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Inspection fédérale de la sécurité nucléaire IFSN
Ispettorato federale della sicurezza nucleare IFSN
Swiss Federal Nuclear Safety Inspectorate ENSI

Implementation of the obligations of the

Convention on Nuclear Safety

CNS

National Report of Switzerland for the Second Extraordinary Meeting in Accordance with Article 5 of the Convention

May 2012

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Executive Summary

On 11 March 2011 a massive earthquake of magnitude 9 followed by a devastating tsunami hit the east coast of Japan's main island Honshu. Those natural events triggered a series of malfunctionings and equipment failures that led to the severe nuclear accident at Fukushima Dai-ichi as it developed in the days and weeks that followed. The consequences of the accident have been dramatic for the Japanese population and the staff involved, and had a major impact on the public opinion as well. In Switzerland in particular, the government and the parliament have decided to suspend the licensing process for the new builds and committed to a nuclear phase-out.

In the global nuclear community the reaction to the accident has led to the adoption of the IAEA Action Plan by all member states and, among others, to a special CNS Extraordinary Meeting scheduled for August 2012. Within this framework ENSI advocates an effective strengthening of the global nuclear safety regime, including mandatory international review missions and enhanced transparency in reporting.

The European Union (EU) initiated a so-called stress test for its member countries with nuclear power plants, in which also Switzerland participates. The EU stress test is a focused reassessment of the European nuclear facilities as regards their protection against extreme external events (namely earthquakes, flooding and extreme weather conditions), against the loss of safety functions (namely in the case of prolonged station blackouts and loss of ultimate heat sink) and severe accident management in general. The reassessment aims at identifying safety margins beyond design and cliff edge effects with a purely deterministic approach.

Beside the various international efforts which Switzerland actively supported, there has been a series of national actions taken by the Swiss Federal Nuclear Safety Inspectorate (ENSI) with the goal of understanding the event sequence in Fukushima and its causes so as to draw consequences for nuclear safety in Switzerland. In fact lessons have been identified, analyses performed and concrete measures adopted. In general terms the safety of the Swiss nuclear power plants has been confirmed as high, being based on particularly robust plant designs and numerous provisions in the beyond design basis domain. The plants have been backfitted in an extensive manner in the course of the years, especially the older units which started operation 40 years ago. Additionally, according to the Swiss legal requirements, the plants go through a comprehensive check at least every ten years during the so called periodical safety review. Nonetheless improvements are always possible and the process of reassessing and reanalysing in the light of new knowledge does not ever, per definition, reach a final answer. This holds true also for the regulator's own supervision processes as well as for the emergency preparedness and the nuclear safety regime at national level. The constant questioning attitude and search for improvements are fundamental factors for a good safety culture and as such enshrined in the Nuclear Energy Act.

In its response to the Fukushima accident ENSI has chosen a stepwise approach. This allows the incorporation of new lessons as soon as they become available from further accident investigations in Japan which will certainly take some more years to be completed.

In concrete terms, ENSI requested the Swiss operators to address topics such as protection against earthquakes and flooding within increased hazard assumptions, design of spent fuel pools and availability of the ultimate heat sink, but also availability and transport of accident management equipment from offsite locations. This was accompanied by topical inspections and resulted in improvement measures ordered by ENSI. Examples of such measures are (depending on the plant): additional level and temperature instrumentation for the spent fuel pools, redundant pool cooling systems, various improvement measures for protection against flooding, the implementation of an alternate ultimate heat sink, and the storage of accident management equipment in an external dedicated storage facility.

The response program launched by ENSI in the wake of the Fukushima accident is not only ambitious in scope but also challenging with regards to its schedule. In fact it aims, once completed, at covering all areas identified to have played a role in the accident in Japan. While the design reassessment for protection against flooding has been concluded, some important reviews as those concerning the protection against earthquakes, based on a comprehensive reassessment of the seismic hazard, have still to be completed. The planning of the further topics to be addressed and the follow-up on the required improvements is done on a yearly basis in a Fukushima action plan issued by ENSI. Concerning the schedule in a medium term perspective, ENSI plans to take all the necessary actions identified to date and enforce the derived measures as demanded in its mandate of national nuclear safety authority by the end of 2015.

0 Introduction: Swiss Response to the Fukushima Accident

0.1 Switzerland and its Nuclear Power Plants

Switzerland is situated in central Europe with a total land area of 41'285 km² and has a population of roughly 7.9 million. Five nuclear power plants are located within the Swiss borders on four different locations: Beznau I and II, Mühleberg, Gösgen and Leibstadt (see Figure 0-1, key data in Table 0-1). These plants contribute about 40% to the country's total electricity production.

Figure 0-1: Locations of the Swiss nuclear power plants.

The Swiss Federal Nuclear Safety Inspectorate ENSI is the supervisory authority for nuclear safety and security. As an independent public-law entity, ENSI's oversight scope extends from the planning, construction, operation to the shutdown of the facilities and final disposal of radioactive waste; its remit also includes radiation protection for nuclear personnel and the general public, as well as protection against sabotage and terrorism. In addition ENSI supervises the transport of radioactive substances from and to the nuclear facilities and the studies on geological disposal of radioactive waste.

Licensing procedures for three new units on existing sites were on-going in Switzerland before the events at Fukushima occurred. ENSI was involved in the procedures and had issued the three corresponding safety evaluation reports. The safety evaluations focused on the reassessment of the potential hazards related to the specific site characteristics. Shortly after the Fukushima accident, the Federal Council suspended these procedures. Over the course of 2011, the Federal Council and the Swiss Parliament decided to phase out nuclear energy by abandoning the building of new plants, whereas the existing plants should continue to operate as long as they can do so safely.

Table 0-1: Key data for the Swiss nuclear power plants

	KKB 1 (Beznau 1)	**KKB 2 (Beznau 2)**	**KKG (Gösgen)**	**KKL (Leibstadt)**	**KKM (Mühleberg)**
Thermal power [MW]	1130	1130	3002	3600	1097
Gross electrical output [MW]	380	380	1035	1245	390
Net electrical output [MW]	365	365	985	1190	373
Reactor type	PWR	PWR	PWR	BWR	BWR
Reactor supplier	W	W	KWU	GE	GE
Turbine supplier	BBC	BBC	KWU	BBC	BBC
Generator data [MVA]	2 x 228	2 x 228	1140	1318	2 x 214
Main heat sink	River water	River water	Cooling tower	Cooling tower	River water
Commercial operation started in	1969	1971	1979	1984	1972
Spent fuel pools (SFP)	2 SFPs in separate buildings	2 SFPs in separate buildings	1 SFP in primary containment, 1 SF loading pond in secondary containment	1 SFP in primary containment, 1 SFP in a separate building	1 SFP in secondary containment
Interim waste storage facility	Internal interim storage facility (air-cooled)	Internal interim storage facility (air-cooled)	External wet storage facility	External interim storage facility	Internal interim storage facility
Holder of operating licence	Axpo AG	Axpo AG	Kernkraftwerk Gösgen-Däniken AG	Kernkraftwerk Leibstadt AG	BKW FMB Energie AG
Number of reactor cooling loops	2	2	3	-	-
Containment type and venting systems	Full pressure containment with filtered venting system	Full pressure containment with filtered venting system	Full pressure containment with filtered venting system	Mark III containment with filtered venting system	Mark I containment with filtered venting system

Switzerland signed the Convention on Nuclear Safety (CNS) on 31 October 1995 and ratified it on 12 September 1996. The Convention came into force on 11 December 1996. In accordance with Article 5 of the Convention, Switzerland submitted five country reports for Review Meetings of Contracting Parties organized in 1999, 2002, 2005, 2008 and 2011 and attended the corresponding meetings.

0.2 Outline of the present report

The present report for the CNS Extraordinary Meeting in August 2012 has been compiled according to the Guidance for National Reports (IAEA, 31 October 2011) and describes the activities in Switzerland resulting from or influenced by the Fukushima accident.

Section 0.3 gives an overview of the legal basis in Switzerland. Section 0.4 outlines the actions taken by ENSI at the very beginning of the accident and the stepwise approach according to the Swiss legal and regulatory framework. The sections 0.5 to 0.8 describe the activities in Switzerland pursuant to this approach. In order to provide a synopsis, the activities are listed in chronological order at the end of this chapter (section 0.9). The subsequent chapters 1 to 6 contain the preliminary or final results of these activities until 31 December 2011, corresponding to the six topics specified in the Guidance for National Reports mentioned above. In accordance with the addendum to the Guidance for National Reports of 18 January 2012, Chapter 7 provides a table summarizing the Swiss activities in the aftermath of the Fukushima accident. Chapter 8 lists the checkpoints and open points identified, Chapter 9 contains the acronyms and chapter 10 the references referred to in the report.

0.3 Legal basis

The statutory and regulatory framework for the peaceful use of nuclear energy is stipulated by the Swiss constitution (first level), Federal legislation (second level), the ordinances (third level) and the ENSI guidelines (fourth level). Legislation regarding the use of nuclear energy and radiation protection is enacted solely at national level. The Federal Parliament and the Federal Council have the sole right to enact laws in this area. The material provisions regarding authorisation and regulation, monitoring and inspection are based on the Nuclear Energy Act (NEA) /A-5/, the Federal Law on Radiological Protection (RPA) /A-16/ and the ENSI Act (ENSIG) /A-19/.

In the context of the present report CNS 2012, reference is made to the fundamental provisions of the Nuclear Energy Act /A-5/ regarding the principles of nuclear safety and the operators' responsibilities for the safety of their nuclear power plants. Fundamental requirements for nuclear safety can be found in the Nuclear Energy Ordinance /A-6/ (NEO) and in the Ordinance of the Federal Department of the Environment, Transport, Energy and Communications (DETEC) on Hazard Assumptions and the Evaluation of Protection Measures against Accidents in Nuclear Installations /A-7/. Finally the DETEC Ordinance on the Methodology and the General Conditions for Checking the Criteria for the Provisional Taking-out-of-Service of Nuclear Power Plants /A-8/ ("Provisional Shutdown Ordinance") contains important provisions for power plant design reassessment in case of a major accident abroad.

Articles 7, 8 and 10 of the NEO contain internationally recognized principles to guarantee the safety of nuclear facilities. The strategy specified in Article 7 to ensure the nuclear safety of nuclear facilities at four levels (the "defence in depth" concept) is stated in more practical detail in Articles 8 and 10. According to Article 8, protective measures for nuclear facilities must be implemented against accidents which originate both inside and outside the facility. In addition, those accidents which must be managed without an inadmissible release of radioactive substances are explicitly stated. Article 10 defines principles for the design of the safety functions of nuclear power plants. These include, in particular, the single failure criterion, the principles of redundancy and diversity, the functional and physical separation, the automation principle and the conservatism in design. As regards compliance with these design requirements, however, the applicable principle according to Article 82, NEO, is that existing nuclear power plants should be back-fitted only to the extent that is necessary on the basis of experience and the state-of-the-art in back-fitting technology and, beyond that, insofar as this results in a further reduction of risk and is appropriate.

The DETEC ordinance /A-7/ stipulates hazard assumptions for accidents which originate inside and outside the plant, as well as the radiological and technical criteria for proof of adequate protection against accidents. Accordingly, hazards due to natural events, in particular earthquakes, flooding and extreme weather conditions, must be determined with the help of probabilistic hazard analysis. For proof of adequate protection against natural events, account must be taken of hazards with a frequency greater than or equal to 10^{-4} per year.

The Provisional Shutdown Ordinance regulates the criteria and conditions under which a nuclear power plant has to be provisionally taken out of service. In the present context the ordinance prescribes that in case of an accident rated 2 or higher on the INES international event scale, a design reassessment of the plant must be conducted, showing that the fundamental safety functions can be fulfilled and the dose criteria met.

ENSI is responsible for drawing up guidelines which are support documents that formalize the implementation of legal requirements and facilitate uniformity of implementation practices. While compliance with the laws and ordinances by the operators is mandatory, ENSI may allow deviations from the guidelines in individual cases, provided that the suggested solution ensures at least an equivalent level of nuclear safety or security.

In connection with the harmonization of European regulations, ENSI has reviewed the body of Swiss regulations on the basis of the Safety Reference Levels of WENRA (the Western European Nuclear Regulators' Association). At present, about twenty percent of the Safety Reference Levels have yet to be adopted in the ENSI guidelines. In parallel, the Swiss nuclear power plants have checked implementation of the WENRA Safety Reference Levels in their installations. ENSI reviewed their assessment and confirmed the operators' conclusion that, for all practical purposes, all the Reference Levels are already implemented in the plants.

0.4 Actions in the course of the accident and ENSI's approach

In the first phase of the accident the ENSI emergency organization became operational, starting on 11 March 2011 at around 2 p.m. Central European Time. ENSI interpreted the events in the affected Japanese units based on the scarce, sometimes contradictory information available. ENSI continuously informed the Swiss public about the accident, thereby cooperating with other federal entities, especially with the NBCN (Nuclear, Biological, Chemical and Natural events) Staff Unit and the National Emergency Operations Centre (NEOC).

In parallel, ENSI initiated a reflection on the lessons to be drawn from this accident. On 23 March 2011 the activities of the emergency organization were transferred to an ad-hoc group ("ENSI Japan-Team"), which instigated an accident analysis with the aim of identifying the factors that contributed to the accident. During the subsequent months, this group compiled and published four reports (/A-10/ to /A-13/) dealing with the event sequences, their radiological consequences and the lessons learned. As a result, 37 checkpoints for the Swiss nuclear facilities were identified needing further investigation (see list in chapter 8).

The reports embodied the systematic approach ENSI pursued, in accordance with the Swiss legal and regulatory framework. This approach was started promptly after the accident and, as such, enables new findings to be added subsequently, as they emerge. Consistent with the approach, the following questions shall be answered in a stepwise manner:

1. **Is there an immediate threat for the Swiss population?** In case an immediate threat is established, the ENSI can order an immediate plant shutdown. The operator must then conduct analyses and take corrective actions (e.g. back-fittings) before ENSI may allow the restart.
2. **Are the criteria for a provisional shutdown fulfilled?** In the case of any accident classified as level 2 or higher on the International Nuclear Event Scale (INES), the licensee has to review the design of the nuclear power plant immediately, as regards the fundamental safety functions, demonstrating that the statutory dose limits are kept. During the reassessment, the plant can operate normally. If the dose limits cannot be met, the plant has to be shut down provisionally, until the necessary corrective actions are taken.
3. **Which measures are necessary to improve safety?** Each accident and incident has to be analysed in detail, and safety improvements leading to a reduction in risk shall then be implemented as far as appropriate. In this last case, the plant can operate normally during the analysis and the implementation of the appropriate measures.

0.5 The question of an immediate threat for the Swiss population (Step 1)

An immediate threat can be described as a set of circumstances which, if left unhindered, would most likely lead to damage in the near future. Hence ENSI clarified whether, in the light of Fukushima, such a threat existed for the Swiss population, as detailed in the following.

Once the accident sequence at Fukushima could be broadly reconstructed, ENSI concluded that, from a technical point of view, no unexpected new phenomena had occurred. Therefore the assessment of a possible immediate threat concerned only the question, as to whether or not the natural hazards had to be re-evaluated in Switzerland, based on the findings from Fukushima.

In global terms, Switzerland experiences low to medium seismicity. An earthquake and a tsunami of the same magnitude as those in Japan on 11 March 2011, can be ruled out for Switzerland. Up-to-date assessments of the earthquake and flooding hazards, based on most advanced methods, are available in Switzerland.

In 2007, the results of the probabilistic earthquake hazard analysis for the locations of the nuclear power plants in Switzerland (acronym PEGASOS in German) were published. This up-to-date study for the NPP sites showed that seismic hazards in Switzerland had been underestimated in the past. Consequently, ENSI asked the operators to consider the new hazard profiles in their probabilistic studies. At the same time, a follow-up project (the so-called PEGASOS Refinement Project PRP) was launched, which aims at refining the local interaction models and trying to reduce the uncertainties in the PEGASOS results.

As regards external flooding, detailed analyses with the most recent methods were performed in 2008 in the context of the site evaluation for the new-build projects, all of which were located at existing sites. The newly evaluated flooding levels are partly somewhat higher than previously determined. However, the newly calculated hazards are, on the whole, at a low to intermediate level.

All nuclear power plants were requested by ENSI to revise their probabilistic safety assessments (PSA) based on the newly evaluated earthquake hazards, and the results have been submitted to ENSI. Besides earthquakes, other external events such as flooding, extreme winds and aircraft crashes have been taken into account. The revised PSAs demonstrate that the IAEA criteria for the core damage frequency are fully met.

Hence, up-to-date hazard assessments exist in Switzerland, and the PSA studies show compliance with the IAEA criteria. The hazard profiles are well known; no significant changes to these profiles are expected as a result of the Fukushima event. Therefore ENSI came to the conclusion that there is no immediate threat to the Swiss population, particularly as all the extreme natural events are very rare.

0.6 The criteria for a provisional shutdown (Step 2)

Concerning the design reassessment of existing nuclear power plants dictated by Swiss law (/A-8/), ENSI issued three formal orders to the licensees within the first two months after the Fukushima accident (on 18 March, 1 April and 5 May 2011, see /A-1/ to /A-3/). These orders specify the reassessment process in detail, including the due dates for the results to be submitted to ENSI. In light of the first insights gained from the accident in Japan, the orders covered the design of the Swiss nuclear power plants against external flooding, earthquakes, and a combination thereof. The licensees were required to submit the results of the reassessments and suggestions for improvement measures until 30 June 2011 and 31 March 2012, respectively.

Details on the content and results of the reassessments are provided in chapters 1-3 and 5.

0.7 The measures necessary to improve safety (Step 3)

During the whole course of action described above, ENSI has identified further measures necessary to improve the safety of the Swiss nuclear power plants.

By order of 18 March 2011 (/A-1/), ENSI required the licensees establish an external emergency storage facility for their plants until 1 June 2011, containing mobile equipment for accident management that can be transported to each NPP site by helicopter. If not already in place, the plants have to install permanent connections to the external equipment until 31 December 2012 (details see chapter 3). The licensees established a central storage facility for all Swiss plants in due time, which was inspected and accepted by ENSI.

The order of 18 March 2011 (/A-1/) also required the licensees to answer questions about the coolant supply for the safety and auxiliary systems and the spent fuel pool cooling until 31 March 2011. In the case of shortcomings that were to be identified, the licensees had to describe by 31 August 2011 how they intended to rectify them. Some plants' specific documentation highlighted some shortcomings during the review process: insufficient proof of the spent fuel pool coolability, lack of a diversified main cooling water source, lack of instrumentation display in the special emergency control room. Regarding these issues, ENSI specified the areas needing correction to be submitted by 31 August 2011 in more detail (/A-3/). ENSI accepted in principle the proposed corrective measures on 15 November 2011, but added several requirements for their implementation, which is due from 2012 to 2014, depending on the plant.

In parallel with the previously mentioned activities, ENSI has performed topical inspections in the Swiss nuclear power plants. The inspections were carried out between May and December 2011 and related to the spent fuel pools, the external storage facility, protection against flooding and the filtered containment venting systems.

In a fourth order on 1 June 2011 (/A-4/) ENSI instructed the licensees to take part in the EU stress test. The purpose of the EU stress test was to examine in particular the robustness of the nuclear power plants. The issues considered were the effect of events such as earthquakes, external flooding and extreme weather conditions, loss of power supply and heat sink beyond the design basis and severe accident management. In the first step of the stress test, the hazard assumptions and design bases for the nuclear power plants were presented, and their adequacy was assessed. The second step identified and evaluated the protective measures implemented and the ensuing safety margins as compared to those from the design base. In conclusion, improvement measures were derived from this information as appropriate. The operators of the Swiss nuclear power plants submitted their reports by 31 October 2011. ENSI reviewed them before 31 December 2011 (/A-20/), confirming that the Swiss nuclear power plants provide a very high level of protection against earthquakes, flooding and other natural hazards, as well as loss of electrical power and ultimate heat sink. However the reassessments revealed the need for further investigation in the form of eight open points (see list in chapter 8).

