Assessment of Beyond Design and Severe Accidents Consequences, Principles and Methods of Emergency Planning and Response at NPP Temelin

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Content

Principles and Methods of Emergency Planning and Response at NPP Temelin

1. Introduction

The general objectives of the emergency preparedness and response system are to:
- reduce the risk or mitigate the consequences of the accident at its source,
- prevent serious deterministic health effects,
- reduce the likely stochastic health effects as much as reasonably achievable.

The first objective is the responsibility of the operator of the NPP. It involves preventing or reducing the release of radioactive material and exposure of workers and the public. The next two objectives are the combined responsibility of the NPP operator and off-site responsible organizations (local authorities, rescue system). They require the implementation of protective measures, actions.

The overall organization in the Czech Republic for emergency planning and response is presented on the block diagrams:
- the emergency planning organization (Fig. 1),
- the emergency response organization (Fig.2).

2. Legislation

General requirements for emergency preparedness and response for nuclear and radiological emergencies are defined by new ”Crisis” legislation (Law No.238/2000 Coll., Law No. 239/2000 Coll., Law No.240/2000 Coll., Law No.241/2000 Coll., Governmental Decision No.462/200039), which were approved by Government and Parliament, and came into force from 1st Jan 2001. New „Crisis“ legislation creates basis for preparation of the National Emergency Response plans, which are now under preparation. Each ministry, organization (licensee) has defined their own responsibilities; the interfaces between them are defined in “Crisis” legislation and relating Laws or Regulations. For radiological emergency beside “Crisis" legislation, the Law No.18/1997 Coll. - Atomic Act and its Regulations are important; in these legislation documents the obligations, responsibilities of licensees for use of nuclear energy and practice with radiation sources are defined.

The Czech Government has established bilateral agreements with neighboring countries and has signed a memorandum of understanding with the IAEA in the case of nuclear or radiological emergency.

To deal with emergency situation the Regional (District) Authorities on the territory of which the NPP is located (by Law No. 425/1990 Coll.) draw up a Regional (District) emergency plans an off-site emergency plan. They shall verify emergency preparedness and shall provide a co-ordinate procedure for rescue, emergency, expert and other services, administrative offices, municipalities, natural persons and legal entities in eliminating the consequences after accident during emergency situation. The notification (initial and additional information on course and consequences of accident) of health officials is part of mentioned plans.

By the legislation SUJB, the NPP and the Local Authorities are obliged to ensure that the on-site and of-site emergency plans are compatible. Agreement has to be reached before emergency plans can be approved (see additional remark 1, page 17).

3. Criteria for Emergency Planning Zones of Temelin NPP Determination

For most accident types, emergency response takes place over two distinct areas:

- on-site area – the area surrounding the NPP within the security perimeter, fence or the other designed property marker. This is the area under the immediate control of the NPP operator;
- off-site area – the area of the planning zones – Precautionary action zone (PAZ), Urgent protective action planning zone (UPZ), Long-term protective action planning zone (LPZ).

PAZ – pre-designated area around the NPP, where urgent protective actions have been preplanned and will be implemented immediately upon declaration of a general emergency. The goal is to substantially reduce the risk of deterministic health effects by taking protective measures and actions before the release.
UPZ - pre-designated area around the NPP where preparations are made to promptly implement urgent protective measures based on environmental monitoring.
LPZ - the furthest pre-designated area around the NPP in which the preparations for effective implementation of protective actions to reduce the long term dose from deposition and ingestion should be developed in advance.

Table 1: Suggested Precautionary, Urgent protective and long term protective action planning zones size recommended by IAEA-TECDOC-953

	Precautionary action zone	Urgent protective action planning zone	Long term protective action planning zone
Recommendation IAEA-TECDOC-953	3-5 km	10-25 km	50-100 km

The size of the **PAZ** is based primarily on the following considerations:

- Urgent protective actions taken before or shortly after release within this zone will **significantly reduce the risk of dose** and **prevent doses** above the deadly threshold for the most severe accidents at the NPP,

- For atmospheric release under **average** meteorological conditions this zone covers the distances where about 90% of the off-site risk of serious deterministic health effects could occur.

The size of the **UPZ** represents a judgement on the extent of detailed planning which must be performed in order to ensure effective response. The zone should cover the distance where about 99% of the off-site risk of serious deterministic health effects could occur. In particular emergency, protective actions, measures might well be restricted to a **small part** of UPZ. On the other hand, for the worst possible accidents, protective measures might need to be taken **beyond** the UPZ. The UPZ is the area where preparations are made to promptly perform radiation monitoring and implement urgent protective measures based on the monitoring results. Plans and capabilities have been developed to implement **sheltering, evacuation and**

distribute thyroid blocking iodine; they reflected the fact that evacuation could be required up to the boundary of the UPZ (reception centers for evacuation are sited outside the zone).

The size of the **LPZ** represents an area where preparation for effective implementation of protective actions to reduce the risk of deterministic and stochastic health effects from long term exposure to deposition and ingestion of locally grown food should be developed in advance. The LPZ area covers distances where about 99% of the off-site risk of dose above generic intervention levels could occur. More time will be available to take effective action within this zone; in general, **protective actions such as relocation, food restrictions and agriculture countermeasures will be based on the radiation monitoring and food sampling.**

The above-mentioned criteria resulting from international recommendations (e.g. IAEA-TECDOC-955/1997 and IAEA-TECDOC-953/1997) for determination of Emergency Planning Zone (hereinafter referred to as EPZ) are in the Czech legislation detailed in the regulation of SÚJB No. 184/1997 Coll. (which is a detailed legal regulation about assurance of requirements of radiation protection to law No. 18/1997 Coll.- Atomic Law), where §§ 64 to 66 give the method and scope of assurance of radiation protection during interventions for mitigation of irradiation as a consequence of radiation accidents (including response levels for the individual types of protective measures), and in the decree of the government of the Czech Republic No. 11 dealing with the emergency planning zone. Under this decree, the proposal for determination of EPZ must contain especially the following:

- list of possible radiation accidents with probability of occurrence for the particular nuclear facility higher or equal 10^{-7}/year (it is necessary to be aware that the requirements of Czech legislation are by two orders stricter than the world practice for the existing NPP`s and by one order stricter than the requirements for the future NPP`s)
- description of the assumed development and course of the individual radiation accidents (determination of probable place within the nuclear facility at which the assumed leakage of radionuclides would occur during the radiation accident, including time course of the radiation accident, etc.),
- list of possible consequences of the particular accident, including assessment of the possibility of irradiation of persons and possibility of exceeding of intervention levels for urgent measures.

4. Initial technical inputs for preparation of analytical documents for assessment of the size of Temelin NPP EPZ

Size of Emergency Planning Zone has been derived based on methodology and calculations by VUJE Trnava Inc. – Engineering, Design and Research Organization (VUJE), using commonly accepted standard approach [NUREG-0771 "Regulatory Impact of Nuclear Accident Source Term Assumptions", RG 1.4 „Assumptions used for evaluating the potential radiological consequences of a loss of coolant accident for pressurized water reactors", Decree of the government of the Czech Republic No.11 as well as codes designed and approved by regulatory body for this purpose. As a basis for the calculation, values of public radiation doses specified in Czech legislation (based on internationally accepted standards) on radiation protection were selected.
Two most severe types of accidents at Temelin, AB (large LOCA with station blackout), and V (large primary-to-secondary leakage also combined with station blackout) were calculated. Based on their source terms, distances for which the Urgent Action Generic Intervention

Levels should be determined. The containment slab melt-through (containment by-pass) scenario has been taken into account and the relevant source term contribution is included in the calculations (see additional remark 2, page 18)

In relation with acceptance of the Decree of the Government No. 11 and availability of PSA 2 results, it was decided to use probabilistic safety assessment techniques to confirm that no more severe accident sequences are likely to occur. The NPP Temelin specific PSA level 2 study used in this process was completed and peer reviewed by the IPERS Missions organized under IAEA umbrella in period of 1994-1996. The study was based on highly conservative data not taking into account some significant upgrading measures. Revision of the study reflecting the present status of the installation was started recently.

According to this governmental decree, operator of nuclear facility, as an input for SÚJB decision making about proposal of determination of size of EPZ, is obliged to provide a list of possible radiation accidents with probability of occurrence for the particular nuclear facility higher or equal 10^{-7}/year. Due to the fact that the decree of the government of the Czech Republic came out only after determination of EPZ for Temelin NPP, the operator presented subsequently a list of possible radiation accidents meeting the criterion of probability of occurrence higher or equal 10^{-7}/year.

Selection of these sequences was made according to the following two criteria:

- sequence with highest frequency, *i.e. with the highest probability of occurrence*
- sequence with highest significance, *i.e. with the highest source term related to frequency*

From the below-mentioned list of sequences we can see that the first two sequences meet both the criterion of high frequency and the criterion of high significance. They are the following sequences:
Major leak from primary to secondary circuit (T9S02)
Large LOCA (S2S02)

The first sequence is defined as major leak from primary to secondary circuit when the operator fails to cool down and depressurize the primary circuit. Damage of the core and significant leak of RA substances will occur after the loss of possibility to cool the core down further as a consequence of emptying the GA201 tank by the activity of emergency systems.

