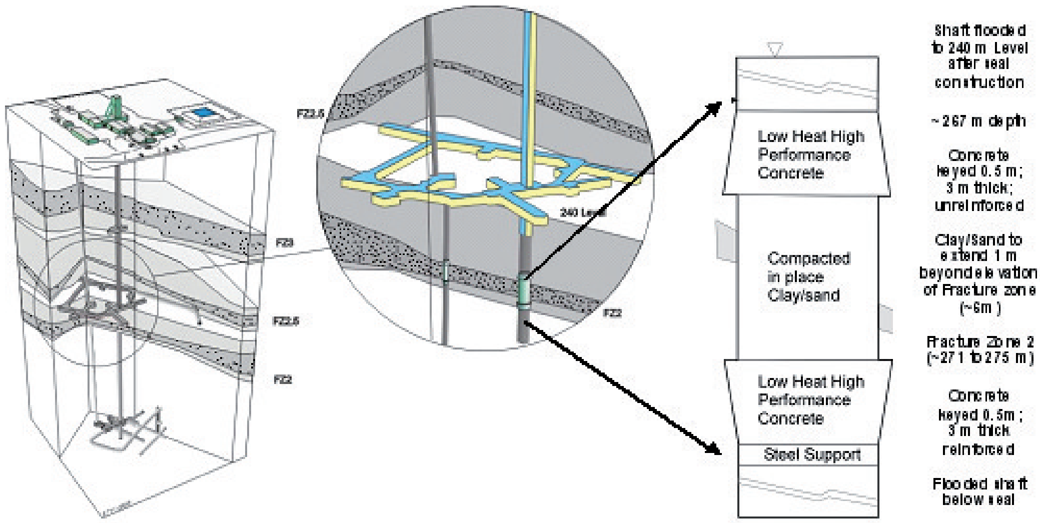

Figure 3: Geologic structure at URL, underground development at 240-Level and schematic showing basic layout of ESP in main shaft.