For this reason ENSI issued a fifth order on 10 January 2012 (/A-21/), requesting the licensees to clarify and assess some of these matters in more detail before 30 September and 31 December 2012, respectively. The remaining open points together with the checkpoints identified from the Fukushima event analysis are being processed in the order of their importance and according to their urgency in an action plan. The action plan is detailed on a yearly basis and illustrates the forthcoming oversight activities of ENSI related to Fukushima. ENSI has set the ambitious goal of investigating the identified checkpoints and implementing the derived measures by 2015.

0.8 Communication and Cooperation

ENSI intensified its communication activities in the direct aftermath of the Fukushima accident, however not only as a direct consequence. It established a new section for communication, thus increasing the dedicated resources to five staff members. In particular, the information to the public on the ENSI website (www.ensi.ch) has been totally reorganized, with the aim of updating it on a more frequent basis and of communicating facts and figures in a proactive manner.

At the national level ENSI actively participates in the interdepartmental working group to review emergency protection measures in case of extreme events in Switzerland (German acronym "IDA NOMEX"). This group was set up by the Federal Council in May 2011 at the suggestion of ENSI (/A-25/), with the aim of assessing the need for organizational and legislative adjustments in the area of emergency preparedness and response, in light of the Fukushima findings. It consists of delegates from the Federal Chancellery, the Federal Department of Foreign Affairs, the Federal Department of Home Affairs, the Federal Department of Justice and Police, the Federal Department of Defence, Civil Protection and Sport, the Federal Department of Economic Affairs, the Federal Department of the Environment, Transport, Energy and Communications, as well as from the Cantons. For details concerning IDA NOMEX refer to chapter 5.

In October 2011 ENSI decided to appoint an Expert Group on Reactor Safety (ERS) to advise ENSI on important issues related to the safety of nuclear power plants. Consisting of renowned international experts, this group enables ENSI to discuss fundamental, sometimes controversial topics, before decisions are issued, thereby giving these decisions a broader footing.

At the IAEA Ministerial Conference on Nuclear Safety of June 2011 and at the IAEA Board Of Governors meeting and general conference of September 2011, Switzerland advocated a mandatory character for the IAEA peer review missions. ENSI itself hosted a second mission of the IAEA Integrated Regulatory Review Service (IRRS) from 21 November to 2 December 2011, which had actually already been requested before the Fukushima event. For this purpose, ENSI compared the Swiss regulations to the IAEA Safety Requirements NS-R-1 (design) and NS-R-2 (operation). Issues dedicated to the lessons learned from the Fukushima were included as well. The comparison resulted in a high degree of compliance and confirmed that the Swiss regulations are up-to-date and in line with established international standards.

As already mentioned, though not an EU member country, Switzerland decided to engage in the EU stress test with a full participation, which implies moreover that Swiss experts took an active part in the international Peer Reviews just recently conducted from January to April 2012 (see also section 0.7).

For details with respect to the international cooperation see chapter 6.

0.9 Overview of the Swiss Activities

The following table provides a chronological overview of the activities in Switzerland initiated by the Fukushima accident.

Table 0-2: Chronology of actions and planned dates in Switzerland in the aftermath of the Fukushima accident.

Date	Type	Subject
18.03.2011	Formal order	**First formal order** by ENSI demanding a design re-assessment, related to the provisional shutdown criteria, with regards to earthquakes and flooding, a re-assessments of cooling water supply and spent fuel pools, and the implementation of immediate measures regarding accident management
31.03.2011	Report	Operators' submission of data on the design of the cooling water supply and of the spent fuel pools
01.04.2011	Formal order	**Second formal order** by ENSI to define the conditions for the design reassessment related to the provisional shutdown criteria
05.05.2011	Formal order	**Third formal order** by ENSI with the review results on the reports submitted by the operators on 31.03.2011 and additional conditions derived therefrom in connection with the improvement measures to be submitted on 31.08.2011, and with the requirement for additional proof for the spent fuel pools
01.06.2011	Implementation	A shared external storage facility for emergency equipment was set up by the operators
01.06.2011	Formal order	**Fourth formal order** by ENSI requesting the operators to perform the assessments as from the EU stress test
30.06.2011	Proof	Operators' submission of revised proof of safety in case of flooding
15.08.2011	Report	Operators' submission of progress reports on the EU stress test
31.08.2011	Statement	Statement by ENSI regarding the review results on the proof of safety in case of flooding submitted on 30.06.2011
31.08.2011	Report	Operators' submission of improvement measures in the areas of cooling water supply and spent fuel pools
15.09.2011	Statement	Statement by ENSI regarding the EU stress test progress reports submitted on 15.08.2011
31.10.2011	Report	Operators' submission of final reports for the EU stress test (Operators' Reports)
15.11.2011	Statement	Statement by ENSI with the review results regarding the improvement measures submitted on 31.08.2011
21.11.2011-02.12.2011	Statement	Integrated Regulatory Review Service IRRS mission to ENSI (IAEA statement)
30.11.2011	Proof	Operators' submission of documents related to seismic resistance
31.12.2011	Statement	Statement by ENSI with the review results on the EU stress test final reports (Operators' Reports) submitted on 31.10.2011

Date	Type	Subject
10.01.2012	Formal order	**Fifth formal order** requesting the operators to clarify in more detail the safety margins related to the seismic robustness and integrity of specified structures and systems (which vary with the plant) and related to the likelihood of debris blockage of hydraulic installations
31.01.2012	Proof/Report	Operator (KKM) submission of proof of the structural integrity of the Wohlensee dam wall in case of a 10,000-year earthquake and the seismic robustness of the reactor scram
31.03.2012	Proof	Operators' submission of revised proof of safety in case of earthquakes and combination of earthquake and earthquake-induced dam failure
30.04.2012	Report	EU-Report on the Peer Review Process on the national report to the EU Stress Test
13.05.2012	Report	Due date for the CNS Extraordinary Meeting National Report compiled by ENSI
30.06.2012	Report	Operators' submission of reports on protection against hydrogen deflagrations and explosions in the area of the spent fuel pool
30.06.2012	Statement	Statement by ENSI with the review results on the proof of seismic safety submitted on 31.03.2012
30.09.2012	Statement	Statement by ENSI with the review results on the reports submitted on 30.06.2012 concerning protection against hydrogen deflagrations and explosions in the area of the spent fuel pools
30.09.2012	Report	Operators' submission related to the assessment of • the seismic robustness of the isolation for the containment and primary circuit (all NPPs) • the seismic stability of containment venting (KKG, KKL) • influence of debris blockage of hydraulic installations on the flooding situation (KKG, KKM).
31.12.2012	Report	Operators' submission of proposals for improving the seismic stability of containment venting (KKG, KKL)
31.12.2012	Implementation	Back-fitting of connections for mobile external accident management equipment
Until 2015	Planning	ENSI's target date for investigating the identified issues and implementing the derived measures

1 External Events

Taking into account ENSI's lessons learned from the analysis of the events at Fukushima /A-12/, the following checkpoints have been identified concerning external events:

- The hazard assumptions for earthquake and external flooding, and also for extreme weather conditions, must be re-evaluated to take account of the latest knowledge.
- A review must be carried out to determine whether the coolant supply for the safety systems and the associated auxiliary systems is guaranteed from a diversified source which is safe against earthquakes and flooding.
- A review must be carried out to determine whether the requisite tightness of buildings containing important safety equipment is guaranteed in case of flooding of the site.

Based on these lessons learned a targeted review was requested by ENSI for earthquake and flooding, and for the combination of earthquake and flooding. In addition, the impact of extreme weather conditions on plant safety has to be assessed in the frame of the EU stress test.

1.1 Earthquakes

1.1.1 Design basis earthquake (DBE)

Seismic hazard

Since the Swiss nuclear power plants were commissioned, ENSI (or HSK, as it was then) initiated several reassessments of the seismic hazard in accordance with the applicable state-of-the-art. This development is reflected in a hazard level which, for all Swiss plants, is defined on a probabilistic basis. The acceleration values on which the seismic design of the Swiss nuclear power plants is based for the safe shutdown earthquake (SSE) are specified for selected reference elevations (bedrock surface, foundation of reactor buildings, ground surface) and are derived from the acceleration spectra assigned in each case. The hazard level applicable today is characterised by a peak acceleration for the SSE with an frequency of exceedance of 10^{-4} per year.

At the end of the 1990s in the course of this ongoing development, ENSI asked the nuclear power plant operators to re-determine the seismic hazard in accordance with the latest methodological fundamentals, and in particular to provide a comprehensive quantification of the uncertainty of the calculation results. In order to implement ENSI's requirement, the nuclear power plant operators commissioned the PEGASOS project (Probabilistic Seismic Hazard Analysis for Swiss Nuclear Power Plant Sites) which was carried out in the period from 2001 to 2004. In PEGASOS, the seismic hazard was redetermined on the basis of a probabilistic method (Senior Seismic Hazard Analysis Committee SSHAC Level 4) developed in the US. To take full account of the level of knowledge in international specialist circles, independent specialist organisations and experts from within Switzerland and from abroad were called in. The main subject areas examined in the project were the characterisation of seismic hypocentres, wave propagation and the local effects at the sites of the nuclear power plants in Switzerland.

The latest Probabilistic Safety Analyses (PSA) by the Swiss nuclear power plants already take account of stricter seismic hazard assumptions derived from the PEGASOS Project. The results indicated that the probabilistic safety objectives recommended by the IAEA for existing plants are attained. In case of new construction projects and back-fitting measures, higher seismic hazard assumptions have already been taken into account by the operators of the Swiss nuclear power plants. Targeted seismic upgrades were implemented at the plants on the basis of the results from the PSA.

The conclusions resulting from the PEGASOS project appear to have a far wider range of uncertainty in comparison with the previous earthquake hazard analysis. In order to reduce the wide range of uncertainty identified in the PEGASOS results, the nuclear power plant operators launched the follow-up PEGASOS Refinement Project (PRP) in 2008. The PRP takes into account the new knowledge that has become available in the field of earthquake research since PEGASOS was completed as well as detailed studies of the site characteristics (e.g. by means of exploratory geological drilling). The PRP will probably continue until the end of 2012 and is being reviewed continuously by ENSI with the help of a team of experts. In this context, taking account of latest knowledge gained from new seismic studies, the seismic hazard applicable today can no longer be assessed as adequate for the design.

Seismic margins

As no confirmed results from the PRP are available as yet, ENSI has stipulated for the purposes of the EU stress test, that the determination of the seismic safety margins should refer to the hazard level applicable today. The results from PEGASOS and PRP are to be qualitatively incorporated into the assessment of the adequacy of the design basis. The operators have determined the seismic safety margins on the basis of IAEA Safety Guide NS-G-2.13 /A-9/. The seismic robustness in respect of the associated safety equipment (Structures, Systems and Components, SSC) was to be determined in each case, as expressed by the so-called HCLPF value (high confidence of low probability of failure). The HCLPF value describes the peak ground acceleration (PGA) at the reference elevation for which the probability of failure of the safety equipment analysed is less than 5%, with a confidence level of 95%. For accelerations below the HCLPF value, it may be assumed that the probability of seismic failure is less than 1%.

The seismic robustness of a safety train[1] is determined by the safety equipment in the train with the lowest HCLPF value. The safety margin is defined by the ratio of the safety train's HCLPF value to the peak ground (horizontal) acceleration value for the hazard level applicable today. The robustness of the plant as a whole is derived from the safety train with the highest HCLPF value.

[1] In the context of the EU stress test the plant safety functions to be ensured for a safe shut down are defined as safety train. The following safety trains are considered:

Safety train 1: Conventional safety systems which are used to control accidents due to internal events and, depending on the original design concept of the nuclear power plant, external events related to natural causes.

Safety train 2: The special emergency systems are primarily intended to control accidents due to external events, but which also provides further protection in addition to the conventional safety systems in the case of internal events. Special design features of the special emergency systems include their functional independence and physical separation from the conventional safety systems, and an autonomous operation of at least 10 hours without manual intervention.

Safety train 3: The accident management measures implemented in all nuclear power plants consist exclusively of manual measures that are to be implemented locally by operating staff; they are stipulated in specific emergency procedures, are ordered by the emergency staff and are carried out with the deployment of either permanent built-in or mobile equipment.

Protection of safety systems

At the Swiss nuclear power plants, the scope of safety equipment protected against the SSE varies according to the plant age. It is generally true that the fundamental safety functions must be fulfilled in case of an earthquake. The resulting specific requirements for SSC relevant to safety are defined by means of structure and earthquake classes. The SSC that are to be designed and classified against earthquakes must not be endangered by the seismic failure of other items of equipment with lower classifications, or with no classification.

For the more recent nuclear power plants (KKL and KKG), the hazard level applicable today was already covered by the design of the safety equipment in safety trains 1 and 2. For the less recent nuclear power plants (KKB and KKM) however, the stipulation of the hazard level as the new design basis created a requirement for a seismic requalification of the original safety equipment so that, in conjunction with the newly installed special emergency systems, availability of an earthquake-resistant safety train 2 was guaranteed. At all the nuclear power plants the core cooling is guaranteed by means of the automatically triggered safety equipment in safety trains 1 and/or 2. The available special emergency systems play an important role in this regard. These systems were required in the past by ENSI in order to ensure protection against the consequences of earthquakes, aircraft crashes, external flooding, explosions, major fires and impacts caused by third parties. With these systems the safety functions for reactor shutdown, core cooling and removal of decay heat are achieved automatically and autonomously for at least 10 hours if needed; in the longer term, switching operations by the operating staff are required.

At the time in question, the spent fuel pools (SFP) were examined in respect of ensuring their integrity in case of strong earthquakes. The SFP cooling systems of the newer nuclear power plants are designed against the hazard level. In the older nuclear power plants, however, spent fuel cooling has to be restored by means of accident management measures in case of strong earthquakes. This was considered to be acceptable in the past, taking into account the extended period of time available to restore cooling.

The necessary administrative protection measures for reactor core and SFP cooling are stipulated in plant-specific operating and accident procedures and in emergency instructions. For accidents that cannot be controlled within the scope of the design base, additional decision-making aids are available (Severe Accident Management Guidelines, SAMG) which are intended to limit the consequences of core damage. The organisational procedures in the event of a severe accident are regularly trained during the emergency exercises.

1.1.2 Findings and safety improvements

Robustness against DBE

As a consequence of the Fukushima accident, ENSI has already asked the operators to provide new deterministic proof of safety for the 10,000-year earthquake, on the basis of the available interim results from the PRP. This proof must be submitted by 31 March 2012.

Based on the insights gained from the EU stress test, ENSI concludes that the Swiss nuclear power plants have a high level of protection against earthquakes. The reported safety margins confirm the conservative seismic design of the Swiss nuclear power plants. However, within the reassessment of the design against earthquakes stipulated as a consequence of the Fukushima accident, some safety issues have been identified which demonstrate the need for some targeted backfitting measures and warrant further investigations. Since the external storage facility at Reitnau has been set up at ENSI's request, the operators of the

Swiss nuclear power plants can also have specific access to additional auxiliary equipment to fight the consequences of severe earthquakes, should the emergency equipment stored on the plant site be unavailable.

It should be mentioned, by way of a caveat, that the HCLPF values reported for the safety equipment were not reviewed by ENSI in the EU stress test. In the context of the proof to be submitted by 31 March 2012, ENSI will also review the determined HCLPF values.

Reactor

In general, the review performed in the frame of the EU stress test confirms that, according to knowledge available at present, adequate preparation measures are in place to manage the SSE in all Swiss nuclear power plants. Hence, performance of the fundamental safety functions is ensured. Furthermore, the safety margins reported by the operators show that robust safety trains are available in the Swiss nuclear power plants in order to bring the plants to a safe shutdown state, even after an earthquake which exceeds the hazard applicable today. In ENSI's view, the arrangement whereby the automatic scrams were triggered in advance via the seismic instrumentation proved its usefulness in the severe earthquakes which occurred in Japan. Triggering of this sort has not yet been implemented in the Swiss nuclear power plants. ENSI will follow up on the question as to whether in the Swiss nuclear power plants automatic scrams should be triggered by the seismic instrumentation.

Spent fuel pool

Except for KKM, the seismic robustness of the SFP in Swiss nuclear power plants can be rated as high, on the basis of the information from the operators. However, the operator of KKM intends to improve the earthquake resistance of the pool slot plugs as they are the limiting component. Given the importance of maintaining SFP integrity, ENSI required, in its order of 5 May 2011 /A-3/, that all Swiss nuclear power plants must systematically reassess the spent fuel pools and the related connections by 31.03.2012.

In the light of the knowledge gained from Fukushima, the investigations undertaken to date have shown that the SFP cooling systems at the less recent nuclear power plants should be seismically improved in order to bring about a further reduction in risk. As requested by ENSI in its order of 5 May 2011 /A-3/, the less recent nuclear power plants will backfit a new SFP cooling system by 2015 at the latest; the design of these systems will be based on the latest seismic hazard assumptions.

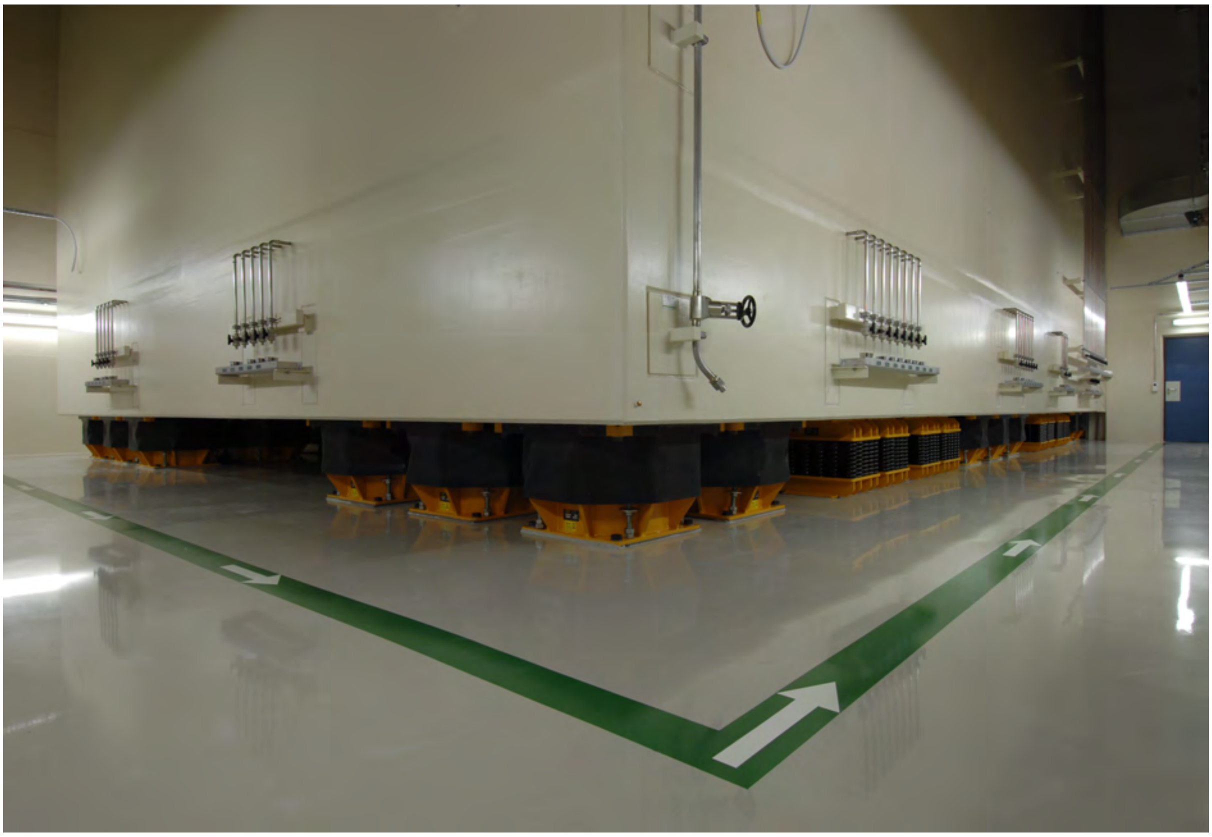

Figure 1-1: Outside view of the external spent fuel pool of the Gösgen nuclear power plant (KKG), equipped with seismic isolation.
Source: KKG

Containment

ENSI considers plausible the operators' statements that the containment shell itself should be rated as extremely robust. The safety margins reported by the operators for the containment integrity are greater than the safety margins for the most seismically robust safety train for core cooling, so that even in case of an earthquake-induced failure of the core cooling, the containment is still preserved as a retention barrier. However, the reported safety margins for containment integrity can only be regarded as plausible, insofar as the containment isolation depends only on the mechanical robustness of the isolation valves, i.e. if the containment isolation features consistent fail-safe behaviour. In respect of the seismic proof that has yet to be provided, ENSI considers that there is a need for another more detailed examination of the seismic robustness of the isolation of the containment and the primary circuit.