The same initiating event defined, however, with simultaneous complete loss of electric power, is sequence V that was analyzed for the purposes of determination of the EPZ. It is obvious that sequence of type V as against the most serious sequence according to PSA means faster course of the accident. The use of results of sequence V as an input for determination of size of EPZ of Temelin NPP is therefore justifiable due to the fact that it is a conservative scenario only.

The second sequence is defined as large LOCA with failure of low-pressure emergency make up system. Other emergency systems remain available. Due to insufficient capacity of these systems, there is a severe damage to the core with subsequent damage to reactor vessel. As a consequence of activity of sprinkler systems, the containment is not challenged due to overpressure, at the moment of loss of integrity, the most important radionuclides have already been washed out from the atmosphere of the containment and captured in containment sump (see additional remark 3, page 19).

Other sequences meeting the criteria of the decree of the government of the Czech Republic No. 11 which have to be assessed from the point of view of their consequences with respect to the size of EPZ are the following:

- Small LOCA (identification S4S10) with failure of emergency make up systems.
- Transient with reactor trip (identification TFRS11) which has been initiated by a fire and results in small LOCA with subsequent failure of high-pressure emergency system of hydroaccumulators.
- Transient without reactor trip (identification TSS06) with complete loss of SG feeding.
- Transient with reactor trip (identification TFRS05) which has been initiated by fire and results in loss of feeding for SG and non-performance of Feed&Bleed function.
- Transient with reactor trip (identification TFRS04) which has been initiated by fire and results in station blackout

From the above-mentioned sequences it is possible to expect that they are characterized by milder course, much longer time intervals and also by lower source terms than those used for determination of size of EPZ on the basis of AB and V sequences.

Therefore, from the above-mentioned analysis of evaluation of correctness of selection of AB and V type sequences for determination of size of EPZ from the point of view of probabilistic assessment of Temelin NPP safety, we can draw the following conclusions:

- Two most significant sequences determined on the basis of PSA level 2 results, should have significantly longer and milder course and also lower source term than AB and V sequence.
- Other significant sequences, determined on the basis of results of PSA level 2, do not have higher significance than the sequences analyzed for the purposes of the EPZ determination.
- PSA results therefore do not indicate any other sequences which would have worse radiation consequences than the analyzed sequences V and AB.
- The use of results of V and AB sequences as inputs for SUJB decision about determination of size of Temelin NPP EPZ was in accordance with the conservative approach. At the same time, this approach was applied beyond the scope of IAEA recommendations and the legislation requirements of the Czech Republic.

On the basis of the evaluation, the necessary scope of analyses was discussed with SUJB, which had to be additionally performed in order to confirm correctness of determination of EPZ. These analyses were conducted in co-operation with the Nuclear Research Institute in Rez and especially the two above-mentioned characteristic types of sequences were analyses, plus other proposed scenarios where it was possible to assume more significant values of the source term. In total, five following groups of emergency scenarios were analyzed in the NRI Rez using MELCOR program:

Sequence 1a - Leak between primary and secondary circuit on leg no. 1 with thermal creep of the hot leg piping

Sequence 1b - Leak between primary and secondary circuit on leg no. 1 without thermal creep of the hot leg piping

Sequence 2_- LOCA accident with no fire of hydrogen

Sequence 3_- LOCA accident with explosion of hydrogen

Sequence 4 - Station blackout with permanent loss of all active safety systems

Sequence 5_ - LOCA accident with renewal of emergency cooling after failure of reactor vessel bottom.

More detailed information see additional remark 4, page 20.

In addition to that, calculations of radiological consequences upon emergency leak of radioactive substances from NPP to the surrounding area were made for these scenarios using RTARC program. The calculations were made for category F of weather stability ("the worst" – the highest values of effective doses are calculated there, although only in a narrow band) and for category D (most probable category).

Probability of categories of weather stability [%] in Temelin NPP region

Category	A	B	C	D	E	F
1994	2,03	6,78	16,46	40,91	11,32	22,49
1995	0,74	5,91	14,18	41,26	13,77	24,14
1990-1995	1,42	6,11	15,76	40,91	13,29	22,55

Probability of categories of weather stability [%] in Temelin NPP region and Mixing layer heights

Category [%]	A 1,42	B 6,11	C 15,76	D 40,91	E 13,29	F 22,55
Mixing layer height [m]	**1300**	**900**	**850**	**800**	**400**	**100**

Distances at which the generic intervention levels are reached for implementation of urgent measures are given in Table 2.

Calculation assumptions used:

- weather stability category D (5m/s) – most probable and F (2m/s) – the worst radiological consequences in narrow band in the wind direction,
- constant speed and direction of wind for the whole time, i.e. 7 days,
- calculations are made below the axis of radioactive plume,
- calculations times 2 days and 7 days from the beginning of leak of radioactive substances to the atmosphere around NPP,
- measures for protection of population have not been adopted, – a man stands outside for 24 hours under the passing radioactive plume and inhales RA substances from it or, after the plume has passed, a man stands on contaminated ground and besides the surrounding radiation also inhales RA substances re-suspended from the ground surface,

Tab 2.1: Results of radiological consequence calculation

Stability class D		
Sequence	2 days	7 days

	Intervention Level			Intervention Level		
	5 mSv	10 mSv	50 mSv	50 mSv	100 mSv	500 mSv
AB_01	2 km	1 km	< 1 km	< 1 km	< 1 km	< 1 km
AB_02	3 km	2 km	< 1 km	< 1 km	< 1 km	< 1 km
AB_03	4 km	2 km	< 1 km	1 km	< 1 km	< 1 km
AB_04	3 km	2 km	< 1 km	< 1 km	< 1 km	< 1 km
ST_V	1 km	< 1 km	< 1 km	< 1 km	< 1 km	< 1 km
ST 1*	14 km	9 km	4 km	5 km	3 km	2 km
ST 1**	15 km	10 km	4 km	5 km	3 km	2 km
ST 2	< 1 km	< 1 km	< 1 km	< 1 km	< 1 km	< 1 km
ST 3*	6 km	4 km	1 km	1 km	< 1 km	< 1 km
ST 3**	6 km	3 km	1 km	1 km	< 1 km	< 1 km
ST 4	< 1 km	< 1 km	< 1 km	< 1 km	< 1 km	< 1 km
ST 5	1 km	< 1 km	< 1 km	< 1 km	< 1 km	< 1 km

These results confirm that the determined EPZ`s, i.e. PAZ and UPZ (5 and 13 km) were determined with sufficient conservatism (the proposal of the operator for a 10 km EPZ would also pass). From the mentioned facts we can see that the requirements, unusually high within Europe, imposed by the Decree of the government of the Czech Republic No. 11, were met.

Tab 2.2: Results of radiological consequence calculation (cont.)

Table 2: Results of the calculation of radiological consequences for selected accidents

Stability class F						
Sequence	2 days			7 days		
	Intervention Level			Intervention Level		
	5 mSv	10 mSv	50 mSv	50 mSv	100 mSv	500 mSv
AB_01	8 km	5 km	<1 km	1 km	<1 km	<1 km
AB_02	14 km	8 km	2 km	2 km	1 km	<1 km
AB_03	18 km	11 km	3 km	4 km	2 km	<1 km
AB_04	16 km	9 km	1 km	2 km	<1 km	<1 km
ST_V	>40 km	>40 km	<1 km	<1 km	<1 km	<1 km
ST 1*	35 km	23 km	2 km	3 km	2 km	2 km
ST 1**	35 km	17 km	5 km	5 km	3 km	2 km
ST 2	<1 km	<1 km	<1 km	<1 km	<1 km	<1 km
ST 3*	27 km	19 km	2 km	2 km	2 km	<1 km
ST 3**	21 km	14 km	2 km	3 km	2 km	<1 km
ST 4	<1 km	<1 km	<1 km	<1 km	<1 km	<1 km
ST 5	5 km	2 km	<1 km	<1 km	<1 km	<1 km

Note:
ST 1 and ST 3* – calculations for real terrain, direction Týn nad Vltavou*
*ST 1** and ST 3** –calculations for real terrain, direction České Budějovice*

5. Calculation codes used for analyses of dispersion characteristics

A number of calculation codes were used upon assessment of the dispersion characteristics of radionuclides and their radiological consequences (especially for the needs of comparison of results), from relatively simple codes provided by IAEA such as InterRASS /described in IAEA documentation TECDOC-955) to RTARC (standardized by SÚJB). Evaluation of source term was made by means of computer code STCP (Source Term Code Package) provided by IAEA to the member countries and modified for VVER reactors and used especially at VUJE, Source Term Analysis was in Nuclear Research Institute Řež conducted by means of MELCOR 1.8.3 program (to the codes used see additional remarks 5, page 21).

The code calculations include atmospheric transport and diffusion, dose assessment (external exposure to the radioactive airborne plume, inhalation of the plume and resuspended radioactivity, external exposure to deposits from the plume), evaluation and displaying of the affected zones, evaluation of the early health effects, concentration and dose rate time dependence in the selected sites etc., the simulation of the protective measures (sheltering, iodine administration) is involved.

The program RTARC was developed in accordance to system of QA implemented and certified by Lloyd's Register Quality Assurance in VUJE.

The computer code RTARC was tested by NRI in process of development and installation at Temelin NPP Emergency Response Facilities**,** verified by company WS ATKINS SCIENCE & TECNOLOGY and by comparative analysis with other codes which are used in the Czech Republic for computing of dispersion radionuclides and radiological consequences and **validation process** of computer code RTARC was realized width using of measurements data in classic power plants in international level (Model Validation Kit – localities Kincaid, Copenhagen, Lillestrom, Indianopolis).