From ENSI's viewpoint, the system for containment venting should in general be at least as seismically robust as the containment integrity, in order to guarantee an effective protection of the containment in case of accidents due to severe earthquakes with failure of the core cooling (an exception may be allowed if the safety margins of the venting system are already quite high). This requirement is not met at the newer nuclear power plants where the containment is especially robust. Therefore, measures to improve the earthquake resistance of the containment venting systems in case of beyond-design basis accidents should be reviewed at the newer nuclear power plants.

Combined effects of earthquake and flooding

In ENSI's view and based on the input provided by the operators for the EU stress test, flooding induced by a severe earthquake does not threaten the safety of the KKB, KKL and KKG nuclear power plants, thanks to the high level of protection for the special emergency systems (safety train 2).

According to present knowledge the Wohlensee dam wall is limiting with regard to the seismic robustness of safety train 2 at KKM. A conclusive evaluation of the seismic robustness is only possible on the basis of the new deterministic seismic proof (submitted until 31 March 2012, under review). In this proof the earthquake resistance of the Wohlensee as well as the Schiffenen and Rossens dam walls, located at a confluent affecting the Aare water level at Mühleberg, are re-examined.

1.2 Flooding

1.2.1 Design basis flood (DBF)

Flood hazard

At KKB, KKL and KKM, the design of protection against flooding was originally determined on the basis of dam and/or weir breach scenarios, whereas the protection design at KKG was based on a 1,000-year flood. The flooding hazard at KKM was re-analysed in 1991 pursuant to the application for an unlimited-term operating licence and/or for the power increase. This analysis produced a lower maximum flood level for the dam-breach scenario, which was also – originally – limiting.

In 2008, the flooding hazards for the Beznau, Gösgen and Mühleberg sites were reassessed in the frame of the general licence applications for new nuclear power plants, which were intended to be built at the already existing sites. The new flooding hazard has been derived either considering a 10,000-year flood or, in case of KKM, an extreme flood scenario which actually gives rise to a higher discharge than the 10,000-year flood. The discharge values for the 10,000-year flood were calculated through extrapolation of river level data considering historical flood records, where appropriate. The flood levels were computed using a 2D-model for the flooding scenarios, including a detailed orographic representation.

Immediately after the Fukushima events, ENSI issued orders to verify the safety of the Swiss nuclear power plants /A-2/ and to set the procedural requirements for design review in respect of earthquakes and flooding /A-3/. Regarding flooding hazard, ENSI ordered to apply the new results which were determined for the new nuclear power plant sites. The results of the new analyses show for KKB and KKL that the original flood design basis remains appropriate and that the flood protection is still adequate. However, this statement does not apply to KKG and KKM because, in the case of KKG, flooding of the plant site – which was considered to be a "dry site" – cannot be excluded and, in the case of KKM, it is impossible to rule out a blockage of the special emergency system cooling water intake structure due to the previously underestimated transport of debris, bedload and sediment. These insights from the KKG/KKM analyses led to measures to increase the flood protection, which are presented in chapter 1.2.2.

In order to evaluate the flooding risk comprehensively, ENSI asked the operators to perform and provide analyses regarding the effects of a total debris blockage of bridges, culverts or hydraulic installations near the sites.

Protection of safety systems

In the original design the protection of the Swiss nuclear power plants against the consequences of flooding consists either in an elevation that ensures, for the power plant site, an adequate safety distance above the height of the design-basis flood, or in flood protection by means of permanently sealed buildings. At the Beznau and Mühleberg nuclear power plants, the protection of important safety equipment is ensured by flood-proof buildings that are sealed beyond the design-basis flooding level, as well as by positioning such equipment above the flood level used to determine the design of buildings that are not flood-proof. At the KKG and KKL plants, the protection of safety-relevant equipment consists in locating the power plant site above the flood level used to determine the design (the "dry site" concept).

One important protective measure that is implemented in all Swiss nuclear power plants except KKM is the diversified cooling water supply from groundwater wells, which ensures the supply of cooling water even in case of the assumed failure or clogging of cooling water intake structures as a consequence of an extreme flood. Groundwater wells of this sort are part of the specially protected, autonomous special emergency systems (safety train 2) that are present in all Swiss nuclear power plants, in addition to the "conventional" safety systems (safety train 1). The special emergency systems also ensure the power supply in case of a failure of the external power supply and of the emergency diesel generators. KKM also has a special emergency system in which (unlike KKB, KKG and KKL) the special emergency cooling water is taken not from groundwater wells but also from the river Aare. The latest analyses have shown that, in certain cases, blockage of the special emergency system intake structure in the Aare cannot be ruled out. During the outage in 2011, a first set of measures were therefore implemented at KKM to increase the reliability of the coolant supply via the special emergency system intake structure (see chapter 1.2.2).

Figure 1-2: High water level of the Aare river at the Beznau site in August 2005. Source: KKB

1.2.2 Findings and safety improvements

Robustness against DBF

For the Beznau site, flooding analyses show that the conventional safety systems (safety train 1), as well as the special emergency systems (safety train 2), are adequately protected against the DBF. The maximum flood levels remain far below the levels at which inundation of these safety systems could occur. There are even considerable safety margins in case of increased discharge values (i.e. DBF + 20%) or in the case of breach of the most limiting weir. While this statement is valid for core cooling and long term residual heat removal from the core, ENSI found potential for improving spent fuel pool cooling as presented below.

The flooding analyses for KKG show that an inundation of the plant site – which was earlier regarded as "dry site" – cannot be ruled out in case of a 10,000-year flood. As a consequence, KKG has already enhanced the flood protection and took the measures given below, which are appropriate to ensure nuclear safety in case of flooding.

The KKL site, located about 21 m above the Rhine river, is flood-proof even under extreme assumptions regarding the flooding hazard. The safety trains are not affected in such scenarios. This statement also applies to the hazard from flood waves due to the failure of hydraulic installations.

At KKM, the improvements listed below have already been implemented in 2011 in order to ensure nuclear safety in case of a 10,000-year flood. Nevertheless, as noted above, blockage of the special emergency system cooling water intake structure in the Aare river cannot be ruled out in certain improbable cases, such as a breach of the Wohlensee dam wall. In order to ensure the cooling water supply even in this very unlikely case, KKM plans to backfit a diversified heat sink.

Backfitting and improvement measures

KKB's flood analyses have shown that the cooling of the reactors in both units is ensured in case of a 10,000-year flood, and that there is no need for additional measures. In its assessment of the reliability of the spent fuel pool cooling in connection with the third order of 5 May 2011 /A-3/, ENSI nevertheless requested that the spent fuel pool cooling must be improved. KKB then proposed to implement the following improvement measures:

- Installation of an additional independent spent fuel pool cooling system with coolant supply from the protected special emergency well
- Extension of the in-plant accident management measures for injection into the spent fuel pools via the existing alternative pool cooling system, and via the new protected pool cooling system
- Installation of redundant temperature and level measurements in each spent fuel pool as accident monitoring overview displays
- Installation of equipment for pressure relief of the spent fuel pool building in the event that all spent fuel pool cooling systems should fail

Already prior to the events at Fukushima, KKG had implemented a number of measures to improve flood protection on the basis of new knowledge about the flooding hazard for the site, such as:

- Introduction of an automatic advance flooding alarm to guarantee timely prior warning
- Additional sealing of building shells, air inlets and doors, etc., of buildings with equipment used for the safe shutdown of the plant
- Specification of the organisational and administrative measures in case of a "flood" accident to be implemented in the emergency procedures
- Preparation for the erection of dam bulkheads
- Installation of flood valves to seal ventilation intakes

As an additional measure, KKG plans to build a flood protection wall to prevent water ingress through a breach in an embankment, in combination with the preparation of a shut-off bulkhead for access via the power plant road, which would simplify accident management measures.

At KKM, the following improvements have already been implemented in connection with orders by ENSI:

- Provision of mountable walls for flooding protection of the auxiliary cooling water pumps in the pump building, and enhancement of the relevant operating instructions
- Provision of mobile pumps to inject water into the special emergency system (SUSAN) cooling water intake structure
- Implementation of an additional injection option (intake shaft) into the SUSAN intake structure
- Backfitting of three special vertical pipes on top of the SUSAN intake structure to ensure the cooling water supply for SUSAN

These measures were implemented from June to September 2011. In order to ensure the availability of the cooling water supply even in case of a total failure of the river water cooling from the Aare, KKM was asked by ENSI to implement a diversified heat sink in the medium term. An additional spent fuel pool cooling system shall be backfitted and the in-plant accident management measures as regards the additional injection capabilities and the monitoring for the spent fuel pool shall be extended.

The KKL flood analyses have shown that the plant is protected against flooding events with high safety margins. No additional measures are required at KKL for the purpose of enhancing the plant's safety against flooding.

Safe shutdown and residual heat removal is also required in case of a total debris blockage of the river where hydraulic installations are present. ENSI asked the operators to perform and provide analyses regarding the effects of such a blockage. ENSI will follow up on this issue.

1.3 Extreme weather conditions

1.3.1 Designs basis loads (DBL)

Characteristics and Methodology used for determination of the hazards

This section focuses on meteorological hazards caused by strong winds, tornadoes, extreme temperatures and snowfall, as well as hydrological hazards resulting from heavy rainfall at the plant site. The effects of flooding caused by heavy rain, snow melt and dam breaks are assessed in Section 1.2 of this report. One of the salient characteristics of the assumptions regarding weather conditions for the Swiss nuclear power plants is the fact that they were evaluated when the plants were originally built in the 1960s and 1970s. The validity of these assumptions was ensured by referring to the standards of the Swiss Association of Architects and Engineers (SIA) which were then, as they are today, enforced for all buildings in Switzerland. The SIA standards give precise guidance for various types of loads resulting for instance from snow or wind conditions prevailing in Switzerland. These loads are then to be assumed in combination with the operational loads when assessing the integrity of a building. In general however, the loads resulting from an earthquake or an airplane impact are higher than those resulting from extreme meteorological conditions.

For extreme weather conditions it is necessary to define a period of time over which a statistical evaluation may be drawn, the so-called recurrence period. This matter is addressed in the DETEC Ordinance /A-8/ on Hazard Assumptions and the Evaluation of Protection against Accidents in Nuclear Plants, according to which, the operators must prove that the loads which could occur on the basis of a 10,000-year recurrence period can be withstood.

Safety aspects affected by extreme weather conditions cover not only the purely deterministic assessment of the degree of protection against the resulting loads. In Switzerland, all operators must also examine the potential effects of extreme weather conditions on the risk of core damage frequency (CDF) as part of the Probabilistic Safety Analysis (PSA). This assessment has demonstrated convincingly that the overall contribution of the considered extreme weather conditions to the CDF is quite small.

Reassessment of the hazards (adequacy of the design basis)

Since the time of their construction, data on conditions prevailing at the sites of the different NPPs have been gathered which are used to enhance the quality and accuracy of the extrapolations regarding extreme weather conditions. Since then, hazard assumptions have been continuously monitored (by PSA and periodic safety reviews) and their evolution was particularly highlighted in the recent and suspended applications submitted by the operators for new-build reactors on the sites of the existing plants. The extreme weather hazard assessment contained therein is quite relevant to a reassessment of these hazards.

Extreme wind gust velocities and tornadoes are explicitly considered in the PSA and are updated frequently. Heavy rainfall at the plant site is screened out due to the very low risk to the plants CDF. Additional extreme temperatures and extreme snowfall are considered in the EU stress test. Operators provide sufficient information as to the original design base temperatures the plants were designed for. Operational experience and functional test conducted over the past years, proves adequate margins exist as regards extreme temperatures, but the need to clearly identify the 10’000-year event is a matter that has been raised by ENSI.

Protection of the safety trains required to achieve safe shutdown state (long term cooling of the reactor and the spent fuel pools, fundamental safety functions)

The protection of the safety trains is to a large extent determined by the ability of the structures they are housed in to withstand extreme weather conditions. In all Swiss NPPs, dedicated reinforced concrete buildings house the equipment relevant to safety. Switzerland has a specifically high degree of protection in this regard as the safety-relevant buildings also comprise special emergency systems in addition to the existing design-base emergency systems. These bunkered steel-reinforced concrete buildings are designed to withstand extreme loads like a safe shutdown earthquake or airplane crash, therefore the robustness of the buildings housing safety trains is considered adequate by ENSI. There are very few exceptions to this rule. One is a main steam relief station which is, however, robust as it is located between two buildings and consists in a steel structure with metal plate cladding.

1.3.2 Findings and safety improvements

Robustness of the safety trains against DBL

Determining the degree of robustness of the safety trains against extreme weather conditions hinges on delivering detailed information on the determination of safety margins. This should begin with an evaluation of the hazard, its complete documentation, through to methods used in determining the effect, finally resulting in factually well-established safety margins. ENSI considers that the information regarding the determination of hazards is wanting in some respects hence an updated statement of the adequacy of the safety margins is expected once the hazards are determined in detail by the operators. In its overall assessment of the robustness of the plants, ENSI considers that there exist sufficient arguments to conclude that the buildings important for safety are adequately protected against extreme weather conditions.

However, a review by ENSI of the submission by the operators concerning extreme weather conditions has demonstrated the need for clarification in order to harmonise methods and fill in gaps in the documented proof, where detailed information is missing, particularly regarding the 10’000-year event. ENSI has therefore advised all operators that this matter is an open point to be followed up on in order to gain a full and complete proof of sufficient protection against extreme weather conditions, including combinations thereof.

Figure 1-3: Aerial view of the Mühleberg nuclear power plant (KKM).
Source: KKM

2 Design Issues

2.1 Loss of electrical power

2.1.1 Design basis to prevent the loss of electrical power

The protective measures implemented in the Swiss nuclear power plants to ensure power supply, which comply with the "Defence-in-depth" principle and have several levels of protection, are designated in this section as "safety layers" of the electrical energy supply. The following safety layers are in place:

1st safety layer:	External main electricity grid the generator feeds into
2nd safety layer:	Auxiliary power supply in island mode in case of failure of the main grid
3rd safety layer:	External reserve grid (third-party grid) in case of failure of the external main grid and of the auxiliary power supply
4th safety layer:	Emergency electrical power supply from an emergency diesel generator or hydroelectric power plants (HPP) in case of failure of the first three safety layers for the electrical power supply of conventional safety systems
5th safety layer:	Bunkered special emergency electrical power supply from special emergency diesel generators for the power supply of the special emergency systems
6th safety layer:	Local accident management (AM) equipment such as for instance mobile emergency power units and possible connections to nearby hydroelectric power plants
7th safety layer:	Accident management equipment stored at the central Reitnau sto age facility and other off-site locations (mobile emergency power units)

As the design basis, classification 1E is generally applicable to all the electrical systems in the conventional emergency electrical power supply within the NPP as well as the special emergency electrical supply, and also to the electrical components of the safety systems. This means that proof of qualification must be provided for all the components relevant to safety functions, i.e. that the components can withstand the earthquake loads in case of a safe shutdown earthquake (SSE) at the location where they are installed, that the installation locations of such components are above the design-basis flood levels, and that the design-basis margins of the components under ambient environment conditions are proven in case of normal operation as well as under accident conditions. Also the electrical system must cope with the single failure, especially the emergency and the bunkered special emergency system.

The following Table 2-1 gives a summary overview of the electric power supply possibilities for safety layers 4 to 7 including the classified diesel equipment, supply from hydro-electric power plants (HPP) and Accident-Management-Equipment (AM-Equipment).

The taking into account of the scenarios LOOP, SBO and Total SBO for Swiss nuclear power plants is explained as follows.

LOOP designates the loss of off-site operational grid power supply and the simultaneous loss of the auxiliary power supply from the power plant's own generators (safety layers 1-3) which equates to emergency power conditions. Based on conservative assumptions, all the

Swiss plants fulfil the minimum period of autonomy of 72 hours in that case. Thereafter, a very long period can be bridged by continued operation of the emergency hydroelectric power supplies or by procuring fuel from external stores until at least one of the redundant external grid feeds is restored. Thanks to the availability of buried emergency hydroelectric power supplies (KKB, KKM) which are directly connected or emergency power connections (KKG, KKL) from the nearby HPPs, a supply is also provided to each of the four Swiss nuclear power plants that is diversified from the fuel-dependent supply and is not subject to any time restriction. This is achieved by means of existing direct connections, and independently of the operability of the high-voltage grids. Hence, the LOOP scenario is covered by multiple and diversified supply options in all the Swiss plants.

Table 2-1: Overview of diesel equipment and supply from hydro plants

Safety Layer	Supply	KKB 1 / 2	KKG	KKL	KKM
4	Number of emergency diesels	2 per unit	4 *2	3	1
	Number of supply trains from hydro-emergency power supply	2 per unit	not available	not available	2
5	Number of bunkered special emergency diese	1 per unit *1	2	2	2
6	Emergency supply connections from nearby hydro plant	not available	available *3	available *3	not available
	Number of local (on NPP site) available, large, mobile electric power supply-AM Power Units	2 *4	2 *5	1	1
7	Number of AM-Power Units in Reitnau central emergency storage facility	3 *6	3 *6	3 *6	3 *6
	Additional AM-Power Units in the vicinity of the power plant	several may be procured from various locations	several may be procured from various locations	additional may be procured from a company	3 smaller ones located close to the installation

*1 1 special emergency diesel can supply both units 1 and 2

*2 in addition 2 other diesels for the 2. cooling water supply

*3 Built-in, cable and connectors available

*4 Since the end of October 2011

*5 Planned for 2012

*6 used in common by all NPP operators

SBO designates LOOP and loss of the ordinary back-up AC power sources (safety layers 1-4). When applied to the Swiss nuclear power plants, the SBO scenario not only involves the loss of all operational feeds (off-site operational grids and the plants' own generator-based supply) but involves also the loss of all safety-classified emergency diesel generators and of the emergency hydroelectric power supplies where initially available. In this scenario, the bunkered special emergency electrical supply foreseen for external events is still available. The SBO scenario is controlled in accordance with the design basis at the Swiss nuclear power plants. The proven period of autonomy of more than five days for all the plants is sufficient to allow off-site diesel stocks to be procured.

Total SBO designates an SBO with the loss of any other diverse back-up AC sources (safety layers 1-5). When applied to the Swiss nuclear power plants, the failure of the special emergency diesel supplies is assumed in addition to the SBO conditions. This extreme scenario, in which it is assumed there is a failure of all non-battery-supported AC feeds for the first five safety layers of the electrical supply, falls within the scope of beyond-design-basis accidents. Depending on the severity of the accident, accident and emergency procedures must be applied, leading up to and including the use of Severe Accident Management Guidance (SAMG). The total SBO scenario can be controlled at all four Swiss NPP sites. Battery-powered DC (direct current) power supplies and the mobile AM diesel generators needed to recharge batteries on the power plant sites are available to control the total SBO scenario. At all the plants, the period of autonomous supply for the total SBO scenario is several hours. In particular, the capacity actually available is always more than four hours, mostly in the range of five hours and in some cases up to the range of 20 hours. The same considerations are valid for the total SBO scenario as for the SBO scenario. Further AM equipment is available in the central emergency storage facility at Reitnau to cope with the total SBO.

In order to control an incident in one of the boiling water reactors, steam-powered high-pressure injection systems (RCIC) supplied exclusively from batteries can be used to bridge over the period until AM measures are implemented for the low pressure injection. In the case of the pressurised water reactors, AM measures for secondary heat removal via the steam generators („feed and bleed“) are of crucial importance.

2.1.2 Findings and new preventive measures

In summary, ENSI has established that the electrical supply to all power consumers relevant to safety in the Swiss nuclear power plants is ensured for all the power supply failure scenarios that have been analysed (LOOP, SBO). Moreover, in the case of the scenario beyond the design basis (total SBO), selected important power consumers can still be supplied for an adequate period.

Even before the events at Fukushima, the potential for improvement regarding the special emergency supply had been identified at KKB. The major project AUTANOVE that has been in progress since the end of 2008 has the primary goal of replacing the existing (seismically weak) emergency hydroelectric power supply for the KKB by redundant seismically qualified emergency diesel generators.

However, the strategies for controlling a long-lasting total power failure will be re-evaluated on the basis of knowledge gained from Fukushima. Through its order of 1 April 2011, ENSI required all Swiss nuclear power plants to submit appropriate proof regarding the 10,000-year earthquake and flood. In addition, this issue is covered by the EU stress test, which was ordered by ENSI on 1 June 2011.

The reviews carried out by ENSI lead to the following issue: ENSI will follow up on the development of a comprehensive strategy for the targeted deployment of the mobile accident management emergency diesels in order to secure the supply of selected direct current and/or alternating current power consumers in the long term under total SBO (resp. SBO) conditions. All the operators keep, or plan to keep, additional mobile AM diesel generators both on site and at the external Reitnau storage facility.

2.2 Loss of cooling

2.2.1 Design basis to prevent the loss of cooling

At all the Swiss nuclear power plants, river water is used as the primary ultimate heat sink for the conventional safety systems. The corresponding cooling water intake structures are designed and positioned on the courses of rivers in such a manner as to provide them with basic protection against a failure due to flooding (blockage by bedload or floating debris). Furthermore, at least one heat sink (whether the primary or the alternative heat sink) is qualified against the safe shutdown earthquake. High availability of the cooling water intakes is achieved thanks to robust mechanical cleaning equipment consisting of raking and screening systems. The supply of the plant with cooling water is closely coupled to the electrical power supply.

Three different safety trains are considered in the assessment of the protection of the heat sinks in the Swiss nuclear power plants. To first give a clear overview of the safety systems, they have been subdivided into three "Safety trains" by which the plants can be brought to a safe shutdown state in case of accidents. The safety trains can be used in all plant operational states (full power operation as well as low power and shutdown states). Safety train 1 consists of the conventional safety systems and is designed in accordance with the principles of functional independence, physical separation and level of automation (redundant and single failure proofed). There are differences between the safety systems of older and newer nuclear power plants. The bunkered specially designed single-failure proof emergency systems ("Notstandsysteme" or Safety train 2) constitute another safety train which is primarily intended to control accidents due to external events, but which also provides further protection in addition to the conventional safety systems in the case of internal events. Particular design features of the bunkered special emergency systems include their functional independence and physical separation from the conventional safety systems, and an autonomous automated operation of at least 10 hours. The preventive accident management measures implemented in all nuclear power plants constitute Safety train 3.

Depending on the design of the plant, multiple diversified heat sinks are available for these safety trains. In KKB and KKL the primary ultimate heat sink supply is provided by safety train 1. In addition, safety train 1 can also be supplied by a groundwater well. The KKG plant has two physically separate intake structures to supply cooling water to safety train 1. At KKM, river water is used to cool safety trains 1 and 2. The cooling water supply for safety train 2 is provided by the special emergency intake structure. The main cooling towers, such as those in place at the KKG and KKL plants, are not credited as heat sinks because they are not classified as relevant to nuclear safety. For keeping the plants in a safe state without external support refer to the previous section for the corresponding safety trains.

With the exception of KKM, all other Swiss nuclear power plants have alternative heat sinks in addition to the primary ultimate heat sinks. Hence, in case of a loss of the primary ultimate heat sink, at least safety train 2 remains available to cool the reactor core by well water. These alternative heat sinks are specially protected against extreme naturally-induced events. KKM alone has only one primary ultimate heat sink. However in KKM the cooling water supplies for safety trains 1 and 2 are physically separated, and the second intake structure has extended protection against flooding as compared to the first structure.

The loss of the primary ultimate and the alternative ultimate heat sinks is covered by the total SBO case for all Swiss nuclear power plants. In the Swiss nuclear power plants, plant-specific accident management measures (safety train 3) have been prepared to control a long-lasting (> 72 hours) total SBO (see also section 2.1.1). Following the occurrence of a total SBO during power operation, automatic measures come into play in the early phase, in order to remove decay heat from the reactor. In the PWR plants (KKB and KKG), removal of the decay heat to the atmosphere is possible thanks to spring-loaded main steam safety valves and because there is sufficient water reserve in the steam generators (SG). In the BWR plants (KKL and KKM), heat is removed via the relief valves to the water reserve in the suppression pool (SP), furthermore the stock of coolant in the reactor pressure vessel (RPV) is automatically supplemented by steam-driven high-pressure pumps (RCIC, reactor core isolation cooling), the controls of which are supplied by batteries.

Core damage is prevented by the initiation of accident management measures (safety train 3) at an early stage, i.e. during the phase when the automatic measures are still in progress. The aim of the AM measures is to use mobile equipment belonging to the fire brigade and stored on-site in order to resupply with water a SG (in the case of the PWRs) or the reactor pressure vessel (in the case of the BWRs). Mains water or fire water, cooling tower basins or hilltop reservoirs for BWRs (for example) may be used as sources of water.

2.2.2 Findings and new preventive measures

ENSI has established that the Swiss nuclear power plants possess essentially an adequate degree of robustness in case of loss of the primary ultimate heat sink. The loss of the primary ultimate and of the alternative heat sinks is covered by the total SBO case. A failure of the primary ultimate heat sink and of the alternative heat sink does not represent an aggravation compared to the total SBO scenario.

Three nuclear power plants have a full-scale alternative supply of cooling water from groundwater wells at their disposal in order to control a failure of the primary ultimate heat sink. Moreover, at KKM, any blockage of both cooling water intakes would be dealt with by using an additional supply option that was back-fitted during the 2011 plant outage. Additional mobile pumps for AM were intended as a bridging measure until a diversified heat sink is back-fitted at the plant for long-term operation, following ENSI’s request.

A review must be carried out to determine whether the coolant supply for the safety systems and the associated auxiliary systems is guaranteed from a diversified source which is safe against earthquakes, flooding and contamination. This requirement follows on the ENSI orders of 18 March 2011. In its order of 5 May 2011, ENSI required improvement measures be taken, based on the operators’ analyses. Staggered failure of the ultimate heat sinks is considered within the framework of the EU stress test, which was ordered on 1 June 2011.

It is necessary for ENSI to check the water resources that can be made available to feed the reactor pressure vessel. The available water resources have already been verified and they are already documented in the existing emergency procedures. As far as is known at present, no further measures are required.

2.3 Containment integrity

2.3.1 Design basis of containment integrity

All Swiss nuclear power plants have a double containment. PWR plants (KKB and KKG) have a separate leak-tight inner steel containment located within an outer concrete shell. BWR plants possess either a Mark I (KKM) or a Mark III (KKL) containment with equipment for rapid pressure reduction provided inside a dedicated distinct adjoining concrete building. Since the commissioning of the plants, systems to enhance the containment integrity were backfitted. All nuclear power plants now have permanently installed systems for containment venting as well as hydrogen control systems in the containment and some of the plants have containment flooding systems.

In order to prevent hydrogen deflagrations or detonations in the primary containment, equipment such as igniters, thermal or passive autocatalyic recombiners or mixing systems are available. The KKM containment is inertised with nitrogen. In addition, hydrogen monitoring systems are available, including displays in the main control room.

Since the 1990s, all the nuclear power plants have a filtered containment venting system to mitigate the consequences of a severe accident. This system consists of a passive train that is secured by a bursting disk in normal operation, and an active train secured by motor- and hand-operated valves. To enable the controlled discharge of radioactive substances, the valves in the active train may be opened, either remotely from the control room or manually from a radiologically protected area. The filters have decontamination factors of at least 100 for inorganic iodine and 1000 for aerosols. At all the plants, the containment venting systems are primarily used to prevent a containment overpressure failure for beyond design base accidents. However, in addition they can be used to avert hydrogen deflagrations or detonations.

In the case of a severe earthquake the assessment of containment integrity generally includes an assessment as to whether the fundamental safety function of "confinement of radioactive material" is fulfilled. For this purpose, it is necessary to ensure the isolation of the containment in order to retain radioactive substances in case of a primary circuit (PC) leak and also to ensure the isolation of the PC in order to prevent a discharge of coolant outside the containment (containment bypass). According to the operators' statements,

containment penetrations and automatically triggered isolation valves are the limiting factors to earthquake resistance. The containment shell itself is rated as extremely robust. The safety margins for the containment integrity are greater than the safety margins for the most seismically robust safety train for core cooling, so that even in case of an earthquake-induced failure of the core cooling, the containment is still preserved as a retention barrier.

2.3.2 Findings and new preventive measures

A review must be carried out to determine whether the verifications regarding the prevention of hydrogen explosions should be extended to additional areas of the plants beyond the primary containment. This issue is dealt with as part of the EU stress test which was required on 1 June 2011. Further details were specified for the spent fuel storage ponds in the order of 5 May 2011.

The design and operation of the systems for filtered venting of the containment must be reviewed anew. The systems for filtered venting installed in the Swiss nuclear power plants are intended to prevent overpressure failure of the primary containment during sequences of events involving a slow build-up of pressure. The system for filtered venting is examined both in the EU stress test ("Measures and design to protect the integrity of the containment") and during ENSI's inspections of key points specifically related to knowledge gained from the Fukushima-Dai-ichi accident.

ENSI identified the following open points: the extent to which, with a view to minimising risk, the existing deployment strategies for the containment venting systems in case of severe accidents should be retained, and whether the restoration of containment integrity during shutdown represents a time-critical measure in case of a total SBO.

2.4 Loss of spent fuel pool cooling

2.4.1 Design basis of spent fuel pool cooling

According to their design basis, the two more recent nuclear power plants (KKL and KKG) have robust Spent Fuel Pool (SFP) cooling systems. The SFP cooling is ensured by the redundant safety systems of the first safety train (KKL) or the first and second safety trains (KKG). Cooling of the SFP is also ensured by alternative heat sinks. KKG has an additional wet storage facility designed with passive cooling and a corresponding high safety margin.

In the two less recent nuclear power plants (KKB and KKM), the SFP cooling systems used for normal operational purposes are dependent on the primary ultimate heat sink. In case of severe earthquakes and floods, long-term SFP cooling can only be ensured by means of accident management measures, for which sufficient time is available. At KKB, the alternative SFP cooling system (safety train 3) must then be put into operation according to the emergency procedures. Accident management measures (safety train 3) must then also be used for SFP cooling at KKM. Due to the large amount of water available, an additional water injection to the SFP is only necessary in the long term (> 72 hours) in order to prevent damage to the fuel assemblies.

In order to ensure the safe storage and cooling of the fuel assemblies in the spent fuel pool, integrity of the fuel pools in case of a severe earthquake is an essential condition. Except for KKM, high safety margins exist for the integrity of the spent fuel pools, which are located in the reactor building or in separate fuel assembly storage buildings, depending on the plant. The integrity of the spent fuel pool at KKM is limited by the seismic resistance of the pool slot plugs.

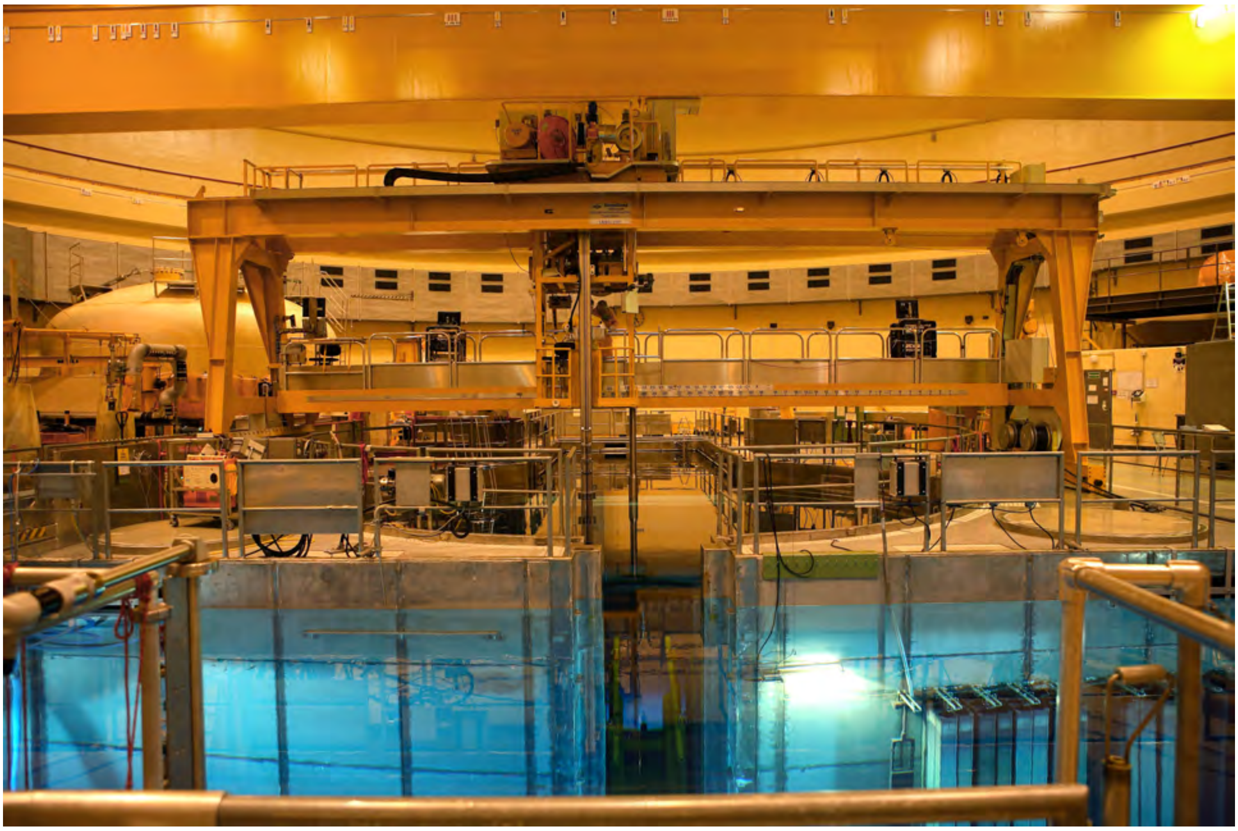

Figure 2-1: The spent fuel pool of the Mühleberg nuclear power plant (KKM). Source: KKM

For the third safety train, the operators credit the high seismic robustness of the SFP, as this maintains, to a limited extend, the large water reserve in the SFP. Furthermore, the cooling of the fuel assemblies is guaranteed by coolant evaporation and the coolant make-up. The integrity of the SFPs is therefore ensured as an essential prerequisite to maintaining cooling of the fuel assemblies stored within them. Cooling of the SFPs is guaranteed for a period of at least 98 hours (during which the fuel is covered) due to the large water inventory.

2.4.2 Findings and new preventive measures

On the basis of experience gained from the Fukushima accident, a review was carried out to determine, whether control of leaks and long-term cooling of the spent fuel storage ponds are guaranteed in case of severe accidents. At first, ENSI requested additional measures prior to the EU stress test in order to improve emergency water injection into the SFPs, removal of heat and monitoring of the SFPs. All Swiss nuclear power plants were required to back-fit two additional external feed options to resupply spent fuel pools with coolant. Resupply of the pools must be possible without entering the pool areas.

Given the importance of maintaining SFP integrity, ENSI required that all Swiss nuclear power plants must systematically reassess the spent fuel pools as well as their connections. The more recent nuclear power plants, KKG and KKL, have spent fuel pool cooling systems which, in ENSI's view, present a high safety margin in relation to an earthquake at a hazard level for which the plant was requalified. Since the less recent nuclear power plants (KKM and KKB) do not have such robust systems, reliable additional supply options are required as accident management measures. The equipment must be qualified or designed against earthquakes at a hazard level consistent with the new deterministic proof regarding the 10,000-year earthquake. For this reason, KKM intends to improve the earthquake resistance of the pool slot plugs as they are the limiting component.

SFP cooling for the two less recent nuclear power plants is not secured by means of alternative heat sinks. In these two cases, the large water reserve and the associated long time delays available to initiate accident management measures provide adequate protection. ENSI requested the back-fitting of a new and specially protected SFP cooling system in connection with the review of SFP cooling. KKM and KKB are in the process to install a new independent SFP cooling system.

Another review must be carried out to determine whether the availability of the instrumentation required to assess the condition of the pools is adequately guaranteed, even in extreme situations. A review of the instrumentation needed to monitor the spent fuel storage ponds was required by the order of 5 May 2011.

It is necessary for ENSI to check the water resources that can be made available to feed the spent fuel storage ponds. The available water resources have already been verified and they are already documented in the existing emergency procedures. As far as is known at present, no further measures are required.

3 Severe Accident Management and Recovery (On-site)

Nuclear Energy Ordinance (NEO, /A-6/) Art. 8 requires that additional technical, organisational and administrative measures must be taken to prevent and mitigate the consequences if harmful quantities of radioactive substances may be released in case of an accident. The implemented measures are presented in the following.

3.1 Personnel resources and training

3.1.1 Emergency Organisation

The Emergency Protection Ordinance (EPO) (/A-15/) describes the duties and tasks of the operators, of ENSI, of other Federal organisations, and of the cantons, regions and communes. Immediate measures to protect the public are ordered by the National Emergency Operation Centre (NEOC). As soon as the Federal NBCN Crisis Management staff are ready to deploy, they take over coordination of the civilian and military operational units, as well as the development of proposals to protect the public for consideration by the Federal Council.

Every Swiss nuclear power plant has its own emergency response organisation (ERO). In case of an emergency, the ERO replaces the line organisation which is responsible for management during normal operation. At all the plants, the ERO comprises the emergency director, the emergency staff and additional emergency bodies. The emergency director is usually the director of the power plant. He is supported by a staff consisting of the heads of those specialist departments relevant for the purpose of dealing with emergencies.

Organisational measures ensure that an appropriate management structure and sufficient staff are available to cope with an emergency. However in general, no specific concepts are available for the case where access to the plant is not guaranteed. This point is taken into account in ENSI's forthcoming supervisory planning on the basis of the "Lessons Learned" from the Fukushima accident (/A-12/, checkpoint 18).

3.1.2 Personnel resources

As a minimum level of staffing with qualified personnel is stipulated for the plants on a 24-hour basis, it is ensured that adequate staff is present in the plant at all times to initiate alarms and the first measures required in case of an emergency. Moreover, all employees of Swiss nuclear power plants are members of the respective ERO, so the plants can always draw on a sufficiently large pool of specialists for their ERO.

The behaviour of the operating staff in emergencies, the definition of types of emergency and the tasks, areas of responsibility and authority in case of an emergency are stipulated in the emergency preparedness procedures and the associated documents.

In an emergency, all Swiss nuclear power plants can have recourse to technical support from the relevant reactor suppliers. This is ensured by agreements between the plants and the reactor suppliers. However, it is unclear how communication with the suppliers is implemented if normal means of communication are unavailable due to external events. This point is already included in the "Lessons Learned" report on the Fukushima accident (/A-12/, checkpoint 17) and will be followed up in the frame of ENSI forthcoming oversight activities.