Quality of used data is verified by using data requested by international or Czech legislation (dose conversion factors for internal exposure from International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources, IAEA, Safety Series No. 115, 1994 implemented in SÚJB Regulation No. 184/97Coll., for external exposure from INTERATOMENERGO/ÈSKAE document Method of calculation of spreading of radioactive substances from NPP and irradiation of surrounding population."

6. EPZ of Temelin NPP

Size and extension of the Temelin EPZ were designated by SUJB Decision on 5 August 1997 based on the CEZ application by deterministic approach and taking into account PSA results. The evaluation of the safety systems status (status of safety systems barriers, dose levels, levels of releases, status of instruments, equipment, etc.) and the consequences, which can result in the situation, when the protective measures shall be implemented, was carried-out. The deterministic approach was based on the methods and procedures recommended by the IAEA, the results of EPZ analysis, which were carried-out in the countries using the same type of reactors. The real demographic and meteorological data for NPP Temelin location were used for these analyses.

Issuing from the analysis results and using above-mentioned criteria the NPP EPZ was determined by SUJB Decision as follows:

Precautionary Action Zone (PAZ) – the area, the boundary of which, is given by the circle on radius about 5 km with the centre in the containment of Unit 1 and area covering territories of municipalities sitting on the circle boundaries including Týn nad Vltavou. Inside of the PAZ the Exclusion zone is delineated on about 3 km radius on which (as against other European countries) no residents are permanently living. Agricultural products raised in the Exclusion Zone are regularly monitored on the radionuclide content. No activity with the possible influence on nuclear or radiation safety is allowed in the Exclusion Zone. In the PAZ the urgent protective measures are planned and prepared based on the above-mentioned criteria.

Urgent Protective Action Planning Zone (UPZ) – the area, the boundary of which, are given by the circle on radius about 13 km with the center in the containment of Unit 1 and area covering territories of municipalities sitting on the circle boundaries. In UPZ the urgent protective measures are planned and prepared based on above-mentioned criteria.

Similarly as for the Dukovany NPP, the Long Term Protective Action Planning Zone (LPZ) was not determined because of size of the country, availability of high density radiation monitoring network and existence of dedicated crisis management and response system (general, for all disasters) for the whole territory of the Czech Republic. The emergency response system includes provisions for LTPA (if needed) on the whole territory based on the results of radiation monitoring. For decision on implementation the long term protective measures - control, restriction of contaminated foodstuffs consumption, relocation, the results obtained by the Czech Republic Radiation Monitoring Network (RMN) will be used. The co-operation with the national monitoring networks of the neighboring countries is planned. The effective implementation of the long protective measures is developed but not planned - needed protective measures will be taken in case of radiation accident depending on its course, extent and monitoring results.

During 80th years the sophisticated the Czech Republic RMN was created by the Governmental Decision No. 62 from 26 March 1987. Depending on results of the RMN, protective measures can be implemented. The RMN is co-ordinate by SÚJB; it operates in two regimes - the normal regime, aimed at monitoring the actual radiation situation and early detection of radiation accidents, and the emergency regime aimed at evaluating the consequences of such a radiation accident. The RMN is composed from the permanent (continuously working) and stand-by (working only during emergency situation) parts.

The parts of the RMN are following:

- Early warning network (EWN), which comprises 58 measuring points (Fig. *4*) with automatic transmission of observed data. The EWN is operated by the Ministry of Environment (Czech Hydrometeorological Institute), the SÚJB/NRPI, the Army of CR.
- Territorial TLD (Fig. *5*) - network of 184 measuring points equipped with thermoluminiscent dosemeters (TLD); this TLD-network is operated the SÚJB/NRPI.
- Local TLD networks (Fig. *5*) with 78 measuring points in the surroundings of the Dukovany and Temelin nuclear power plants, operated by the Environmental Radiation Monitoring Laboratories NPP and the SÚJB/NRPI.
- Mobile (aircraft, car) groups – operated by the SUJB/NRPI (7-14), the Ministry of Defense; equipped with instrumentation for dose rate measurement in the air (radionuclides volume activity), on the territory (deposition of radionuclides),
- Territorial network of 11 air contamination measuring points (Fig. *6*) - operated by the SÚJB/NRPI and the Environmental Radiation Monitoring Laboratories NPP.
- Territorial network of water and food contamination measuring points – operated by the

Ministry of Environmental and the Ministry of Agriculture (hydrology service, food control).

- Network of 11 laboratories (Fig. 6) - 9 laboratories of the SUJB/NRPI, 2 of the Environmental Radiation Monitoring Laboratories of NPP, equipped with gamma-spectrometric and radiochemical analytical instrumentation to quantitative radionuclides in environmental samples (aerosols, fall-out, foods, drinking water, animal food, etc.).

The Dukovany and Temelin NPP have established the on-site Emergency Response Facilities. They are protected against damage by environmental conditions that could occur in the nuclear or radiological emergency and their habitability is assured under all circumstances. Monitoring in the hermetic zone and exhaust stack provides early indication of release on site. Fixed fence monitors are installed by the NPP. The most important information is available to SUJB on-line. The details on the RMN can be found on the Internet address: http://www.sujb.cz/sujb.html

7. Comparison of size of EPZ for Temelin NPP and Dukovany NPP and comparison of size of EPZ and implementation of planning of protective measures with other countries

In the case of Temelin, as against Dukovany NPP, it was possible to reduce the extent of UPZ from the distance of 20 km to 13 km for the following reasons of:

- design of the robust containment and higher order of assurance of integrity of containment defined by permanent value of containment non-integrity at the level of 0.1 % of weight/24 hours
- higher quality of the level of protection (under the terminology INSAG 3 and 12), i.e. both the technological equipment and the instrumentation and control systems and last but not least, for the reason of implementation of Emergency Response Facilities and Emergency Information System which is one of the best ones in Europe due to its content, technical equipment available and personnel and organizational assurance, as it was confirmed by the last OSART mission conducted by IAEA at Temelin in February 2001.

It may be say for the comparison of size of PAZ and UPZ of NPP Temelin with EPZ in other countries:

- the EPZ of Temelin NPP was determined quite conservatively (France 5 and 10 km, Japan 8 – 10 km, Spain 5 and 10 km, China 5 and 10 km, Sweden 12-15 km); in the USA and in Switzerland, in some cases UPZ reaches longer distances;
- it has to be emphasized again what the purpose of determination of UPZ is implementation of urgent protective measures; these measures are planned to be taken within UPZ,
- the iodide prevention in the mentioned countries (distribution of potassium iodide) is ensured only after declaration of radiation accident, while in the Czech Republic, distribution of potassium iodide was ensured to all families within the UPZ as early as at the time of fuel loading into the reactor;
- further urgent measures – sheltering of population, preparation of evacuation can be implemented on the basis of development of the particular radiation accident and results of monitoring also beyond the boundary of UPZ because both national system of radiation situation monitoring and system of notification and warning are assured;
- the existing system of emergency preparedness of Temelin NPP has been designed in a way that implementation of protective measures for population, i.e. evacuation could be performed as early as during the pre-release phase of radiation accident development; corresponding to this, sophisticated Emergency Response Facilities were built right on

Temelin NPP site, and beyond the EPZ boundary in Ceske Budejovice;
- all mentioned measures create conditions for effective and early implementation of urgent protective measures within the EPZ of Temelin NPP (in accordance with the international recommendations) and at the same time, it constitutes one of the real reasons for reduction of UPZ of Temelin NPP as against the Dukovany NPP.

8. Assurance of notification of regulatory bodies and organizations and warning of population

The condition for early and effective implementation of protective measures in the case of radiation accident is:
- assurance of early notification of regulatory bodies and administrative organizations participating in evaluation of the radiation situation occurred
- preparation of recommendations for implementation of optimal protective measures and last but not least also implementation of the protective measures, also in the case of their implementation beyond the boundary of UPZ.

These conditions in the case of Temelin NPP create a system of notification of regulatory bodies and organizations which results from the system of notification of the Ministry of Interior (so-called CAS 100 system) and it is redundantly complemented by other commercial notification systems including the following:
- ➢ uniform telephone network
- ➢ specific-purpose telephone network
- ➢ system of electronic mail of state administration bodies
- ➢ utilization of GSM telephone networks
- ➢ newly prepared emergency cellular telephone network designed exclusively for state administration employees, this network would be independent of the public network

Using these means of notification, important information during control process and implementation of intervention of response forces can be communicated, including the possibility of manual start of all sirens within EPZ in the case of their unlikely but possible loss of the central remote control of their start.

Notification of population would in the case of threat of radiation accident be assured by means of national warning system administered by the Ministry of Interior. The system is based on the infrastructure of technical PAGING covering the whole territory of the Czech Republic and enabling remote start of all sirens or only selected groups of sirens on the territory of the Czech state. Density of this network prescribed by the technical standards of the Ministry of Defense is such within EPZ, that the criterion of assurance of audibility of the warning signal under normal atmospheric conditions has to be assured on the whole territory with permanent inhabitants, i.e. within all villages and settlements within EPZ of NPP Temelin. These means of the national warning system enable operational start of sirens in any part of the territory of the Czech Republic, i.e. also beyond the boundary of UPZ.