3.1.3 Limiting exposure to the operating staff

The radiological situation with respect to staff deployment is monitored by radiation protection staff which is integrated into the emergency response organisation. The potential radiological hazard in the operational area is assessed before deployment. Protective measures are implemented as necessary, for the operational staff. In the absence of measurement results, information regarding the estimation of radiation exposures may be used instead. This information also indicates the radiological conditions for persons present at special working locations on the power plant site.

The operators provide information (with reference to the Radiological Protection Ordinance (RPO) (/A-17/) regarding the maximum permissible radiation doses for the operational staff (persons subject to mobilisation) deployed to deal with accidents, and to protect the public and save human life. For activities in connection with accident management, the limit for radiation exposure for mobilised personnel is 50 mSv. In order to protect the public and in particular to save human life, up to 250 mSv may be accumulated by a single individual who is mobilised.

For work in high-dose areas, remotely readable dosimeters can be used to monitor the operational staff. In addition, the pre-defined and optimised work paths and procedures should be used for work involving intense doses. Dose maps of the affected buildings are further aids that are also available after an accident. These maps make it possible to determine optimised access routes with minimum radiation exposure.

The operators of the nuclear power plants also make provision for evaluations using their own dosimeters (basically TL and DIS dosimeters) in other personnel dosimetry units that are not affected by the accident if their own personnel dosimetry units can no longer be operated.

Following a study of the consequences of the Chernobyl accident, the Swiss NPPs have already provided proof of sufficient protection against radiation exposure of the shift staff in the main control room (MCR) as well as the emergency staff in the emergency room or standby emergency room. The protection of emergency buildings against external events such as earthquakes or floods is a point already included in the "Lessons Learned" report on the Fukushima accident (/A-12/, checkpoint 10) and will be followed up in the frame of ENSI forthcoming oversight activities.

3.1.4 Training

Training courses, education and exercises for members of the emergency response organisation are specified in the relevant instructions for the nuclear power plants. These activities take place regularly on the basis of training programmes and refresher courses.

In addition to the internal emergency exercises, one emergency exercise is carried out each year with ENSI as an observer. Within a cycle of four years, each element of the emergency response organisation must be practised at least once as part of the overall emergency response organisation. At longer intervals, the Federal emergency organisations participate actively in an emergency exercise within the scope of their respective remits, alongside the in-plant emergency response organisation.

Over a lengthy period, the scenarios for the emergency exercises cover all the types of emergencies defined in the emergency preparedness procedures; technical emergencies that originate from technical damage to the plant are included more frequently. However, security scenarios are also trained. Exercise scenarios involving core damage are periodically included in the programme for the emergency exercises, in liaison with the supervisory authority.

Each emergency exercise is systematically evaluated and the results are used to optimise procedures, and for the training and development of members of the emergency response organisation.

Regular emergency exercises on scenarios with loss of spent fuel pool (SFP) cooling are not carried out at any of the Swiss nuclear power plants. However, the existing SAMG (Severe Accident Management Guidance) includes instructions on checking and (where applicable) restoring SFP cooling. The emergency exercises based on scenarios with loss of cooling of the fuel located in the reactor pressure vessel (RPV) also consider the conditions in the SFP. ENSI regards the level of such exercises as adequate; nevertheless, this point is also included in the "Lessons Learned" report on the Fukushima accident (/A-12/, checkpoint 16) and will be followed up in the frame of ENSI forthcoming oversight activities.

3.2 Adequacy of procedures

The behaviour of the operating staff in emergencies, the definition of types of emergency and the tasks, areas of responsibility and authority in case of an emergency are stipulated in the emergency preparedness procedures and the associated documents.

As part of Accident Management (AM) measures before occurrence of fuel damage are in place at all sites and are incorporated in the procedures. These measures include, for example, venting of the steam generators (SG) without external power, venting of the RPV via alternative trains, the supply (by means of fire brigade pumps) of borated water from the SFP into the RPV, coolant supply via the fire extinguishing system and cross-switching of power supply systems. Similar accident management measures are established specifically for accidents during non-power operation (NPO).

As part of Severe Accident Management (SAM) measures after occurrence of fuel damage are established and incorporated into the procedures (Severe Accident Management Guidance, SAMG). These measures include for example filtered venting of the containment before or after a RPV failure, flooding of the containment and using mobile accident management equipment. In each Swiss plant, provision is also made for a water supply to the containment – preferably before, but also after the RPV failure. The strategies for implementing these SAM measures are defined in the SAMG.

SAMG are written decision guidance documents designed to support the Emergency Response Organization (ERO) and in particular the decision-making part of the ERO, the Emergency Response Team (ERT), during severe accidents, such that the ERT can determine the optimal strategy to terminate incipient fuel damage, to maintain the integrity of the containment and to minimise radioactive releases. In addition to the written decision guidance, the SAMG is supported by other help tools, such as analytical guidance and computer simulation models, to support decision-making. In many EROs, a SAMG Group reporting to the ERT typically uses these tools.

The technical basis of the strategies developed in the framework of SAMG is selected thermal hydraulic calculations and the full-scope, plant specific level 2 PSAs, which are reviewed regularly. The developed decision-making support tools were checked for their applicability (validation) by the participants in the ERO. Furthermore, the validation was performed by means of exercise scenarios, for which SAMG plays the major role in managing the accident. The SAMG are updated by the operators according to the state-of-the-art. ENSI reviews the SAMG by inspections and as part of emergency exercises and of the periodic safety review.

The SAMG for each Swiss plant is symptom-oriented and covers power operation (since 2006) as well as non-power operation (since the end of 2010). ENSI regards these accident management measures as an important contribution to the mitigation of the consequences of accidents beyond the design basis. Knowledge gained from the Fukushima accident indicates that the SAMG should be reviewed including the regulatory requirements (ENSI-B12). In this regard, it is necessary to check whether adequate consideration is given to a Station Blackout (SBO) of long duration and the simultaneous occurrence of events in multiple-unit plants, so-called multi-unit events (see "Lessons Learned" report on the Fukushima accident /A-12/, checkpoint 16).

All the plants have met the requirement (as per guideline ENSI-B12 /A-14/) to examine and take account of the behaviour of the instrumentation under severe accident conditions in the course of the introduction of SAMG. ENSI therefore regards the instrumentation as generally adequate. Continuous review and improvement is included in supervisory activities such as the Periodic Safety Reviews (PSR) or inspections. The availability of the instrumentation required for accident management measures is also included in the "Lessons Learned" report on the Fukushima accident (/A-12/, checkpoint 5) and will be followed up in the frame of ENSI forthcoming oversight activities.

3.2.1 Accident Management Measures for Spent Fuel Pool Cooling

Due to the dimensioning of the SFPs, sufficiently long time is available after the failure of SFP cooling at all the plants, in every operating condition (power operation or shutdown with full core discharge), in order to implement the prepared accident management measures. These accident management measures include the re-injection of water into the SFP, thereby compensating the evaporation and/or vaporization volume. The prepared accident management measures in respect of SFP cooling at all the Swiss plants are generally effective and appropriate, and they basically cover the requirements. However, for two plants (KKB, KKM), the in-plant accident management measures to remove decay heat in case of a failure of SFP cooling do not provide adequate coverage. Improvement measures in this regard were to be submitted to ENSI by 31 August 2011.

ENSI has reviewed these measures and assessed them as basically adequate and appropriate. The implementation of these measures will be staggered over time until 2015 (EU-Stresstest, Swiss National report /A-20/).

3.3 Equipment availability

3.3.1 Filtered Containment Venting System

All plants have a Filtered Containment Venting System (FCVS). The FCVS in place in the nuclear power plants is conceived for accidents that exceed the design basis. It ensures that the primary containment does not fail due to excessive internal pressure, with the uncontrolled release of radioactive substances. A wet scrubber is integrated into the release train.

The filtered venting systems in Switzerland's nuclear power plants can be controlled remotely and also locally (e.g. in case of a total power failure). These systems were inspected again by ENSI in November and December 2011 as a follow-up measure after the severe accident in Japan. No significant deficiencies were identified during these inspections.

According to the guideline ENSI-B12 (/A-14/) the timing of any filtered venting that may be required should be agreed with the responsible authorities, as far as possible. The procedures in all Swiss plants include this requirement appropriately.

Guideline ENSI-B12 specifies among others requirements for the accident instrumentation to be kept available to deliver the measured values that are needed to implement the SAMG. For example, this includes so-called accident monitoring displays to show the pressure, temperature and dose rate in the containment. Compliance with the requirements for accident instrumentation was (and is) reviewed.

3.3.2 Mobile accident management equipment

The emergency equipment available at each nuclear power plant (NPP) site includes, in particular, mobile motor-driven pumps and standard fire brigade equipment (e.g. hoses) as well as radiation protection equipment (e.g. protective suits).

Mobile emergency power units are also available on site at three nuclear power plants (KKB, KKL, and KKM). For KKG (where a total of six permanently installed emergency diesel generators are available), it is planned to make a mobile accident management diesel generator available.

All the nuclear power plants have permanently installed connectors for alternative injection into the reactor pressure vessel (RPV) and/or into the steam generators (secondary-side); with one exception (KKM, which will be backfitted) all the plants also have permanently installed connectors for emergency injection into the spent fuel pool (SFP).

A flood-proof and earthquake-resistant external storage facility at Reitnau has been in place since June 2011, containing various operational resources for emergencies that can readily be called up. These resources include notably mobile motor-driven pumps, mobile emergency power generators, hoses and cables, radiation protection suits, tools, diesel fuel and boration agents.

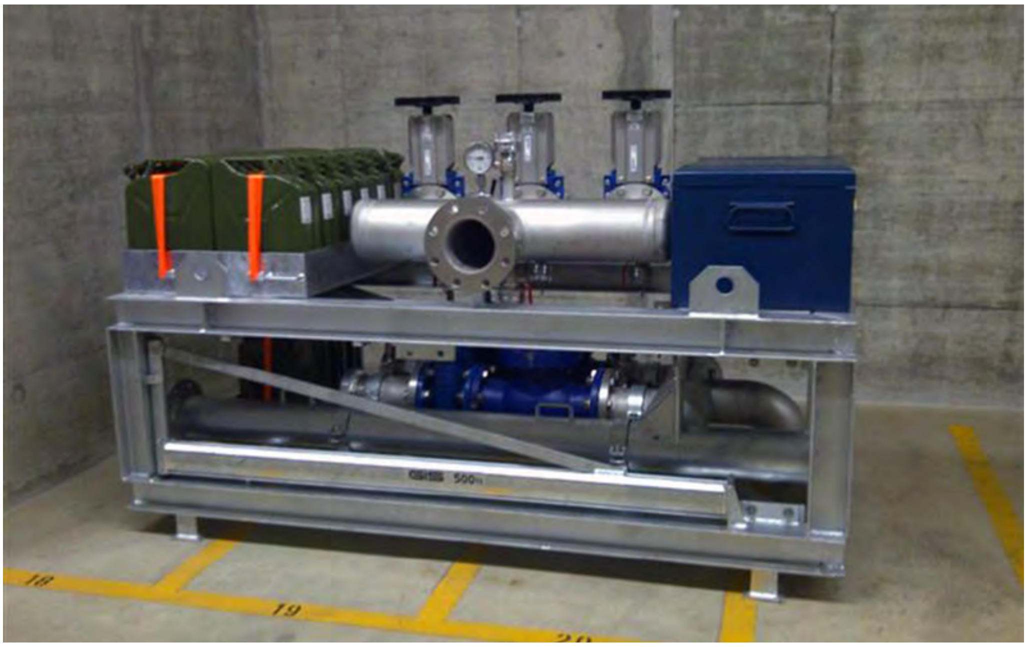

Figure 3-1: Transportable equipment for accident management in the new external storage facility at Reitnau.

For a situation where transport from the external storage facility Reitnau to the power plant by road (first priority) is prevented, there is the option of air transportation via helicopter. According to the concept for the storage facility, about 8 hours should be planned as the time between calling up emergency equipment and its availability on site.

This external storage facility increases the availability of the resources required for accident management measures, thereby creating additional safety reserves. The first introductory phase for the storage facility ended in May 2011 with the acquisition of the building and provision of the operational resources. Among other activities, the next phase includes the integration of the external storage facility into the emergency operating and AM procedures.

Each NPP has adequate diesel fuel to operate the permanently installed emergency diesel generators and special emergency diesel generators for a period of at least 3 days. All the nuclear power plants refer to the possibility of supplementing these stocks from the external storage facility. ENSI regards a supply of diesel fuel for at least 3 days as adequate, also in view of the option of supplementing the stocks from the external storage facility within 8 hours.

3.3.3 Hydrogen control

In order to prevent hydrogen deflagrations or detonations in the primary containment, all the nuclear power plants have systems such as igniters, thermal or passive autocatalyic recombiners or mixing systems. For one plant (KKM) the primary containment is nitrogen inerted during full power operation.

All the plants have a system for venting the containment which, according to the relevant safety analysis reports, is fitted with filters with decontamination factors of at least 100 for iodine and 1000 for aerosols. The containment venting systems all have (at least partly) a two-train contaminated gas piping, of which one train is sealed with a rupture disk. The shut-off valve upstream of the rupture disk is closed during normal operation at one plant (KKG) but is open at all other plants.

At all the plants, the containment venting systems are used not only to prevent hydrogen deflagrations or detonations but also to prevent a containment overpressure failure.

In studies on hydrogen combustion, pressures were until now mainly calculated on the basis of complete adiabatic isochoric combustion in the primary containment. It is standard that the computer codes normally used for this purpose model combustion with a hydrogen concentration of 10% in the relevant control volume. This procedure largely corresponds to the international state-of-the-art. Nevertheless, it neglects, for example, the fact that hydrogen may accumulate locally in higher concentrations, which can lead to more energy-rich combustion and hence to higher pressures. Further analysis is therefore required. This point is also included in the "Lessons Learned" report on the Fukushima accident (/A-12/, checkpoint 7) and will be followed up in the frame of ENSI forthcoming oversight activities.

In ENSI's view, the systems for filtered venting generally correspond to the state-of-the-art. In case of a failure of manual alignment of the containment venting system, however, automatic passive alignment via the rupture disk cannot always be assumed at all plants. This is because the shut-off valve upstream of the rupture disk is normally closed at one plant (KKG) or it is closed as an immediate measure in case of a severe accident (KKB). Furthermore, in another plant (KKM) the drywell cover seal at high temperatures can fail earlier than rupture of the disk. Clarification is still required regarding an optimised deployment strategy for the containment venting systems, e.g. as regards blocking off the rupture disk. Therefore, from the point of view of risk minimisation, ENSI will follow up on the extent to which the current deployment strategies for the venting systems in severe accidents should be retained (EU stress test, Swiss National report /A-20/).

Hydrogen accumulations outside the containment have not been systematically analysed for all plants. In its order of 5th May 2011 /A-3/, ENSI required an assessment of the protection against hydrogen deflagrations and detonations in the area of the spent fuel pools. Further analysis is also envisaged in the context of the "Lessons Learned" report on the Fukushima (/A-12/, checkpoint 7).

3.3.4 Prevention of recriticality

For Accident Management Measures, borated water is always preferred if it is available. According to the latest knowledge and current SAMG strategies, it is also generally appropriate to cool a core melt with non-borated water in an emergency. It should also be noted that additional stocks of boron are kept available on-demand for accident management measures at the external storage facility. ENSI regards the measures to prevent recriticality after core damage as adequate.

3.3.5 Communication systems

Multiple internal means of communication are available for operational and emergency-related purposes in all four Swiss nuclear power plants. For internal emergency communication, the focus is on radio telephone systems, including cordless telephone systems for the emergency teams, combined loudspeaker and alarm systems (for announcements and alarm signals), as well as selective voice connections via intercom(munication) systems (ICS) or telephone systems using conventional analogue technology (Stanofon systems, military telephones) with self-supplied / autonomously powered voice units and permanently installed connections with wiring boxes/sockets.

The internal means of communication can be subdivided according to their functions into alarm systems, paging systems and voice systems, whereby certain systems used in the NPPs perform dual functions in this regard, and certain important functions (e.g. paging of personnel) are implemented redundantly. In Switzerland, the internal communication systems used for emergency communication in relation to nuclear safety are classified as safety-relevant (with electrical classification 0E), and they are subject to mandatory permits. At all the plants, most of these systems (unless they are self-supplied from the equipment's own batteries) are connected to uninterruptible, battery-buffered supply bus bars, or else they have their own UPS (Uninterruptible Power Supply) feeds that are supplied via emergency power bus bars. In most of these systems, the fixed-position and mobile components are set up so as to protect them against flooding. Charging of the battery-powered systems is ensured by various supply options.

In respect of the accident management measures, the operators pursue a flexible operational strategy for emergency communication that is adapted to the accident conditions. The aforementioned internal means of communication and their supplies are basically assessed as suitable, and this assessment includes their use for accident management measures.

At each Swiss NPP, some of the systems can be regarded as robust in the event of seismic impacts, as has been confirmed by specific studies and flanking measures.

Due to the events related to the accident at Fukushima in March 2011, the means of communication are being analysed again in relation to extreme natural events (see the "Lessons Learned" report on the Fukushima accident /A-12/, checkpoint 17).
Pursuant to Article 6, paragraph 2 of the EPO (/A-15/), the operators procure and install appropriate means of emergency communication in order to communicate with:

a. ENSI
b. The National Emergency Operation Centre (NEOC)
c. The organisations designated by the cantons containing communities (communes) which are located wholly or partly in a Zone 1.

For further details regarding the external communication in case of emergency see chapter 5.

3.4 Multiple unit events

As described in chapter 0, there is one twin unit plant (KKB). The KKB emergency organization consists of the emergency staff, the technical support centre (TSC), the shift groups of each unit, the fire brigade and other emergency groups. There is a complete staff team on site for each unit. In the last seven years, the yearly emergency exercises included four scenarios where both units were affected. Examples were in 2007 with a seismic event with one unit being at power and one unit at shutdown, and in fall 2011 when the plant conducted an emergency preparedness exercise with a scenario which affected both units (LOOP). In all exercises, the KKB emergency organization was capable of managing the multi-unit problems. Nevertheless, the issue of a multi-unit event is addressed in report /A-12/ on the Lessons Learned from the Fukushima accident (Checkpoint 16).

Figure 3-2: Aerial view of the Beznau nuclear power plant (KKB), comprising two units.
Source: KKB

4 National Organizations

The regulatory framework in Switzerland clearly allocates responsibilities and specifies the functions of the authorities responsible for safety. In case of an emergency, specific legal provisions apply; defining the tasks of the competent authorities and of the operators of nuclear facilities.

In the event of a radiological emergency, the Federal NBCN (Nuclear Biological Chemical Natural) Crisis Management Board is called into action. The NBCN Crisis Management Board consists of the directors of all Federal Offices concerned, including the ENSI director general. It assesses the overall situation, proposes the necessary measures to the Federal Council (government), ensures coordination with other authorities and the deployment of resources required to cope with the event (e.g. civil and military elements, expert support by laboratories). It runs a stand-by emergency service, the National Emergency Operations Centre (NEOC), which is responsible for alerting and informing the public and for initiating early countermeasures in the event of a radiological accident.

Chapter 4 focuses on the general organizational topics relevant for maintaining and enhancing nuclear safety. The communication in case of emergency is described in chapter 5.

4.1 Organizational changes and improvements

4.1.1 Activities performed by the operators

After the decision of the Swiss Federal Council to put on hold the new build projects, the project organization for new NPPs was reassigned to supporting the Swiss NPPs in the analysis of Fukushima related issues raised by legal obligations and ENSI's formal orders.

As regards the operators' organizations themselves, no major organizational changes were performed or are foreseen up to now within the Swiss NPPs. ENSI has reviewed the NPP's reports on the EU stress test. A reflection on the results of this test and the questions raised from ENSI's Lessons Learned from the accident of Fukushima will show if there is a need for additional organizational requirements. The completion of ENSI's action plan resulting from the Lessons Learned from Fukushima is foreseen for 2015.

All Swiss NPPs underwent OSART missions including a follow-up mission (the last follow-up mission took place in 2002 in Mühleberg) and all of them have implemented the recommendations listed in the OSART reports. All Swiss NPPs are member of the WANO and have a schedule for periodic WANO Peer Reviews.

4.1.2 Activities performed by the regulator

Immediately after the Fukushima accident, ENSI created a Fukushima analysis team which collected information on the accident from different institutions and the media. The Lessons Learned from this analysis were collected and areas for further investigations were identified (ENSI-Report "Lessons Learned", /A-12/). The review performed for the EU stress test highlighted additional open points which, together with the previous ones, are being processed according to their importance and urgency in an action plan. The action plan is detailed on a yearly basis and illustrates the forthcoming ENSI oversight activities (inspections, reviews, analyses, etc.) related to Fukushima.

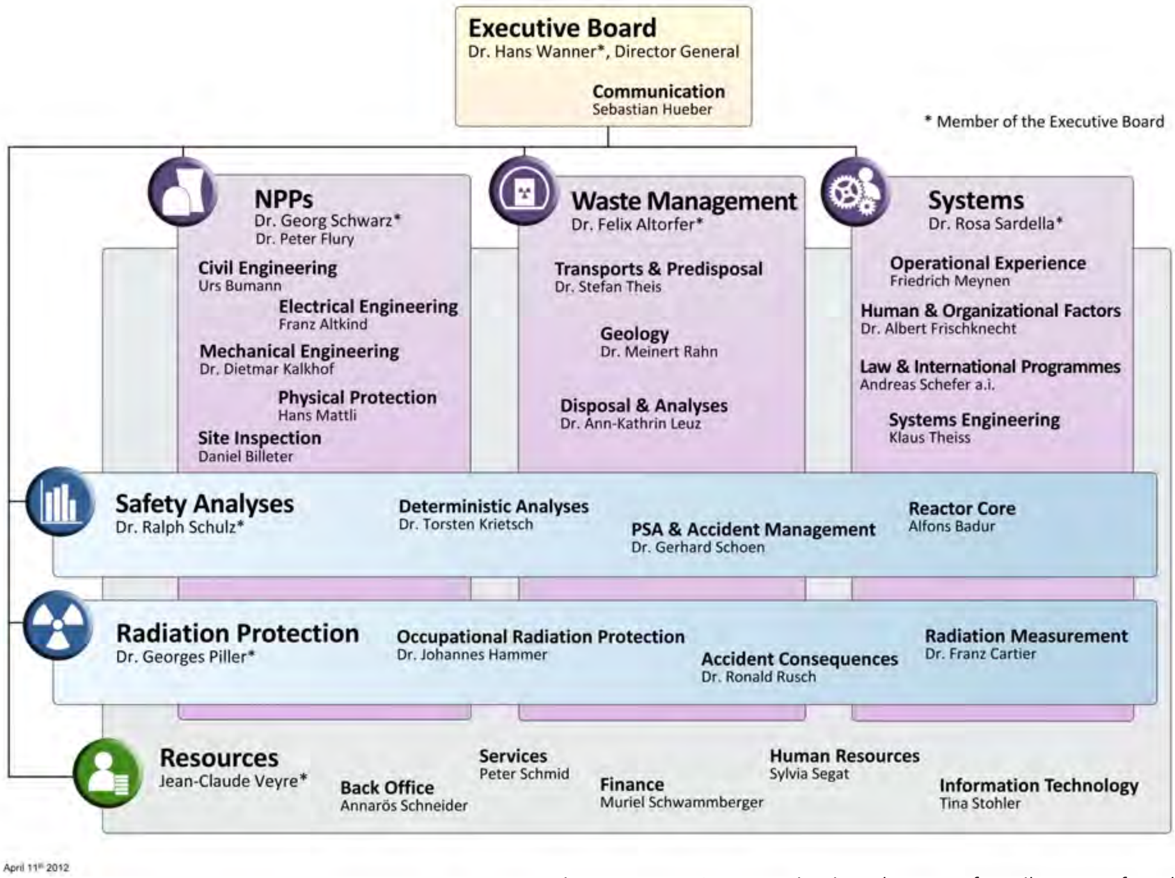

Figure 4-1: ENSI's organization chart as of April 2012, after the reorganisation in September 2011.

The action plan was established in February 2012. ENSI has the intention of completing these follow-up actions by end of 2015.

As a result of the ENSI management review meeting in June 2011 a new division "Systems" including a section for "operational experience" was created, in a major reorganization of ENSI on 1 September 2011. In particular, the process "Occurrence Processing" is undergoing a reanalysis with the goal of strengthening the processing of international events. The review of the process will be completed by end of 2012.

In October 2011 ENSI created an advisory group "Expert Group for Reactor Safety" (ERS). The group consists of independent internationally renowned experts from the nuclear area, which will advise ENSI on important questions related to the safety of NPPs.

By the end of October 2011, an ENSI-internal project was launched to analyse the ENSI "oversight culture". In a first step the project team is analysing several regulatory decisions made in the past, in order to identify potential improvement areas in the decision making process. Several ENSI-internal workshops are planned with the aim of increasing the awareness of ENSI staff in relation to safety-oriented decisions. The results of this analysis will be used to identify changes in the ENSI processes or the need for training and further workshops to develop a good "oversight culture" within the ENSI organization. The first phase of this project will last in the years 2012 through 2013. The schedule for further phases has to be determined later.

In November/December 2011 ENSI underwent an IRRS mission. The IRRS team identified no need for major changes of ENSI's structures and processes. The IRRS recommendations and suggestions will be implemented before the IRRS follow-up mission (foreseen for 2014).

4.2 Interaction among organizations

4.2.1 Activities performed by the operators

All Swiss NPPs have a well-established network of contractors and have good contacts with their vendors. All Swiss operators are members of the WANO and benefit from an extensive information exchange on operational experience within this network. In addition WANO serves as an advisor to the operators in several organizational areas. In fact, many of the programs promoting safety recommended by WANO have been implemented in all Swiss NPPs (i.e. Managers in the Field, Pre-Job-Briefing, etc.).

At the very beginning of the nuclear industry in Switzerland, the Swiss NPPs founded the "Group of Swiss NPP Managers". The group itself and the subgroups in the areas of Operations, Training, Management Systems, Human Systems Interface, etc. meet regularly several times a year for exchange of experience and for the development of new concepts.

ENSI sees no need for additional action in this area.

4.2.2 Activities performed by the regulator

Several external experts support ENSI in its duties: engineering companies, research and academic institutions as well as competent individuals provide support, amongst other things, in the areas of inspection of pressure-bearing systems and components, seismic hazard assessment, deterministic safety analysis, probabilistic safety analysis and accident management. ENSI requires, as a contractual obligation, that these experts have no conflicts of interest and that they have an internal quality control system. Any expert advice is internally reviewed according to ENSI's quality management system (double check).

The Federal Nuclear Safety Commission (NSC) gives its opinion on fundamental questions related to nuclear safety, provides a second evaluation on license applications according to the Nuclear Energy Act and may comment on ENSI guidelines and reports. The Federal Commission for Radiological Protection and Monitoring of Radioactivity (RPRC) advises several governmental institutions in Switzerland mainly on issues of interpretation, harmonization and application. The connections, communication and collaboration with experts and the above mentioned institutions are well established.

In the past, ENSI made important decisions based on its own expertise and on the expertise of external experts. These decisions were published and then commented on by external interested parties, e.g. federal commissions. The IRRS team recommended that ENSI collect the information from interested parties (e.g. commissions) before taking the decisions in order to avoid later questioning of ENSI's statements. This issue is handled in the framework of the resolution of IRRS recommendations.

ENSI actively participates in the IDA NOMEX which aims to assess the need for organizational and legislative adjustments in the area of emergency preparedness and response in the light of the Fukushima findings. For more information on IDA NOMEX refer to chapter 5.

The broad network of experts on which ENSI can draw for specific subjects has proven its value, also during the acute phase of the Fukushima accident. In particular, the calculations done by the Paul Scherrer Institute (PSI) supported ENSI's evaluation and communication activities regarding the possible consequences of the Fukushima accident.

4.3 Transparency/Openness

4.3.1 Activities performed by the operators

A Swiss NPP hosted a Japanese delegation (Regulatory Body, universities, utilities) for the demonstration of the provisions against severe accidents. Further collaboration in this area is foreseen.

The Mühleberg NPP applied for an OSART mission which is scheduled by the IAEA for October 2012. All Swiss OSART reports are deristricted and available to the public.

4.3.2 Activities performed by the regulator

Since early 2009, ENSI has been established as an independent body constituted under public law which reports directly to the government and is fully separated from the Swiss Federal Office of Energy. By law and thanks to its independence, ENSI has no conflicts of interest. Acting in the politically sensitive field of nuclear energy ENSI is kept under close scrutiny by the media, the public and NGOs. Furthermore, as a federal authority, ENSI is subject to the Federal Act on Freedom of Information in the Administration. According to this law, all ENSI documents are public with a few exceptions, such as for instance security-related information, personal data or trade secrets. Therefore, ENSI has a vital interest in maintaining its independent position from the nuclear industry and from political interference.

ENSI is able to exercise its authority to intervene in cases where nuclear facilities or activities may pose significant radiation risks. According to the Nuclear Energy Act, ENSI shall order all necessary and reasonable measures aimed at preserving nuclear safety and security. In the event of an immediate threat, it may impose immediate measures that deviate from the issued license or order.

ENSI regularly informs the public about its activities. For instance, regular meetings with stakeholders like the mayors of Zone 1[2] communities are organized. In these meetings, all aspects of safety, including emergency preparedness and response (see chapter 5) are addressed. ENSI is committed to objectivity and avoids any speculation or placation.

ENSI's Communication section has been newly created in September 2011 and is responsible for the organization of the information activities. The section with five staff members reports directly to the ENSI Director General.

ENSI appreciates the operators' communication activities related to experience exchange at an international level (e.g. WANO, OSART).

[2] Zone 1 is the area around the NPP where, in the case of a severe accident, a threat to the population may require immediate protection measures.

Figure 4-2: Aerial view of the Leibstadt nuclear power plant (KKL).
Source: KKL

5 Emergency Preparedness and Response and Post-Accident Management (Off-Site)

5.1 Present status of emergency preparedness in Switzerland

The emergency preparedness concept and plans of Switzerland are the result of discussions and debates over the past decades. The present section briefly describes and summarises the implemented concept, plans and measures in case of an accident in a NPP.

Emergency plans are available at the national (federal), the local, and the international level. At the national level, the "Concept for the Emergency Protection in the Vicinity of Nuclear Power Plants" (2006) has been adopted. A national strategy for NBC protection has been set up (2007) with the participation of the cantons. Agreements concerning information exchange exist with neighbouring countries and international institutions. Switzerland is part of the EMERCON and ECURIE information systems.

In case of an emergency, the responsible department (of the Federal Council) or the responsible federal office takes the lead concerning information. The information of the federal council is coordinated by the federal chancellery. The information to the public is coordinated with the cantons.

In an emergency, the regulatory body ENSI informs on technical matters concerning the plant, the assessment of conditions at the site, the probable evolution of conditions at the site, and radiological forecasts for the event.

The off-site emergency organisation is based on resources built up as part of the general protection concept developed for the entire Swiss population. These resources consist of a well-developed protection infrastructure and well-trained troops for fire and disaster intervention. Under the ordinance on protection in the case of an emergency, each NPP in Switzerland has three distinct emergency planning zones. Zone 1 is the area around an NPP in which there could be acute danger to the public in the event of an accident and where immediate protective measures are required. Depending on the NPP's power rating, Zone 1 covers a radius of about 3 – 5 km. Zone 2 is adjacent to Zone 1 and encloses an area with an outer radius of about 20 km. Furthermore, it is divided into 6 overlapping sectors of 120° each. The public can thus be alerted in individual sectors, as necessary. The rest of Switzerland, (outside of Zones 1 and 2) is referred to as Zone 3. It is not expected that measures would be necessary to protect the public in Zone 3 during the passage of a radioactive plume. If, however, measures were nevertheless necessary, it is assumed that they could be implemented without detailed pre-planning. Potassium iodide tablets are distributed to all houses, schools and companies in Zones 1 and 2. In Zone 3, the tablets are stored, such that they are available to the general public within 12 hours.

An automatic dose rate monitoring and emergency response data system (MADUK/ANPA) has been installed for all NPPs in Switzerland. The system monitors dose rates continuously (updated every 10 minutes) at 12 to 17 locations in the vicinity of each NPP and provides online access to measurement data for about 25 important plant parameters. The regulatory body ENSI uses special software – the Accident Diagnostics, Analysis and Management system ADAM – to visualise these measurements, diagnose the state of the plant, and simulate the development of potential accidents into future. Furthermore, radiological forecasts are performed hourly, using the ADPIC dispersion code with current and forecast meteorological data.

In case of an accident, NPPs are responsible for detecting and assessing the accident, for implementing on-site countermeasures to control it, and for disseminating information immediately and continuously to the relevant off-site authorities. Detailed requirements for the on-site emergency organisation are laid out in the Radiological Protection Act (/A-16/), Nuclear Energy Act (/A-5/), Nuclear Energy Ordinance (/A-6/) and guidelines ENSI-G07 ("Organisation of nuclear installations"; /A-22/), ENSI-B11 ("Emergency exercises"; /A-23/), and ENSI-B12 ("Emergency preparedness in nuclear installations"; /A-14/). All plants have appropriate, validated guidance for the mitigation of severe accidents during full-power operation. To ensure communication in an emergency situation, there are dedicated telephone and fax lines between the NPPs, ENSI and the National Emergency Operation Centre.

Pursuant to Article 6, paragraph 2 of the EPO (/A-15/), the operators procure and install appropriate means of emergency communication in order to communicate with:

a. ENSI

b. The National Emergency Operation Centre (NEOC)

c. The organisations designated by the cantons containing communities (communes) which are located wholly or partly in a Zone 1.

Each year, ENSI inspects the external means of communication in the nuclear power plants. These inspections are intended to show that documented equipment to send alarms to external organisations is available, that specified requirements for periodic functional tests are in place, and that proof of the implementation of these requirements is available. In addition, random functional checks are carried out on communication equipment to verify that it functions correctly, and also that it is used in the emergency exercises observed by ENSI.

All the nuclear power plants can reach ENSI, the NEOC and the cantonal organisations by means of the following external connections:

- Fixed network with diverse connection to two public exchanges for communication via telephone and fax with ENSI, the NEOC and the relevant canton
- Dedicated line (leased line) connection, NPP Inland, for communication via telephone and fax with ENSI, the NEOC and the other nuclear power plants
- With their security guards, all the nuclear power plants have an encrypted wireless connection (POLYCOM) for communication with external emergency services.

Thus, all the nuclear power plants can communicate with the designated organisations via the means of emergency communication required by the Emergency Protection Ordinance.

The accident in Fukushima has outlined critical issues in emergency preparedness. ENSI actively participates in the IDA NOMEX (see chapter 0.8) which aims to assess the need for organizational and legislative adjustments in the area of emergency preparedness and response in the light of the Fukushima findings. In the frame of the IDA NOMEX, a report on possible short-, middle- and long-term measures is to be compiled by the second quarter 2012. Within the IDA NOMEX, the following topics have been addressed, among others:

- Reference scenarios for emergency preparedness and concept of emergency zones
- Redundancy and diversity of communication and data transmission systems
- Redundancy and diversity of measurement networks and prognosis systems
- Treatment of strongly contaminated and irradiated persons
- Revision of the concept of contact points
- Evacuation of the population
- Revision of the concept for the distribution of iodine tablets
- Readiness of federal agencies in case of emergency

The following sections focus on issues identified by Switzerland as a consequence of the events in Fukushima. Further information on the present status of emergency preparedness in Switzerland may be found in the CNS report of 2010 (/A-24/).

5.2 General emergency preparedness issues

5.2.1 Communication facilities

Analyses have shown that today's means of telecommunication have insufficient availability: redundancy and diversity must be improved. The locations where communication equipment is set up and the accessibility of such equipment in case of extreme natural events will be examined, so that communication with the responsible units is guaranteed. In case of a power failure of long duration, it must be ensured that the communication means required to cope with the emergency are able to function. This topic is addressed within the context of IDA NOMEX.

Transmission of plant parameter data must be re-evaluated as well, with respect to an alternative, independent means of data transmission. This also includes re-evaluation of whether the transmitted data is adequate to track and evaluate incidents.

As in the case of emergency communication, a review of the design against earthquake and flooding of the monitoring network for automatic dose rate measurement in the vicinity of nuclear power plants (MADUK) will be carried out with respect to experience gained from the Fukushima accident.

5.2.2 Extended international emergency support

Coordination with other international partners is required to determine whether and how an international network for central international emergency support can be set up, in addition to present collaborations and agreements.

The services to be provided in an emergency must be re-defined. Agreements must be reached with the participating institutions for this purpose.

5.2.3 Radiological dispersion simulations

A review must be carried out to determine whether the necessary information regarding fore-casts of releases and radiation exposure is provided in a timely and continuous manner in case of an accident. The correctness of the dispersion calculations has to be reviewed as well, taking into account several potential sources (multiple-unit plants, spent fuel storage ponds).

In the context of the project RADUK, whose aim is to implement a new and modernised system for dispersion calculations, the physical range of modelling will be increased up to 250 km. The main motivation for this step has been that the Fukushima accident has shown the necessity of extending calculations to distances greater than a few tens of kilometres. Furthermore, since in Switzerland a lot of international organisations are based in Geneva (whose closest distance to a NPP, Mühleberg, is about 130 km), many demands for prognoses for the area of Geneva are expected in case of an accident at a NPP.

Furthermore, it is necessary to examine the extent to which the availability of the meteorological data required for dispersion calculations is guaranteed in case of extreme natural events like earthquakes or flooding. A concept for substitute meteorological data should ensure that dispersion calculations can still be carried out in case of a total power failure of long duration.

Additionally, as a consequence of IDA NOMEX discussion, it is planned to state more precisely the definite requirements with respect to redundancy and reliability on measurement and prognosis systems in conjunction with emergency protection (e.g. plant parameters, MADUK measurement network in the vicinity of NPPs, dispersion models, meteorological data and prognoses of the Federal Office of Meteorology and Climatology MeteoSwiss for events in Swiss NPPs in the Emergency Protection Ordinance).

5.2.4 Concept of information in case of an accident

Regarding information to be provided to the general public, a review has to determine whether the organisational responsibilities for informing the public as well as the local authorities and support staff are clearly stipulated and are uniformly understood by all parties involved.

The information platform for natural hazards used by authorities shall be developed further. Essential elements therein shall be the integration of additional data (weather, flood, earthquake, etc.) provided by federal offices, cantons and municipalities as well as private entities. Furthermore, interfaces to other information systems, especially the National Emergency Operation Centre's electronic situation report, shall be extended. This topic is addressed within the context of IDA NOMEX.

A further review should be carried out to determine whether the timely communication of radiological effects, including calculated forecasts, is also ensured beyond Switzerland's borders.

5.2.5 Readiness of federal agencies in case of emergency

According to the review of IDA NOMEX, it has been identified that the requirements for the readiness of federal agencies in case of emergency and appropriate means of command must be defined and specified. Furthermore, the resilience of agencies involved over an extended timespan has to be ensured.

5.3 On-site relevant issues

5.3.1 Requirements for emergency rooms and substitute emergency rooms

Nuclear power plants must have suitable, seismically robust, appropriately protected, ventilated and well-equipped emergency rooms and substitute emergency rooms, which can also withstand external impacts such as earthquake or flooding. These rooms require adequate equipment and must be of such a nature as to guarantee the health and radiological protection of on-site staff and also so to ensure that the staff are accommodated and provided with supplies. In the aftermath of the Fukushima accident, it has become clear that a review must be carried out to determine whether the existing emergency rooms and the substitute emergency rooms at the Swiss nuclear power plants still meet these requirements. The protected room for the ENSI emergency organisation must also be reviewed.