The warning system includes automatic broadcasting of radio programs prepared in advance on the radio circuit of Czech Radio covering the whole republic and TV programs on CT1 channel within the whole region of Ceske Budejovice. For the needs of assurance of warning of population, a five-party contract was concluded between CEZ-Temelin NPP, District Office Ceske Budejovice, Regional Office Ceske Budejovice, Czech Television and Czech Radiocommunication which enable flexible input to broadcasting of Czech Television provision of instructions for the population. This assures, both technically and from organizational point of view, that information about start of notification and warning within EPZ will reach the population, also beyond the boundary of EPZ, in time.

9. Implementation of protection measures, conclusions

Based on result of radiological consequences calculation (see Table 2) above mentioned size, extent of EPZ was determined using following assumptions:

- in PAZ and UPZ only the urgent protective measures are planned,
- conservative approach of emergency planning was used - several protective measures were pre-implemented:
  - iodine tablets were pre-distributed to all residents in the EPZ;
  - restricted zone, i.e. zone in which no residents are living, no practice with consequences on radiation and nuclear safety is allowed, control of agricultural production is controlled,
  - implementation of sheltering and I - administration in EPZ are planned and prepared to be implement before release in all EPZ
- evacuation is planned and prepared to be implement:
  - before release in PAZ - depending on time and course of accident, i.e. unless condition make evacuation dangerous,
  - during or immediately after release - depending of monitoring results and real meteorological conditions,
- the urgent protective measures may be but need not be implemented beyond the UPZ border, the capabilities, means, tools are planned,
- the long term countermeasures, i.e. regulation of distribution and ingestion of foodstuffs and water will be implemented based on the course of accident, the results of monitoring (including real weather, meteorological conditions),
- the intervention levels presented in tables 3 - 7 (which are implemented in the Czech Republic legislation) were used.

Based on the calculation of radiological consequences analyzed sequences and above mention assumptions can be concluded:

- Protection of the Czech Republic people is ensured by correct implementation of off-site and districts emergency planes.
- Irradiation of neighboring countries people on dose levels (i.e. for accidents with the probability equal or lower than 10^{-7}/year), for which implementation of the urgent protective measures is justified and reasonable, can not be occurred[1)].
- The area receiving deposition from the plume of released radionuclides in reality would have a more complicated shape due to variations in meteorological conditions. Therefore, in the period following an accident, may be useful to control and restrict the consumption of contaminated foodstuffs[2)]. In this case intervention levels presented in tables 6 and 7 shall limit doses. It is recommended to compare systems appointed for planning of the long term protective measures used in neighboring countries and, based on experts discussion prepare:
  - organization of inter-comparison measurements of the laboratories involved in the system,

- agreements on exchange information on that fields, i.e. methods of collection, measurements (distribution of localities of collection) the samples and interpretation of results, according of Direction No.2000/473/EURATOM.

Notice 1:
For the accidents with probability lower than 10^{-7} the very large releases of radionuclides are possible only in connection with accident sequences, which lead to early global containment failure, i.e. during high- or low-pressure core meltdown with the subsequent a hydrogen detonation or a steam explosion. Both possibilities, however, are so improbable that they are not considered (see as example the German Risk Study, Compendium of Measures to Reduce Radiation Exposure Following Events with not Insignificant Radiological Consequences, Bundesministerium fur Umvelt, Naturschutz und Reaktorsicherheit, Vol. 1,2, Dec. 2000). The protective measures for that type of accident are evaluated but not planned - they can be implemented ad hoc, depending on course and consequences of real accident and monitoring results obtained by RMN. As illustration for the selected radionuclides inventory of a 1300 MW_{el} PWR and for the cumulative release fraction for several sequences, including "Global containment failure", the possible radiological sequences may be estimated using tables attached (see pages 31-36). For the released activity of presented in the table the effective dose 10 mSv within 7 days may be occurred at distances of 300 km.

Notice 2;
No countermeasure shall be implemented in neighboring countries for design basis accidents. The neighboring countries people doses for the accidents are bellow values (250 µSv/year, 12,5 mSv/50 years) for which no exposure regulation, no requirements from side of radiation protection are demanded.

Attachment

A.1 ADITIONAL REAMARKS

1) In the case of nuclear or radiological emergency the SUJB is responsible for:

- co-ordination of Nation-wide Radiation Monitoring Network,
- prediction and assessment of the consequences for the Czech territory of nuclear or radiological accident in the Czech Republic or abroad,
- preparing the basis and advice concerning the countermeasures for decision makers on local and governmental level the Inter-ministerial Emergency Headquarters Operational Center serves for central co-ordination of rescue tasks.
- operation of National Contact Point (according the IAEA Convention on Early Notification of a Nuclear Accident) which is responsible for:
- issuing and receiving the notification and information in case of a nuclear or radiological emergency,
- activation of emergency response plan of SUJB,
- notification of Inter-ministerial Emergency Headquarters, Operational Center of Integrated Rescue System and Civil Protection Headquarters (see Fig. 1 and 2),
- notification of the National Radiation Monitoring Network and transmission of detailed requests for monitoring,

Notification of the meteorological service and transmission of requests for prognosis of the dispersion of released radioactive material,
Transmission of advice on countermeasures to Local Authorities and Inter-ministerial Emergency Headquarters.

Ministry of Interior operates in case of a nuclear or radiological emergency following contact and co-ordination centers:

- Operational Center of Integrated Rescue System that serves for activation of off-site emergency response in emergency planning zone and is the contact point for the Local Authority
- District Police Headquarters Operational Center
- Inter-ministerial Emergency Headquarters Operational Center that serves for central co-ordination of rescue tasks and is also responsible for organization of mutual assistance in rescue tasks according to bilateral agreements with neighboring countries.

The Civil Defense and the Czech Energy Company have an agreement with the national broadcasting companies (TV and radio) about information to the public in case of emergency including nuclear or radiological emergency. Similar agreements exist on the regional level. The parts of Integrated Rescue System (Police, Fire Brigades, Fast Medical Service, Civil Defense) are responsible for notification and warning on the Czech Republic territory. It is a duty of the NPP (licensee) to notify immediately SUJB and Local Authorities in EPZ. The nature of the subsequent response is dependent on the classification of the emergency which is incorporated in the on site emergency plan approved by SUJB. The plan also includes specification of the required actions dependent on the circumstances that have occurred.
By the Article 46 of the Law No. 18/1997 Coll. the Ministry of Health shall create a system of special medical care provided by selected clinics to persons irradiated in the course of nuclear or radiological emergency. The following contact centers for co-ordination of specialized medical assistance in the emergency-planning zone are working:

- Regional center of medical emergency service Brno (for NPP Dukovany),
- Regional center of medical emergency service Ceske Budejovice (for NPP Temelin),

Three clinics:

- the Burns Clinic of the 3rd Faculty of Medicine UK Prague,
- the Center for Treatment of Persons Externally Exposed and Contaminated with Radionuclides on the Clinic of Occupational Diseases of the 1st Faculty of Medicine UK Prague,
- the unit of Intensive Hematological Care on Internal Clinic of the Faculty of Medicine UK, Hradec Kralove,

are working as parts of specialized medical care system of Ministry of Health.

2) AB - sequence (large LOCA with station blackout) - analyzed in the year 1996 up to Source Term evaluation by using of STCP-M with core initial inventory corresponding to Westinghouse fuel. Conservative boundary assumptions were made:
Initiating event – instantaneous guillotine rupture of main circulation line (2 x 850 mm) in the cold leg near reactor vessel, complemented by total loss of offsite & onsite electric power (i.e. all diesel generators not available), during the time period of 48 hours. No operator interventions to mitigate consequences during analyzed period were modeled, only 2 accumulators available were assumed. Real value of permanent containment design leak of the 0.1vol.%/day directly to environment was considered, i.e. without FP retention in the auxiliary buildings in the lower part. Despite the total frequency of the sequence is 1.44E-10 /reactor years, which is below usual threshold, it was believed that this scenario will cover all other cases with higher frequency.

Source Term – AB sequence (AB_01)

Total cumulative leakage expressed as a fraction of core initial inventory: Noble gases: $<$ 4.0E-3 Aerosols – volatile FP : $<$ 8.0E-5 (during MCCI negligible except of Te) Aerosols – non-volatile : from 2.0E-6 up to 6.0E-5 (leak not negligible also during initial phase of MCCI)

V - sequence (large primary-to-secondary leakage also combined with station blackout) **-** analyzed in the year 1996 up to Source Term evaluation by using of STCP-M with core initial inventory corresponding to Westinghouse fuel. Analyzed also as worst case, from the point of view of the leakage from primary to secondary (containment by-pass). Also here the conservative boundary assumptions were made:
Initiating event – break of the SG hot collector cover header (d_e = 107 mm), complemented by total loss of offsite & onsite electric power (i.e. all diesel generators not available), during the time period of 24 hours. No operator interventions to mitigate consequences during analyzed period were modeled, only 2 accumulators available were assumed. Real value of permanent containment design leak of the 0.1vol.%/day directly to environment was considered after RV bottom failure, i.e. without FP retention in the auxiliary buildings in the lower part. Despite of the total frequency for this sequence 7.18E-10 /reactor year also this scenario was believed to cover all other similar cases with higher frequency.

On the basis of evaluation of these conservative (from the point of view of probability of occurrence) and serious accidents (from the point of view of radiological consequences), taking into account the international recommendations and experience of countries using the same type of reactors, the EPZ was determined by qualified engineering procedures so that it delimits areas beyond which the relevant urgent protective measured did not have to be implemented.

Source Term – V sequence

The most important leakage of FP is realised during in-vessel phase of accident (from 35th to 90th minute). Fractional cumulative leakage :
Noble gases : ≈ 0.78
Aerosols – volatile FP : < 0.19
Aerosols – non-volatile : < 0.01

3) The same initiator, however, with a complete loss of electric power, was defined as sequence AB analyzed for the purposes of determination of the EPZ. Also in this case it is obvious that AB sequence means faster course of the accident and from the point of view of possible radiation consequences it provides much worse results than sequence according to PSA. A part of the analyzed scenario was also such development of the event, which would lead to melt-through of the containment slab and leak of RA substances through the containment to the outside atmosphere. Therefore, also in this case the use of AB sequence results as input for determination of size of the EPZ of Temelin NPP is fully justifiable due to conservative character of this scenario. Criterion of highest frequency according to the PSA level 1 results are met by the following scenarios:

Identification	Frequency (CDF), year^{-1}	Sequence description
T9S02	4.07E-005 (45,5%)	Major leak from primary to secondary circuit, operator fails to cool down and depressurize primary circuit by fast trend, GA201 tank is thus emptied via to the leak
X2S02	8.54E-006 (9,5%)	Rupture of SG tube, TK make-up system fails and operator fails, for a long term, to cool down and depressurize primary circuit; tank GA 201 is thus emptied via to the leak
X1S03	4.51E-006 (5,0%)	Rupture of SG tube, operator fails, for a long term, to cool down and depressurize primary circuit; tank GA201 is thus emptied via to the leak
X1S12	4.36E-006 (4,9%)	Rupture of SG tube, operator incorrectly closes fast closing valve on the streamline of damaged SG. Primary circuit is successfully cooled down by fast trend but the system of long-term heat removal fails.
S2S02	3.90E-006 (4,4%)	Large LOCA, low-pressure system of emergency make up fails
S2S04	3.75E-006 (4,2%)	Large LOCA, the function of coolant from hydroaccumulators fails
S4S10	3.10E-006	Small LOCA, both high- and low-pressure emergency make

	(3,5%)	up systems fail
TSS06	2.61E-006 (2,9%)	Emergency protection is actuated but reactor is not tripped, both auxiliary and emergency feedwater systems for SG fail
X1S04	2.54E-006 (2,8%)	Rupture of SG tube, TK system functions but the operator fails to cool down and depressurize primary circuit by fast trend prior to emptying the TB tanks; high-pressure emergency make up system fails
T4AS04	2.08E-006 (2,3%)	Transient with loss of the turbine-driven feedwater pump. Both auxiliary and emergency feedwater systems for SG fail and the Feed&Bleed function not performed.
S5S03	1.72E-006 (1,9%)	Very small LOCA, operator fails to cool down and depressurize primary circuit and high-pressure emergency make up system fails
T9S04	1.60E-006 (1,8%)	Major lead from the primary to the secondary circuit, SG emergency feedwater system fails and operator fails to cool down and depressurize primary circuit by fast trend

Criterion of highest significance according to PSA level 2 results are met by the following scenarios:

Identification	Description	Frequency	Relative risk
T9S02	T9-O2	4,07E-05	19,11%
S2S02	S2-D2	3,62E-06	9,09%
S4S10	S4-D1-D2-CS	2,89E-06	7,61%
TFRS11	S4-D1-ACC; S4-D1-FR1	2,83E-06	7,10%
TSS06	TS-K-M2-L	2,46E-06	6,45%
TFRS05	T1-M-L-FB; T5-L-FB	2,55E-06	6,41%
TFRS04	Station blackout (fire)	2,25E-06	5,91%

Note: Significance of the scenario was evaluated on the basis of size of the source term, i.e. quantity of radionuclides, which may be potentially released to the environment during an accident.

4) These sequences (with its related Source Terms) are defined as follows:

ST 1:
Scenarios have been initiated by major leak from primary to the secondary circuit with an opening of d_{ekv} = 40 mm. The operating personnel fail to intervene, containment bypass occurs. Scenario of 1A type assumed damage of hot leg of the primary piping by thermal creep. Scenario of 1B type started by the same initiating event was resolved under the assumption that primary circuit will remain hermetically tight and the sequence further develops as high-pressure, the following complex phenomenon will occur upon damage of reactor vessel bottom: direct heating of atmosphere. Both for scenario 1A and for scenario 1B a time course of leak of radionuclides from the containment (source term) was determined.

This case was proposed because its Source Term can cover PSA scenarios T9S02, T9S04 X2S02, X1S03, X1S04 and X1S013 from previous Tables. The likelihood that such scenarios could occur is from 1.60E-06 /reactor year to 4.07E-05 /reactor year.

ST 2:
Sequences belonging to this group have been initiated by large LOCA accident (d_{ekv} = 200 mm) on the connecting piping leading to the pressuriser. In scenario of 2A type, all active emergency core cooling systems failed. During the sequence of 2B type, activity of one leg of the high-pressure emergency core cooling was successfully renewed. The source term was determined only for scenario 2A, which leads to severe degradation of fuel in the core.

This case was proposed because its Source Term can cover PSA scenarios S2S02, S2S04 S4S10 and S5S03 from previous Tables with the assumption that containment integrity is not challenged during analyzed period. The likelihood that such scenarios could occur is from 1.72E-06 /reactor year to 3.90E-06 /reactor year.

ST 3:
Sequence similar to the previous scenario but the function of catalytic recombiners and origination of deflagration type fires (slow burning) is not considered. Therefore, hydrogen accumulates in the containment and subsequently explodes in the containment. The scenario of 3M type determined the maximum value of pressure in the containment after hydrogen explosion and the corresponding time course of leak of radionuclides from the containment.

It was proposed because containment integrity can be challenged in this case giving different Source Term. It again covers the same PSA scenarios S2S02, S2S04 S4S10 and S5S03 from previous Tables, but Source Term is calculated with containment failure.

ST 4:
The scenario commenced with station blackout and hermeticality of primary circuit was lost by thermal creep. After damage to the reactor vessel bottom, a pool of melted material will originate at the bottom of the shaft, the melt penetrates to vertical channels for neutron measurement where it will freeze and will not penetrate further. Also in this case the source term of the particular sequence was determined.

This case was proposed because its Source Term can cover remaining types of PSA scenarios TSS06, T4AS04, TFRS04, TFRS05 and TFRS11 from previous Tables. The likelihood that such scenarios could occur is from 2.83E-06 /reactor year to 2.08E-06 /reactor year.

ST 5:
The sequence has been initiated by large LOCA accident with not functioning systems of emergency cooling of the core and sprinkler system in the containment. After failure of the bottom of reactor vessel and origination of the pool of melted material at the bottom the reactor shaft, activity of one leg of low-pressure reactor cooling system is renewed and water is poured on the melt pool in order to create a layer of coolant on the top of it. The purpose of analysis of scenario type 5 was to assess the impact of cooling of the melt on its penetration through the base slab of the containment. Source term was determined.

This case was proposed because its Source Term can cover PSA scenarios S2S02, S2S04 S4S10 and S5S03 from previous Tables. The aim was to confirm whether it is possible to stop MMCI in the late phase of the severe accident.

5) Source Term **C**ode **P**ackage - **STCP** was originally developed in the USA (NUREG/CR-

3988, July 1986) to study possible Source Term in a case of severe accident on PWR and/or BWR units. The STCP consists of several codes – e.g. MARCH3, TRAP-MELT3, VANESA, NAUA, which make it possible to model all important physical phenomena typical for severe accident sequences (thermal-hydraulics in reactor coolant system, fuel melting and core degradation, fission products release from fuel and their transport and retention inside the containment volumes) up to Source Term evaluation. For VVER units modified version **STCP-M** was developed and verified in the framework of IAEA Regional Projects RER/9/004 during the time period of 1988 - 1992 years (Participating countries: Czech & Slovak Republic, Hungary, Russia, Bulgaria, Poland). This modified version has been able to take into account specific design features of the VVER units (e.g. horizontal SG, bubble tower, etc.....) and has been standardized by Czech Atomic Energy Commission (ÈSKAE) as computer code suitable for analysis of severe accidents on VVER units. This modified version **STCP-M** has been used for analysis of the severe accident scenarios of Temelin NPP, which were performed during the years of 1992 – 97. Before performing of the final analysis, code **STCP-M** has been again verified at the beginning of the year 1997 by comparison with first available results of new computer codes on selected severe accident scenarios analyzed for VVER-1000 and/or VVER-440 units: **MELCOR 1.8.3** (the code of US NRC), **MAAP4/VVER** (the code of Westinghouse Energy Systems Europe S.A.) and **ESCADRE** (the code of CEA/IPSN France). The main results of the comparison with the mentioned codes was the fact, that the STCP-M is conservative from the point of view of source term assessment (predicts higher leakage) especially for volatile – most important nuclides as Iodine, Cesium and Noble gases (Xe, Kr).