5.3.2 Emergency planning and emergency exercises

Symptom-oriented decision-making guidance for emergency management in case of severe accidents (SAMG) at nuclear power plants have been developed for power operation as well as non-power operation. Knowledge gained from the Fukushima accident indicates that the SAMG should be reviewed including the regulatory requirements (ENSI-B12). In this regard, it is necessary to check whether adequate consideration is given to a Station Blackout (SBO) of long duration and the simultaneous occurrence of events in multiple-unit plants, so-called multi-unit events.

The release of non-nuclear hazardous substances in case of events in excess of the design basis could exert additional influence on the accident progress, and which counter-measures are required, will be examined.

Emergency exercises have to be conducted annually by each NPP. Every two years, there is a combined exercise in order to practice co-operation between the various stakeholders involved in a nuclear or radiological emergency. In these exercises the information of the public is simulated and reviewed as well. An examination of whether procedures are trained often enough during emergency exercises shall be carried out. Particular attention should be focused on a functioning inter-organisational chain of communication. In the planning of emergency exercises, special consideration has to be given to incidents involving an SBO of long duration.

Organisational emergency protection measures and emergency management have to take into account human and organisational factors. In particular, these include the aspects of decision-making processes and means for dealing with emergencies as well as qualifications and competences of the individuals involved in dealing with an emergency. Further consideration is to be given to aggravated physical and psychological working conditions in emergency plans and education/training for staff. Clarity regarding the roles and responsibilities of organisations involved in dealing with an emergency, including interfaces within and between the organisations, is another issue, as suggested by IDA NOMEX. This includes ensuring that the necessary qualified staff is available at all times not only to the licence-holders but also to the authorities and institutions involved.

5.3.3 Radiation protection

The exposure of operating staff to radiation during emergencies has already been addressed in so-called post-LOCA studies, which resulted in a number of improvements. The operators are expected to continue developing the measures to limit personal doses by implementing organisational, administrative and technical improvements and optimisations. This will be followed up in the frame of forthcoming ENSI oversight activities. The adequacy of the amount of available radiation protection personnel in case of severe accidents will be reviewed.

Furthermore, the issue of dealing with large volumes of contaminated water, radioactive waste or environmentally hazardous substances in case of severe accidents will be examined. This includes the integration of stipulated procedures into emergency management. It will be examined how the necessary technical resources can be made available in case of deployment, and whether resources should be kept in readiness.

5.4 Off-site relevant issues

5.4.1 Emergency preparedness concept

The emergency preparedness concept is intensively discussed in Switzerland, especially within the scope of IDA NOMEX.

The Fukushima accident has demonstrated the possible necessity of measures for a prolonged period in an area up to distances of a few tens of kilometres from the NPP site. Even areas not directly affected by an accident, further away may be needed for important tasks, such as accommodating evacuees, traffic management, etc. Currently, the Emergency Preparedness Ordinance lacks such requirements. The concept of emergency planning zones as well as the reference scenarios used for emergency planning will be reviewed, incorporating recommendations of international bodies like IAEA, ICRP and HERCA (Heads of European Radiological protection Competent Authorities). With respect to the reference scenarios, utilities have been required to submit new analyses until 30 September 2012.

It must be conclusively established up to which distances, which plans and which preparations are necessary for emergency management. The preparations for warning the authorities, alarming the population, and ordering protective measures need to be reviewed (e.g. definition of decision-making processes, measures, requirement on the remote control of sirens, etc.). The basis for these preparations are the updated reference scenarios and the concept of adopting measures based on dose rate.

The concept of evacuation is also under re-evaluation. The tasks of accommodating and assisting evacuees from cantons, regions and communities not directly affected have to be clarified and formulated in a binding manner.

The current rule for the distribution of potassium iodide tablets in case of an event outside the defined alarm zones has also to be reviewed with regards to necessity, practicability and available timespan. If necessary, alternative solutions have to be developed, taking into account the reference scenarios which are at the moment being revised.

The experience in Japan shows that not only radiation protection but the whole spectrum of hazards have to be taken into account when ordering protective measures for the population. Current preparations in Switzerland are primarily geared towards coping with a pure NPP accident. Missing are considerations for handling a multidimensional NBCN crisis with massively disrupted infrastructure, as occurred in Japan through combination of a natural disaster with an accident in a NPP with radiological consequences for the population and the environment. Therefore, the concept of measures based on dose shall be extended to a comprehensive concept of measures for the acute phase of events with increased radioactivity. This concept of measures defines which additional factors have to be considered, apart from radiation protection criteria, and how they have to be factored in.

Emergency management will also be reviewed to determine further potential for improvement. It is already clear today that as preparation for the medium- to long-term handling of a similar event in Switzerland, many material, organisational, and conceptual deficiencies have to be resolved. Clarity must be achieved regarding the roles and responsibilities of federal and cantonal authorities involved in crisis management, including interfaces within and between the organisations.

Figure 5-1: Aerial view of the Gösgen nuclear power plant (KKG).
Source: KKG

5.4.2 Handling of soil contamination in the vicinity of NPPs

In case of soil contamination, it is necessary to examine which resources are suitable to contain the contamination and to limit its effects. When required, the necessary resources must be available within appropriate periods, or must be kept in readiness. These resources may include binders (spray resins, cement), covering materials (to fix or cover loose contamination) and cleaning equipment (suction equipment, pumps, grippers and grabs, etc.).

Arrangements for dealing with contamination in the area surrounding nuclear plants following severe accidents have to be stipulated.

For the case of contamination of the population, an examination has to be carried out whether the requisite resources and arrangements are also adequate for larger groups of people.

6 International Cooperation

An objective of the Convention on Nuclear Safety is "to achieve and maintain a high level of safety worldwide through the enhancement of national measures and international co-operation". This chapter focuses on Switzerland's international contractual obligations and cooperation activities which are considered to be relevant in the context of the Fukushima accident and the lessons learned from it. In light of this accident, Switzerland decided to further increase its engagement and contributions to strengthening the global nuclear safety regime.

Switzerland's nuclear regulatory body, the Swiss Federal Nuclear Safety Inspectorate ENSI, is already represented in more than 70 international committees with the goal of exchanging operational and regulatory experience, developing the state-of-the-art in science and technology to a level up to international standards. The majority of these bodies are part of the International Atomic Energy Agency (IAEA) and the Nuclear Energy Agency (NEA) of the OECD. ENSI furthermore actively participates in organisations covering national bodies: As Chair of the Western European Nuclear Regulators' Association (WENRA), as observer in the European Nuclear Safety Regulators' Group (ENSREG) together with in the European Nuclear Energy Forum (ENEF), and as a member of the European Union Clearinghouse as well as in the Network of Regulators of Countries with Small Nuclear Programmes (NERS).

In November 2011, Switzerland hosted an Integrated Regulatory Review Service (IRRS) mission of the IAEA. This peer review mission on the governmental, legal and regulatory framework for safety had already been initiated prior to the Fukushima accident.

6.1 Conventions

Switzerland is a signatory state of the relevant international agreements like the Convention on Nuclear Safety (CNS), the Convention on the Physical Protection of Nuclear Materials, the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, the Convention on Early Notification of a Nuclear Accident and the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency.

6.2 Bilateral treaties

Switzerland has signed bilateral treaties on the early notification and mutual assistance in case of a nuclear emergency with all neighbouring countries. Based on these treaties, bilateral commissions of the nuclear safety authorities were established which usually meet once a year. An important aspect of these bilateral commissions is the exchange of operational and regulatory experience and the cooperation in emergency preparedness and response matters. The French-Swiss and the German-Swiss commissions comprise dedicated sub-commissions for this topic.

6.3 Communications

Incidents and accidents in Switzerland are reported to the IAEA Incident and Emergency Centre (IEC) by using the Unified System for Information Exchange in Incidents and Emergencies (USIE). In case of a serious incident or an accident in a Swiss nuclear installation, the national emergency response organisation is mobilised according to the Emergency Protection Ordinance /A-15/ and the Ordinance on the Organisation of Operations in Connection with NBC and Natural Events /A-26/, defining the governmental bodies responsible for mitigation of the accident, their duties and communication lines (see chapter 5). According to the Convention on Early Notification of a Nuclear Accident and corresponding bilateral agreements with Switzerland's neighbouring countries, the IAEA and the authorities of Germany, France, Italy and Austria are notified instantly. Switzerland is part of the EMERCON and ECURIE information systems.

An automatic dose rate monitoring and emergency response data system has been installed for all NPPs in Switzerland. The data is transmitted online to ENSI, the National Emergency Operations Center and – regarding the Leibstadt and Beznau NPPs which are close the German border – also to the responsible authorities in Germany. ENSI's radiological prediction results are provided to the National Emergency Operations Centre and to the German authorities (for more information see chapter 5).

6.4 Cooperation with and assistance from international organizations

Switzerland considers that one of the lessons learned from the Fukushima events is that coordination with other international partners is required to determine whether and how an international network for central international emergency support can be set up, because the services to be provided in an emergency must be defined jointly. Agreements must be reached with the participating institutions for this purpose. In this respect and in relation to the IAEA Action Plan on nuclear safety, Switzerland supports the French initiative to create a Rapid Reaction Mechanism and the establishment of an international training centre on emergency preparedness and response under the auspices of the IAEA. Furthermore, Switzerland intends to join the IAEA Response and Assistance Network (RANET) and the WHO Radiation Emergency Medical Preparedness and Assistance Network (REMPAN).

As stipulated above, Switzerland is a signatory state of the Conventions on Early Notification of a Nuclear Accident and on Assistance in Case of a Nuclear Accident or a Radiological Emergency and closely cooperates with its neighbouring countries in the field of emergency preparedness and response. It is part of the EMERCON and European Community Urgent Radiological Information Exchange (ECURIE) information systems.

6.5 Sharing operating and regulatory experience

The Swiss Nuclear Energy Act, the Nuclear Energy Ordinance and regulatory guidelines include requirements on the notification of events. The Ordinance also requires each plant to form a group that investigates events, defines corrective actions and follows through their implementation to prevent events from reoccurring. The insights from these events, as well as from international events, must be reported to ENSI at least every three months.

In addition, operators are legally obliged to review their NPP design after every INES 1 event in their own plant or after any INES 2 event in another NPP in Switzerland or abroad.

Accordingly, ENSI issued an order to all NPP operators one week after the nuclear accident in Fukushima. This order was followed by three others, regarding the procedure and deadlines for the design reviews, the first measures to be taken based on the preliminary results of the reviews and the reassessment of the safety margins in the framework of the EU stress test.

As the regulator, ENSI has established a group of specialists to review domestic and international operating experience. The review of operating experience may result in regulatory action and, as appropriate, in requirements to the operator. The yearly assessment of the safety situation at each Swiss NPP is based on the operating experience. This systematic safety assessment, which includes findings from inspections as well as from event investigation, is for instance used to focus the inspections on a particular aspect, the following year, representing a true feedback of operating experience into the regulatory actions. In light of the events in Fukushima and in order to improve the process of evaluating and examining national and international operational experience, ENSI established a new section for operating experience comprising six staff members in September 2011.

ENSI issues an annual report compiling information on regulatory safety research, lessons learned from events in foreign NPPs, international cooperation and current changes and developments in the basics of the nuclear regulatory process. In some cases, e.g. for incidents of global interest or with main relevance to Swiss NPPs, ENSI prepares reports on its examination and response actions (e.g. Forsmark report, four reports on the analysis of the Fukushima accident).

Nuclear incidents in Switzerland are reported to the International Reporting System for Operating Experience (IRS) jointly operated by the IAEA and the NEA. ENSI is a member of the NEA Working Group on Operating Experience, the NEA Working Group on Inspection Practices and the European Network on Operational Experience Feedback (EU Clearinghouse). Sharing of operating and regulatory experience is also a constant agenda item of the bilateral commission meetings with the neighbouring states and of the meetings of the Network of Regulators of Countries with Small Nuclear Programmes (NERS), currently comprising eleven countries.

On a bilateral level, inspectors of the French Nuclear Safety Authority regularly participate in so-called cross inspections in Swiss NPPs and vice versa. For instance, in autumn 2011 ENSI inspectors participated in inspections of the French Fessenheim and Bugey NPPs which are located close to the Swiss border. These inspections focused on Fukushima issues like earthquake resistance, flooding protection, loss of power and ultimate heat sink, and emergency preparedness and response.

6.6 Hosting international peer reviews

All Swiss NPPs underwent Operational Safety Review Team (OSART) missions including the Follow-up missions. In December 2011, Switzerland called for another OSART mission to the Mühleberg NPP which will mark 40 years of commercial operation in 2012. All Swiss NPPs also underwent at least one World Association of Nuclear Operators (WANO) mission at their own initiative.

Switzerland hosted the first International Regulatory Review Team (IRRT) mission to a Western country in 1998 (follow-up mission 2003). The ENSI Ordinance stipulates that ENSI "subjects itself periodically to a review by external experts regarding its compliance with the requirements of the IAEA". In other words: ENSI is legally obliged to regularly host IRRS missions. The last mission to Switzerland took place in November 2011, including issues dedicated to the lessons learned from the Fukushima event (Swiss response to the event, formal orders issued by ENSI, creation of an external storage facility, participation in the EU Stress Tests and NPPs reassessment). Furthermore, ENSI experts so far participated in sixteen IRRT and IRRS missions to other countries and chaired two of these missions.

As a consequence of the accident in Fukushima, Switzerland advocates strengthening the global system for nuclear safety. The background for this position is the call for mandatory IAEA review missions to all countries with NPPs to assess their regulatory framework and activities as well as their NPP's design and operation. Furthermore, Switzerland aims for more transparency in the reporting on the CNS meetings and the review missions, by calling for mandatory publication of the review results. The Swiss position was actively put forward at an international level and was presented at the Ministerial Seminar on Nuclear Safety of 7 June and the OECD Forum on the Fukushima Accident of 8 June in Paris, as well as at the IAEA Ministerial Conference on Nuclear Safety of 20 to 24 June 2011 in Vienna. The IAEA Action Plan on Nuclear Safety, which was endorsed by the IAEA General Conference of 19 to 23 September 2011, includes these elements on a non-mandatory basis and is considered to be a first step towards the effective strengthening of the global nuclear safety regime.

6.7 Utilization of IAEA safety standards

Switzerland is a committed signatory state of the CNS, actively participates in the CNS processes and supports strengthening of the international nuclear safety regime based on the standards and services of the IAEA. The Swiss legal and regulatory framework reflects the main international regulatory requirements: The Safety Fundamentals are included in the legislation covering nuclear energy, radiation protection and emergency response organization; specific IAEA requirements and guides are included in the ENSI guidelines. Another important basis for nuclear regulation in Switzerland are the WENRA Safety Reference Levels, virtually all of which have been implemented by the Swiss nuclear operators. Discrepancies from IAEA and WENRA standards have to be justified when setting up new guidelines. In view of the IRRS 2011 mission to Switzerland, ENSI also performed a self-assessment on the effective implementation of the WENRA Safety Reference Levels and of the IAEA NS-R-1 and NS-R-2 requirements in the Swiss regulations.

The accident in Fukushima showed once again the importance of an effectively independent regulatory body according to Art. 8 of the CNS. Switzerland's nuclear regulatory body ENSI is an independent authority which is constituted under public law and whose functions are separated from those of any other body concerned with the promotion or utilization of nuclear energy. Neither the government, nor any other institution has discretionary power regarding ENSI's safety decisions, which are based on the expertise of 120 scientists and engineers. Nevertheless, after the Fukushima accident, ENSI decided to further broaden its knowledge base for nuclear safety decisions and launched a new advisory body, the Expert Group for Reactor Safety. This group includes five internationally recognized experts and advises ENSI on specific nuclear safety questions.

ENSI is able to exercise its authority to intervene in connection with any nuclear facilities or activities that present significant radiation risks, irrespective of the possible costs to the authorized party. According to the Swiss Nuclear Energy Act, ENSI shall order all necessary and reasonable measures aimed at preserving nuclear safety and security. In the event of an immediate threat it may impose immediate measures that deviate from the issued license or ruling. If necessary, ENSI can seize nuclear goods or radioactive waste and eliminate sources of threat at the cost to the owner.

The ENSI Act states that nuclear safety has priority in carrying out tasks. By law and due to its independence, ENSI has no conflicts of interest. Acting in the politically sensitive field of nuclear energy ENSI is followed closely by the media and the public. Therefore, ENSI has a vital interest in maintaining its independent position from the nuclear industry and political influence.

6.8 Conclusion

Switzerland strives to comply with the IAEA Safety Standards and other relevant international nuclear safety provisions like the WENRA Safety Reference Levels. It actively contributes to the advancement of the state-of-the-art in nuclear science and technology, operational and regulatory experience feedback and to international efforts aimed at upgrading safety standards. Nuclear accidents have impacts beyond national boundaries, both politically and – in case of a major release of radioactivity – also radiologically. Therefore, the international nuclear community has a common interest and responsibility in preventing future accidents. Switzerland is convinced that this common responsibility requires the strengthening of the global nuclear safety regime by effective implementation of the existing international regulatory framework in countries using nuclear power. This implementation should be regularly reviewed by IAEA peer reviews missions in the areas of national regulatory framework and activities, NPP design and NPP operation. Furthermore, the common international responsibility for nuclear safety requires full transparency in reporting on these review missions and on the findings of the triennial CNS review meetings.

7 Table Summarizing the Swiss Activities

The following table contains the most important activities performed in Switzerland in the aftermath of Fukushima.

Activity	Activities by the Operator*			Activities by the Regulator*		
	(Item 2.a) Activity - Taken? - Ongo-ing? - Planned?	(Item 2.b) Schedule Or Miles-tones for Planned Activities	(Item 2.c) Results Available - Yes? - No?	(Item 3.a) Activity - Taken? - Ongo-ing? - Planned?	(Item 3.b) Schedule Or Milestones for Planned Activities	(Item 3.c) Conclusion Available - Yes? - No?
Topic 0 – General Issues						
Analysis of the Fukushima accident	Taken		Yes	Taken	Additional information will be included as becoming available; investigation of checkpoints & implementation until 2015	Yes
Clarification whether there is an immediate threat for the Swiss population				Taken		Yes
Specific inspections in the Swiss nuclear power plants related to spent fuel pools, the external storage facility, protection against flooding and the filtered containment venting systems				Taken		Yes
New ENSI-section in charge to analyse the operating experience				Taken		Yes
New ENSI section for communication increasing the dedicated resources				Taken		Yes

Activity	Activities by the Operator*			Activities by the Regulator*		
	(Item 2.a) Activity - Taken? - Ongoing? - Planned?	(Item 2.b) Schedule Or Milestones for Planned Activities	(Item 2.c) Results Available - Yes? - No?	(Item 3.a) Activity - Taken? - Ongoing? - Planned?	(Item 3.b) Schedule Or Milestones for Planned Activities	(Item 3.c) Conclusion Available - Yes? - No?
Topic 1 – External Events						
Description of the characteristics and methodology used for determination of the **seismic hazard**	Taken		Yes	Taken		Yes
Reassessment of the **seismic hazard** in order to determine if the design basis is adequate	Taken / Ongoing	PEGASOS project carried out from 2001 to 2004, Follow-up project started in 2008 will continue until end of 2012	Yes, first results are available	Taken		Yes
Evaluation of the robustness of the safety systems to achieve safe shut down against **design basis earthquake**	Taken		Yes	Ongoing / Planned	New deterministic Proof of safety for the SSE has to be submitted by 31 March 2012 Additional reviews and back-fitting measures have to be performed by steps until 2015 the latest	No
Description of the characteristics and methodology used for determination of the **flood hazard**	Taken		Yes	Taken		Yes
Reassessment of the **flood hazard** in order to determine if the design basis is adequate	Taken		Yes	Taken		Yes

Activity	Activities by the Operator*			Activities by the Regulator*		
	(Item 2.a) Activity - Taken? - Ongoing? - Planned?	(Item 2.b) Schedule Or Milestones for Planned Activities	(Item 2.c) Results Available - Yes? - No?	(Item 3.a) Activity - Taken? - Ongoing? - Planned?	(Item 3.b) Schedule Or Milestones for Planned Activities	(Item 3.c) Conclusion Available - Yes? - No?
Topic 1 – External Events						
Evaluation of the robustness of the safety systems to achieve safe shut down against **design basis flood**	Taken		Yes	Planned	Additional back-fitting measures have to be performed by steps until 2015 the latest	No
Description of the characteristics and methodology used for determination of design basis loads resulting from **extreme weather conditions**	Taken		Yes	Taken		Yes
Reassessment of **extreme weather conditions** in order to determine if the design basis is adequate	Taken		Yes	Planned	A full and complete proof of sufficient protection against extreme weather conditions, including combinations thereof have to be performed by 2015 the latest	No
Evaluation of the robustness of the safety systems to achieve safe shut down against **extreme weather conditions**	Taken		Yes	Planned	See below	No

Activity	Activities by the Operator*			Activities by the Regulator*		
	(Item 2.a) Activity - Taken? - Ongoing? - Planned?	(Item 2.b) Schedule Or Milestones for Planned Activities	(Item 2.c) Results Available - Yes? - No?	(Item 3.a) Activity - Taken? - Ongoing? - Planned?	(Item 3.b) Schedule Or Milestones for Planned Activities	(Item 3.c) Conclusion Available - Yes? - No?
Topic 2 – Design Issues						
Power supply (Strategy for the targeted deployment of the mobile accident management emergency diesels)	Ongoing	2015	Preliminary results available	Taken		Yes
Development of independent alternative heat sink	Ongoing	2015	No	Taken		Yes
Containment integrity (Evaluation of the seismic robustness of Containment isolation and containment venting systems)	Ongoing	2015	Preliminary results available	Taken		Yes
Back-Fitting of alternative SFP-cooling system	Ongoing	2014	Preliminary results available	Taken		Yes
Topic 3 – Severe Accident Management and Recovery (On-Site)						
External storage facility Reitnau with additional auxiliary equipment for sustaining the power supply	Taken		Yes	Taken/ Ongoing	Concept for deployment of the equipment under review	Yes
Additional accident management measures for SFP cooling	Ongoing	2015	No	Taken		Yes
Re-evaluation of hydrogen risk				Planned	2015	No

Activity	Activities by the Operator*			Activities by the Regulator*		
	(Item 2.a) Activity - Taken? - Ongoing? - Planned?	(Item 2.b) Schedule Or Milestones for Planned Activities	(Item 2.c) Results Available - Yes? - No?	(Item 3.a) Activity - Taken? - Ongoing? - Planned?	(Item 3.b) Schedule Or Milestones for Planned Activities	(Item 3.c) Conclusion Available - Yes? - No?
Topic 4 – National Organizations						
Lessons learned report on Fukushima	Taken	February 2012	Yes, Report	Taken	February 2012	Yes
Action plan 2012 drawn from lessons learned report	Ongoing	March 2012	Yes, action plan	Taken	February 2012	Yes Completed action plan
Completion of the action plan	Ongoing Action plan established Annual plan 2012 established	Each year definition of annual plan	Yes, some actions from annual plan 2012	Planned	Completion of actions: 2015 Completion of annual plan 2012	No
ENSI-internal project « oversight culture »	Ongoing	First phase 2012-2013	Project plan, project organization. Kick-Off-Meeting February 2012	Planned	First phase 2012-2013	No
Implementation of the IRRS recommendations and suggestions	Development of action plan	Activities start 2012	No	Planned	Conclusion 2014	No
IDA NOMEX project: Report on priorities				Ongoing	Report to federal council expected by mid-2012	No
Topic 5 – Emergency Preparedness and Response and Post-Accident Management (Off-Site)						
Review of the emergency preparedness concept				Ongoing	Requirements and timeline under discussion (Lessons learned and IDA NOMEX)	No
Review of the reference scenarios and related zone concept for emergency planning				Planned	No schedule available yet	Yes (first conclusions available)
Communication and data transmission	Ongoing	Requirements and timeline under discussion		Ongoing	Requirements and timeline under discussion	Yes (first conclusions available).
Extended range of dispersion calculations				Ongoing	Implementation by 2015	Yes

Activity	Activities by the Operator*			Activities by the Regulator*		
	(Item 2.a) Activity - Taken? - Ongoing? - Planned?	(Item 2.b) Schedule Or Milestones for Planned Activities	(Item 2.c) Results Available - Yes? - No?	(Item 3.a) Activity - Taken? - Ongoing? - Planned?	(Item 3.b) Schedule Or Milestones for Planned Activities	(Item 3.c) Conclusion Available - Yes? - No?
Topic 6 – International Cooperation						
Participation of the Swiss NPPs in the EU stress test	Taken		Yes	Taken	Further investigation & implementation until 2015	Yes
Integrated Regulatory Review Service IRRS mission to Switzerland				Taken		Yes
2nd OSART mission at Mühleberg NPP	Planned	October 2012	No	Ongoing	October 2012	No
New Expert Group on Reactor Safety (ERS) with members from foreign countries				Taken	First meeting in spring 2012	No
Participation to IAEA Response and Assistance Network RANET				Planned		No
Cross-inspections with France	Taken		Yes	Taken		Yes

8 List of Checkpoints and Open Points

8.1 Checkpoints

From the complex events related to the accident at Fukushima, ENSI has derived 37 checkpoints which will help to achieve an additional increase in the safety of Swiss nuclear plants. These checkpoints are listed below. For details including explanations and implementation see /A-12/.

Focus Area: Design

Checkpoint 1
The hazard assumptions for earthquake and external flooding, and also for extreme weather conditions, must be re-evaluated to take account of the latest knowledge.

Checkpoint 2
The control strategies for a long-lasting total power failure must be re-evaluated on the basis of knowledge gained from Fukushima.

Checkpoint 3
A review must be carried out to determine whether the coolant supply for the safety systems and the associated auxiliary systems is guaranteed from a diverse source which is safe against earthquakes, flooding and contamination.

Checkpoint 4
A review must be carried out to determine whether the requisite tightness of buildings containing important safety equipment is guaranteed in case of flooding of the site.

Checkpoint 5
On the basis of experience gained from the Fukushima accident, another review must be undertaken to determine whether the availability of the instrumentation required to assess the condition of the plants is guaranteed adequately even in extreme situations.

Checkpoint 6
A review must be carried out to determine whether control of leaks and long-term cooling of the spent fuel storage ponds are guaranteed in case of severe accidents.

Checkpoint 7
A review must be carried out to determine whether the verifications regarding the prevention of hydrogen explosions should be extended to additional areas of the plants beyond the primary containment.

Checkpoint 8
The design and operation of the systems for filtered venting of the containment must be re-viewed again.

Checkpoint 9, Covered by IDA NOMEX
It is necessary to carry out a new review of design against earthquake and flood of the monitoring network for automatic dose rate measurement in the vicinity of nuclear power plants (MADUK), in relation to experience gained from the Fukushima accident.

Checkpoint 10, Covered by IDA NOMEX

A review must be carried out to determine whether the emergency rooms and the substitute emergency rooms at the Swiss nuclear power plants still meet the requirements, based on the experience gained from the Fukushima accident.

Checkpoint 11

The access control system for nuclear power plants and the associated arrangements must be reviewed to determine the accessibility of rooms where intervention is required in case of severe accidents, while maintaining appropriate plant safety and security. Monitoring of radiation protection must continue to be guaranteed in this context.

Focus Area: Emergency Management

Checkpoint 12

The emergency measures for heat dissipation in case of a complete failure of the cooling water supply must be reviewed and verified under conditions resulting from the destruction of the infrastructure and the power supply.

Checkpoint 13

It is necessary to review how the alternative supply of water and power for emergencies is ensured.

Checkpoint 14

It is necessary to examine the water resources that can be made available to feed the reactor pressure vessel, the spent fuel storage ponds and the containment.

Checkpoint 15, Covered by IDA NOMEX

Emergency management must be reviewed to determine further potential for improvement.

Checkpoint 16

ENSI has identified the following issues as checkpoints for improving emergency planning and emergency exercises:

a) The decision-making guidance for emergency management in case of severe accidents (SAMG) at nuclear power plants, including the newly planned checkpoints to deal with severe accidents, must be reviewed on the basis of knowledge gained from the Fukushima accident.
In this regard, it is particularly necessary to check:
- o Whether adequate consideration is given to a Station Blackout (SBO) of long duration and the simultaneous occurrence of events in multiple-unit plants;
- o Whether there is any need for measures, auxiliary resources and equipment that must be available to §ensure that criticality safety is maintained over the long term in case of severe accidents.

b) Consideration given to incidents involving an SBO of long duration in the planning of emergency exercises.

c) Examination of whether the procedures are trained often enough during emergency exercises. Particular attention should be focused here on a functioning inter-organisation chain of communication across the various organisations.

Checkpoint 17, covered by IDA NOMEX
A review must determine whether and to what extent the communication facilities are designed with adequate redundancy and diversity.

Checkpoint 18, covered by IDA NOMEX
At all times, it must be ensured that adequate staff are available to accomplish all necessary emergency management activities.

Checkpoint 19
Measures that increase the organisation's ability to react to unexpected events must be reviewed again on the basis of experience gained from Fukushima.

Checkpoint 20, covered by IDA NOMEX
Transmission of plant parameter data must be re-evaluated with respect to an alternative, independent means of data transmission.

Checkpoint 21, covered by IDA NOMEX
The evacuation concepts must be reviewed, taking account of knowledge gained from the Fukushima accident.

Checkpoint 22, covered by IDA NOMEX
Coordination with other international partners is required to determine whether and how an international network for central international emergency support can be set up.

Checkpoint 23, covered by IDA NOMEX
A review must be carried out to determine whether the necessary information regarding fore-casts of releases and radiation exposure is provided in a timely and continuous manner in case of an accident.

Checkpoint 24, covered by IDA NOMEX
The following improvement measures were identified regarding information to be provided to the general public:
a) It must be ensured not only that the requisite infrastructure and the necessary individuals and/or organisations and equipment are available for crisis communication, but also that the necessary means of communication are in place. The relevant precautions must be taken. Regular training must be provided on the associated procedures. This point also includes a functioning network of experts who are available to the media to supply neutral and objective information.
b) Review to determine whether the organisational responsibilities for informing the public as well as the local authorities and support staff are clearly stipulated, and are uniformly understood by all involved parties.
c) A review should be carried out to determine whether the timely communication of radiological effects, including calculated forecasts, is also ensured beyond Switzerland's borders.

Checkpoint 25
It is necessary to examine the extent to which the release of non-nuclear hazardous substances in case of events in excess of the design basis could exert an additional influence on the accident progress, and which counter-measures are required.

Focus Area: Experience Feedback

Checkpoint 26
The process of evaluating and examining the applicability of national and international operating experience must be optimised on the basis of knowledge gained from the Fukushima accident.

Checkpoint 27
It must be guaranteed that the knowledge gained from national and international operating experience (the procedure for processing events) in the operators' organisations reaches all the relevant individuals and units (including those at group level).

Focus Area: Supervision

Checkpoint 28
It must be ensured that internationally harmonised assessment standards for nuclear safety are established at a high level of safety.

Checkpoint 29
Greater importance should also be accorded in the international sphere to the recommendations resulting from international reviews (IRRS, OSART (Operational Safety Review Team)) and from the regular Periodic Safety Reviews (PSR). The transparency of ENSI's supervision and of the operators' safety-related activities must be increased.

Checkpoint 30
ENSI is reviewing the significance of the lessons from the Fukushima accident for its supervision.

Focus Area: Radiation Protection

Checkpoint 31
Additional emergency resources must be kept in readiness for radiation protection in case of severe accidents.

Checkpoint 32
It is necessary to examine whether the emission and immission measurements in place on the power plant sites in order to determine the substances released due to activities are guaranteed in case of loss of offsite power (LOOP) or in case of an emergency.

Checkpoint 33, covered by IDA NOMEX
It is necessary to examine the extent to which the availability of the meteorological data required for dispersion calculations is guaranteed in case of extreme natural events.

Checkpoint 34, covered by IDA NOMEX
It is necessary to stipulate arrangements for dealing with contamination in the area surrounding nuclear plants following severe accidents.

Checkpoint 35
It is necessary to examine how to deal with large volumes of contaminated water, radioactive waste or environmentally hazardous substances in case of severe accidents.

Checkpoint 36
As part of the emergency planning for severe accidents, it must be ensured that sufficient radiation protection staff are available on site.

Focus Area: Safety Culture

Checkpoint 37
The knowledge gained from the Fukushima accident must be taken into account in the programmes to foster and develop the safety culture in Swiss nuclear power plants.

8.2 Open Points

As an outcome of the EU Stress Test, eight new "open points" were identified which ENSI will follow up to further improve the safety of the Swiss nuclear power plants. These open points are listed in table 8-1 (see also /A-20/).

Table 8-1: Open points (OP) derived within the EU stress test

OP no.	Subject	NPPs affected			
		KKB	KKG	KKL	KKM
2-1	ENSI will follow up on the question as to whether in the Swiss nuclear power plants automatic scrams should be triggered by the seismic instrumentation.	X	X	X	X
2-2	In respect of seismic proof that has still to be supplied, ENSI will follow up on a more detailed examination of the seismic robustness of the isolation of the containment and the primary circuit.	X	X	X	X
2-3	ENSI will follow up on measures to improve the seismic stability of the containment venting systems in case of beyond-design basis accidents for KKG and KKL.		X	X	
3-1	ENSI will follow up on the impacts of a total debris blockage of hydraulic engineering installations.	X	X		X
4-1	ENSI will follow up on the proofs of protection against extreme weather conditions, including combinations thereof.	X	X	X	X
5-1	ENSI will follow up on the development of a comprehensive strategy for the targeted deployment of the mobile accident management emergency diesels in order to secure selected direct current and/or alternating current consumers in the long term under total SBO (resp. SBO) conditions.	X	X	X	X
6-1	From the point of view of risk minimisation, ENSI will follow up on the extent to which the current deployment strategies for the venting systems in severe accidents should be retained.	X	X	X	X
6-2	ENSI will follow up on whether restoring containment integrity during shutdown in the case of a total SBO represents a time-critical measure.	X	X	X	X

All the aforementioned points (checkpoints and open points from the EU stress test review) will be followed up on the basis of key thematic issues in the frame of ENSI forthcoming oversight activities. It is planned to complete the processing of all these points by 2015.

9 List of Abbreviations

AC	Alternate Current
ADAM	Accident Diagnostics, Analysis and Management system
ADPIC	Atmospheric Diffusion Particle-In-Cell Model
AM	Accident Management
ANPA	Data system for plant parameters (German: Anlageparameter)
BBC	Brown, Boveri & Cie
BWR	Boiling Water Reactor
CET	Core Exit Temperature
CNS	Convention on Nuclear Safety
DBE	Design Basis Earthquake
DBF	Design Basis Flood
DC	Direct Current
DETEC (UVEK)	Department of Environment, Transport, Energy and Communication (Eidgenössisches Departement für Umwelt, Verkehr, Energie und Kommunikation)
ECURIE	European Community Urgent Radiological Information Exchange
EMERCON	A descriptor referring to the official system for issuing and receiving notifications, information exchange and assistance provision through the IAEA's Incident and Emergency Centre in the event of a nuclear or radiological incident or emergency.
ENEF	European Nuclear Energy Forum
ENSI	Swiss Federal Nuclear Safety Inspectorate ENSI (Eidgenössisches Nuklearsicherheitsinspektorat)
ENSREG	European Nuclear Safety Regulatory Group
EPO	Emergency Protection Ordinance
ERO	Emergency Response Organisation
ERT	Emergency Response Team
FA	Fuel Assembly
FCVS	Filtered Containment Venting System
FN (AN)	File Note (Aktennotiz)
GE	General Electric
GLA	General License Application
HCLPF	High Confidence of Low Probability of Failure
HPP	Hydro(electric) Power Plant
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
ICS	Intercommunication System
IDA-NOMEX	Interdepartmental Working Group to Review Emergency Protection Measures in case of Extreme Events in Switzerland (Interdepartementale Arbeitsgruppe zur Überprüfung der Notfallschutzmassnahmen bei Extremereignissen in der Schweiz)
INES	International Nuclear and Radiological Event Scale

IRRS	Integrated Regulatory Review Service
IRRT	Integrated Regulatory Review Team (precursor of IRRS)
IRS	International Reporting System for Operating Experience
KKB	Nuclear Power Plant Beznau (Kernkraftwerk Beznau)
KKG	Nuclear Power Plant Gösgen (Kernkraftwerk Gösgen)
KKL	Nuclear Power Plant Leibstadt (Kernkraftwerk Leibstadt)
KKM	Nuclear Power Plant Mühleberg (Kernkraftwerk Mühleberg)
KWU	Kraftwerk Union AG
LOCA	Loss Of Cooling Accident
LOOP	Loss Of Offsite Power
MADUK	Measurement network in the vicinity of NPPs (Messnetz zur automatischen Dosisleistungsüberwachung in der Umgebung der Kernkraftwerke)
MCR	Main Control Room
NBC	Nuclear, Biological and Chemical
NBCN	Nuclear, Biological, Chemical and Natural
NEA	Nuclear Energy Agency of the OECD
NEO	Nuclear Energy Ordinance
NEOC	National Emergency Operations Centre (Nationale Alarmzentrale NAZ)
NERS	Network of Regulators of Countries with Small Nuclear Programmes
NEWS	Nuclear Events Web-based System
NPO	Non-Power Operation
NPP	Nuclear Power Plant
NSC	Nuclear Safety Commission
OBE	Operating Basis Eartquake
OECD	Organization for Economic Co-operation and Development
OSART	Operational safety Review Team
PC	Primary Circuit
PEGASOS	Probabilistic Earthquake Hazard Analysis for the Locations of the Nuclear Power Plants in Switzerland (Probabilistische Erdbebengefährdungsanalyse für die KKW-Standorte in der Schweiz)
PRP	PEGASOS Refinement Project
PSA	Probabilistic Safety Analysis
PSR	Periodic Safety Review
RADUK	Radiological dispersion calculations in the vicinity of nuclear facilities (Radiologische Ausbreitungsrechnungen in der Umgebung von Kernanlagen)
RANET	IAEA Response and Assistance Network
RB	Reactor Building
RCIC	Reactor Core Isolation Cooling
REMPAN	WHO Radiation Emergency Medical Preparedness and Assistance Network
RPO	Radiological Protection Ordinance
RPRC	Federal Commission for Radiological Protection and Monitoring of Radioactivity
RPV	Reactor Pressure Vessel

SAMG	Severe Accident Management Guidance
SBO	Station Blackout
SFOE	Swiss Federal Office of Energy
SFP	Spent Fuel Pool
SG	Steam Generator
SIA	Swiss Association of Engineers and Architects (Schweizerischer Ingenieur- und Architektenverein)
SP	Suppression Pool
SSHAC	Senior Seismic Hazard Analysis Committee
SSC	Structures, Systems, and Components
SSE	Safe Shutdown Earthquake
SSHAC	Senior Seismic Hazard Analysis Committee
SUSAN	Special emergency system of KKM (Selbstständiges, Unabhängiges System zur Abfuhr der Nachzerfallswärme)
TB	Turbine Building
Total-SBO	Total Station Blackout
TS	Technical Specification
TSC	Technical Support Centre
UPS	Uninterruptible Power Supply
USIE	Unified System for Information Exchange in Incidents and Emergencies
W	Westinghouse
WANO	World Association of Nuclear Operators
WENRA	Western European Nuclear Regulators' Association
WGIP	NEA Working Group on Inspection Practices
WGOE	NEA Working Group on Operating Experience

10 References

Italics = available only in German

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/A-3/ ENSI
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Formal order of 01.06.2011: Re-evaluation of the safety margins for the Beznau nuclear power plant pursuant to the EU stress tests

/A-5/ Nuclear Energy Act (NEA) of 21 March 2003 (Status as on 1 January 2009)

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/A-7/ DETEC SR 732.112.2, Ordinance on the Hazard Assumptions and the Assessment of the Protection against Accidents in Nuclear Installations of 17 June 2009 (Status as on 1 August 2009)

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