RTARC (**R**eal **T**ime **A**ccident **R**elease **C**onsequence) is a computer code developed at the Nuclear Power Plants Research Institute, Trnava, Slovak Republic to calculate and predict atmospheric transportation and off-site radiological consequences in the event of a nuclear accident or radiological emergency during the early phase. The code is used by nuclear facilities for basic emergency response planning and preparedness, real time dose projection and dispersion calculations during an accident, and for post-accident analysis. **RTARC** is intended for "quick and easy" consequence calculations in the event of accident or radiological emergency. The code is used in Temelin NPP Emergency Response Facilities and nuclear authority governments too for basic emergency response planning and preparedness and real-time dose projection and dispersion calculations during an accident. System is designed for early phase analysis, i.e. during period from the time when the potential for off-site exposure of the public is recognized to the time when significant amounts of radioactive material are released.

A.2 TABLES

Table 3: The intervention levels for deterministic health effects

Organ, tissue	Expected E or $H_T(\tau)$ [a])

	[Gy]
Whole body	1[b])
Lungs	6
Skin	3
Thyroid gland	5
Eye lens	2
Gonads	1

[a]) *It is assumed that doses will be received during the less than 2days*

b) *The possibility of immediate damage of foetus at the assumed doses greater than roughly 0.1 Gy shall be taken into account at the justification and optimisation of the relevant intervention level for the urgent measures.*

Table 4: The intervention levels for the urgent measures

Protective Measure	Interval	
	Effective doses	equivalent doses in individual organs and tissues
The sheltering and the iodine prophylactics	5 mSv to 50 mSv	50 mSv to 500 mSv
The evacuation of inhabitants	50 mSv to 500 mSv	500 mSv to 5000 mSv

Table 5: The intervention levels for the subsequent (follow-up) measures

Protective Measures	Interval	
	Effective doses	Equivalent doses in individual organs and tissues
Regulation of distribution and ingestion of contaminated foodstuffs, water and feeding-stuffs	5 mSv to 50 mSv	50 mSv to 500 mSv
Relocation of people	50 mSv to 500 mSv	*not stipulated*

Table 6: Intervention levels for the regulation of distribution and ingestion of foodstuffs and water

Radionuclide	Intervention level of mass activities [Bq/kg] [a])	
	milk, drinking water, children nutrition	Basis foodstuffs [b])

^{134}Cs. ^{137}Cs. ^{103}Ru. ^{106}Ru. ^{89}Sr	1000	1000
^{131}I	100	1000
^{90}Sr	100	100
^{241}Am. ^{238}Pu. ^{239}Pu	1	10

a) *From the practical reasons there are the intervention levels for individual groups of radionuclides compared with the sum of activities in this group, without regard to the activity of radionuclides of other groups.*

b) *The specific intervention levels, to tenfold higher than for the basic foodstuffs, there may stipulate for the regulation of several sorts of foodstuffs creating the small part of total consumption.*

Table 7: The intervention levels of activity of radionuclides for the import and export of foodstuffs after the radiation accident

Radionuclide	The guidance levels of the mass or equilibrium concentration of radionuclides for the import and export of foodstuffs after the radiation accident [Bq/kg] or [Bq/l]			
	Foodstuffs for children [a])	Milk products	Other foodstuffs [b]) [c])	Liquid foodstuffs [d])
Sr-90	75	125	750	125
I-131	150	500	2000	500
Pu-239 a Am-241	1	20	80	20
All other nuclides[e)] $T_{1/2} > 10$ d Cs-134 a Cs-137	400	1000	1250	1000

a) *The children meals - between the 4th and 6th month of life*
b) *The mass or equilibrium concentration of radionuclides applicable for the concentrated or dried foodstuffs*
c) *For the less significant foodstuffs creating the small part of total consumption there are the highest admissible activities 10 times higher*
d) *The mass or volume activities for the liquid foodstuffs are computed with regard to the consumption of drinking water and the same value shall be used for the supply of drinking water.*
e) *There are not included radionuclides of H-3, C-14, K-40.*

A.2 Figures

Fig.1: Emergency planning organization

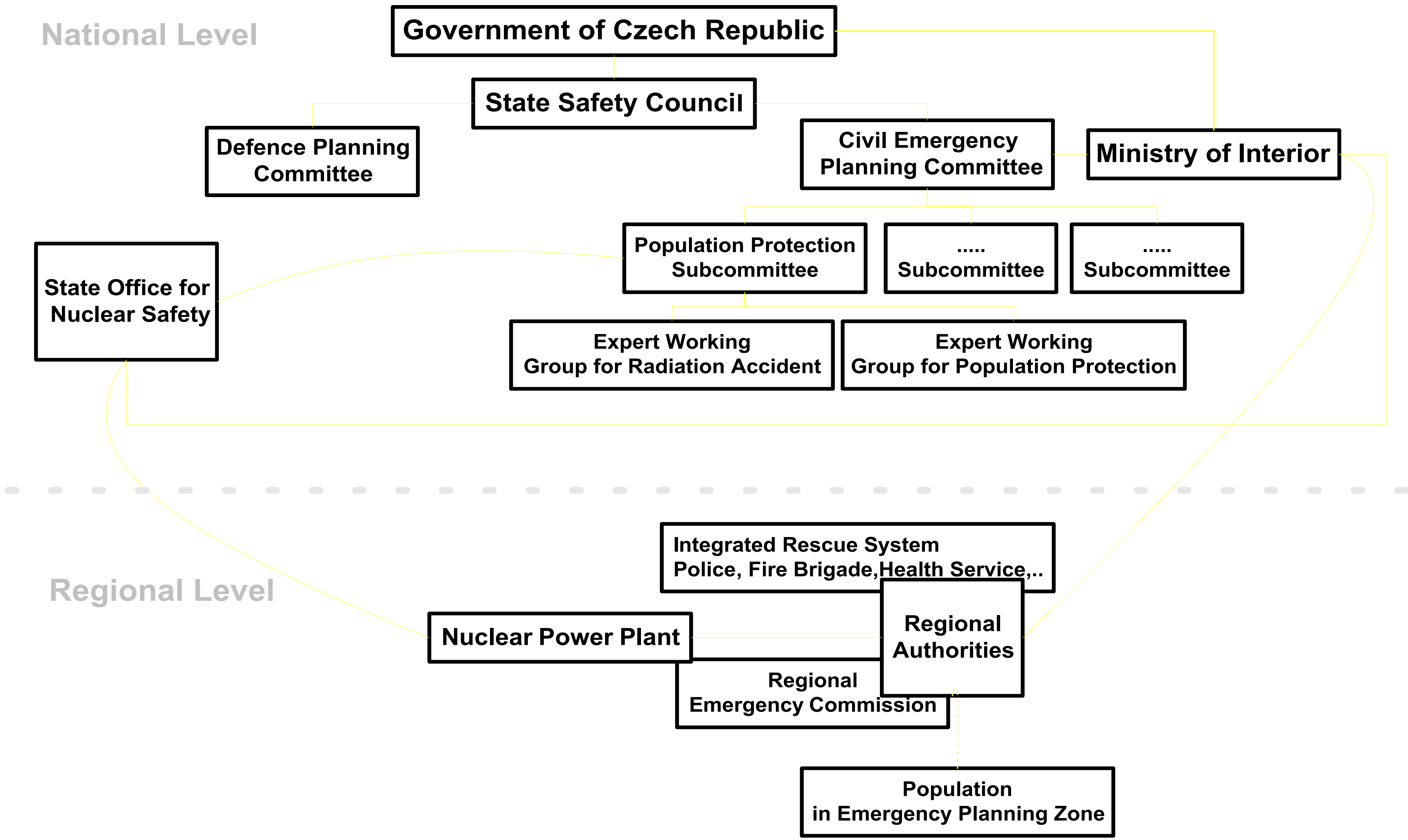


Fig 2: Emergency response organisation

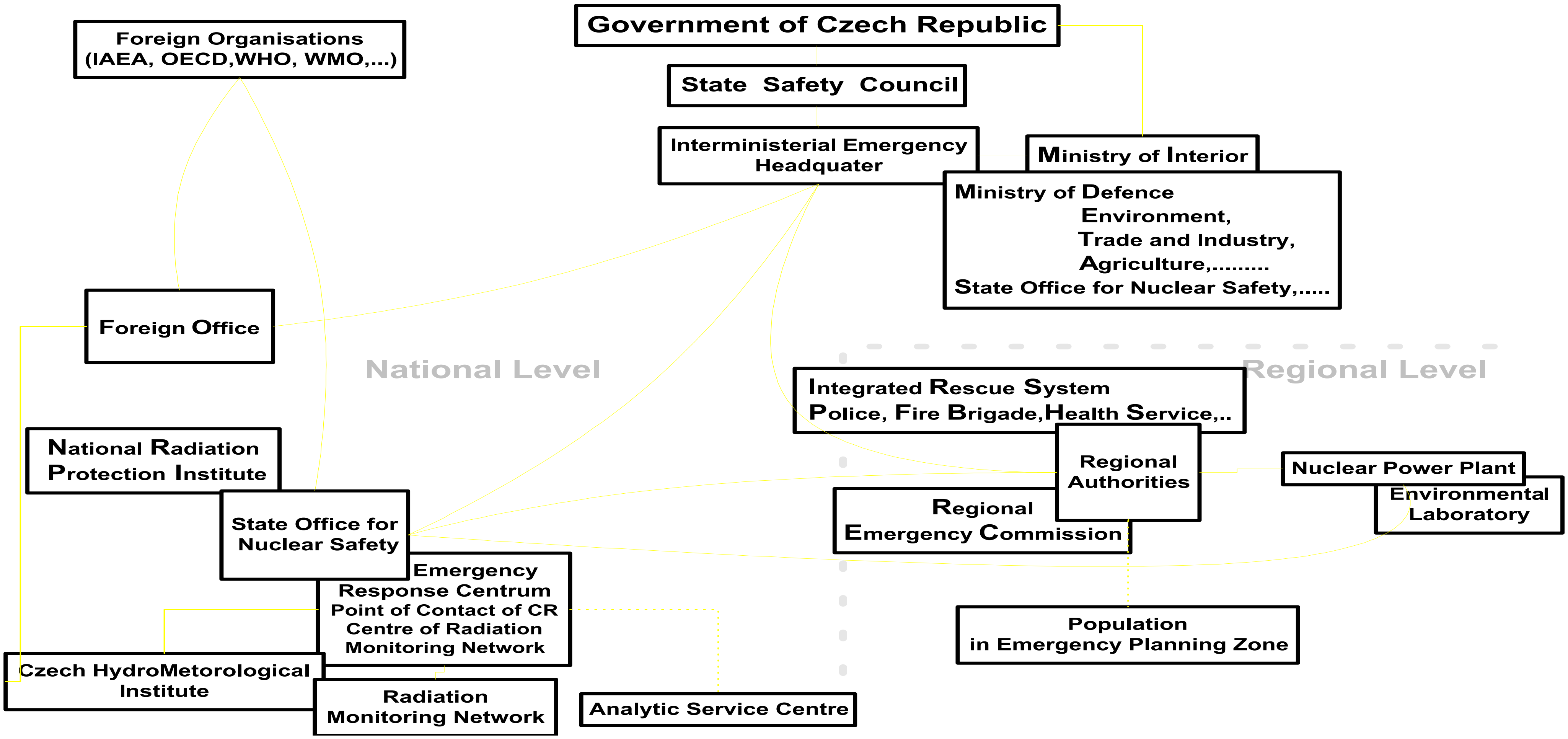


Fig.3: NPP ETE Emergency Planning Zones Delineation

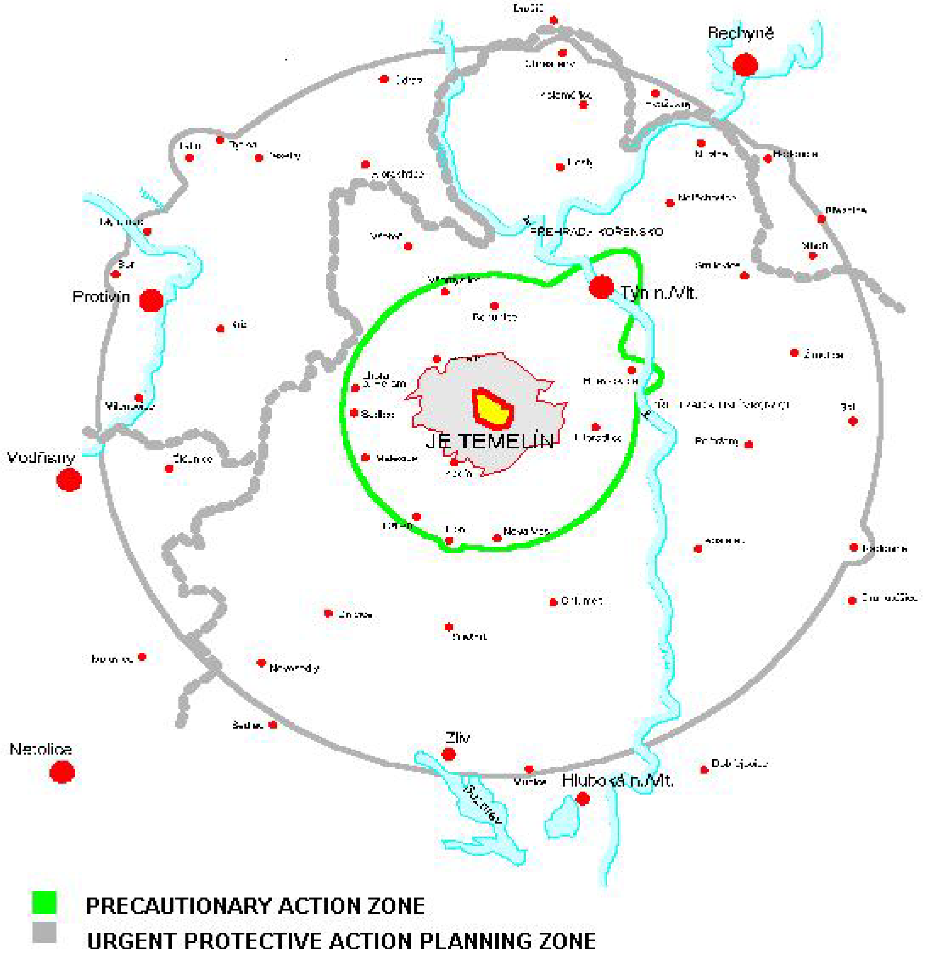


Fig 4: The Early Warning Network

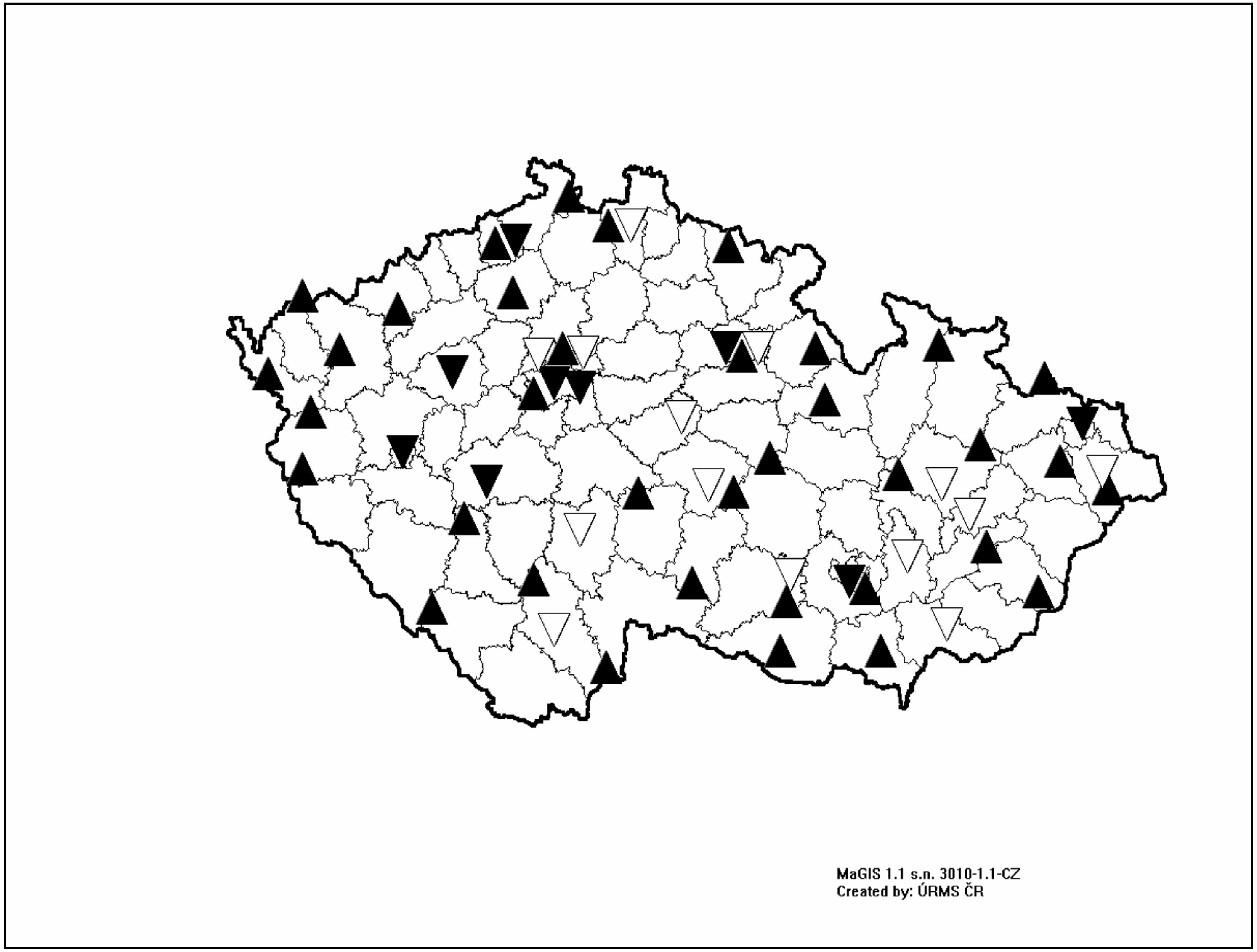


Fig. 5: TLD Monitoring Network

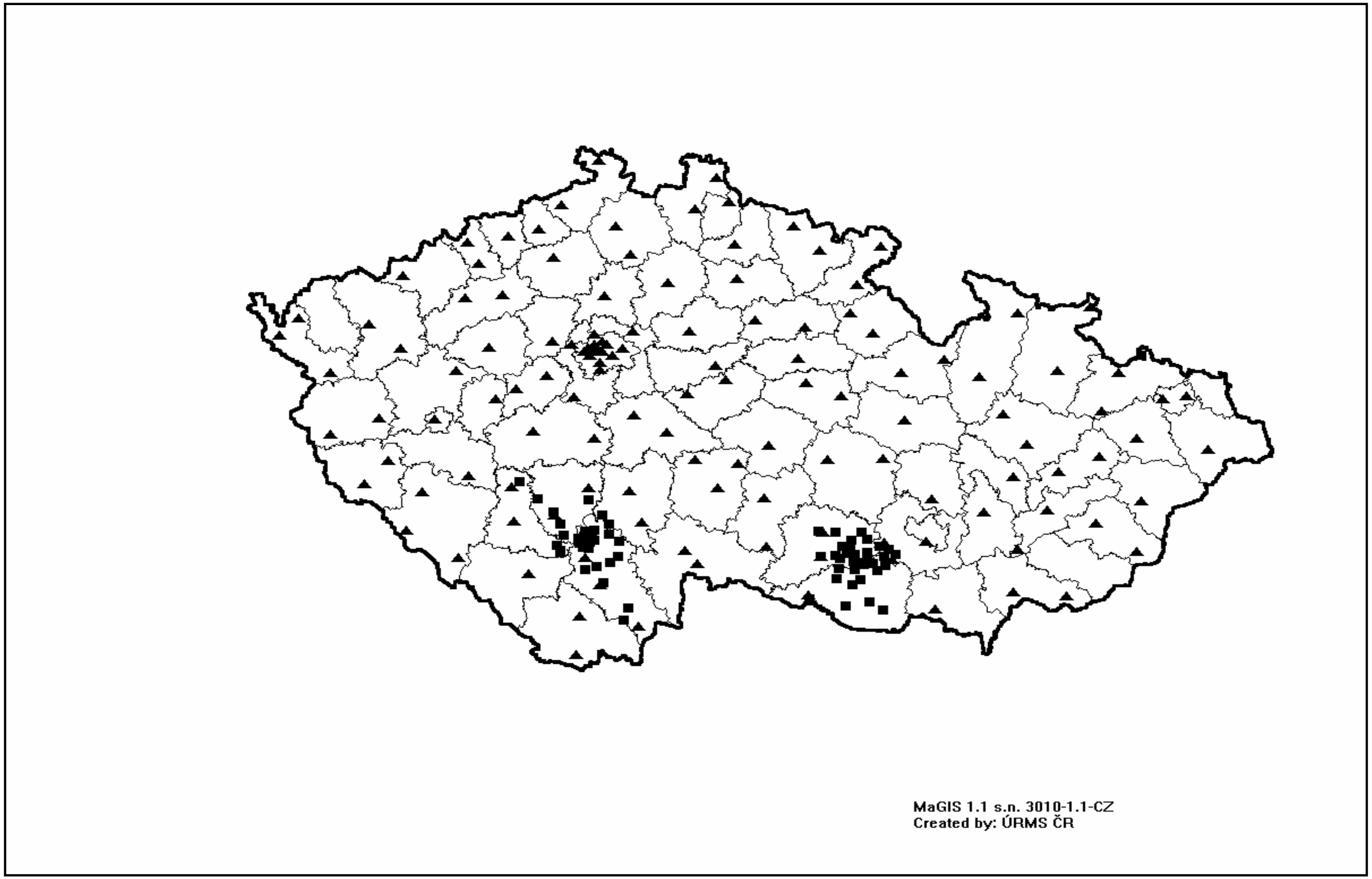
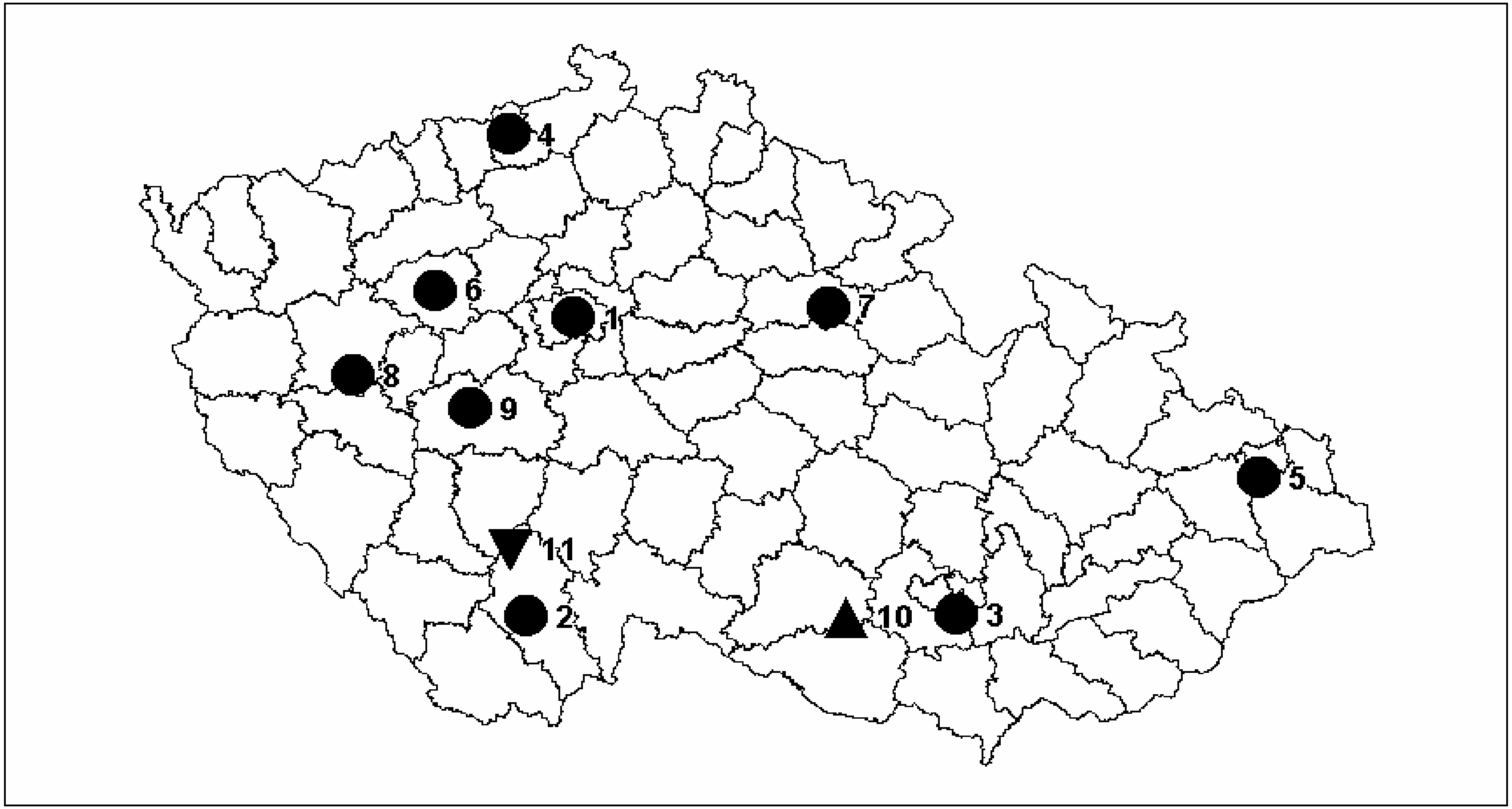


Fig.6: Territorial Network of Air Contamination Measuring Points and RMS Laboratories



A.4 Comparison Tables to Notice 1 on page 15

Bundesministerium
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Compendium of Measures to Reduce Radiation Exposure Following Events with not Insignificant Radiological Consequences

(Catalogue of Countermeasures)

Volume 1

December 2000

Table 4.2-4 Released activities which at distances of 100 km and 300 km, respectively, may lead to an effective dose of 10 mSv within 7 days

Nuclide	Deposition	Released activity at the source (Bq) Time of release early (6 h after shut-down of the reactor)	late (120 h after shut-down of the reactor)
Distance source - receiving point: 100 km (receiving point along trajectory)			
*I 131	dry	3.2E+17	5.2E+17
I 131	dry	1.4E+18	1.8E+18
Te 132	dry	2.7E+18	2.7E+18
Cs 137	dry	1.5E+18	1.5E+18
*I 131	5 mm/h rain	1.6E+16	1.6E+17
I 131	5 mm/h rain	1.2E+17	7.1E+17
Te 132	5 mm/h rain	2.8E+16	2.8E+16
Cs 137	5 mm/h rain	6.1E+16	6.1E+16
Xe 133	none	3.5E+21	3.5E+21
Distance source - receiving point: 300 km (receiving point along trajectory)			
*I 131	dry	8.3E+17	1.4E+18
I 131	dry	3.6E+18	4.5E+18
Te 132	dry	6.9E+18	6.9E+18
Cs 137	dry	3.9E+18	3.9E+18
*I 131	5 mm/h rain	4.1E+16	4.0E+17
I 131	5 mm/h rain	3.0E+17	1.8E+18
Te 132	5 mm/h rain	7.1E+16	7.1E+16
Cs 137	5 mm/h rain	1.6E+17	1.6E+17
Noble gases	none	1.4E+21	9.2E+21
Xe 133	none	9.2E+21	9.2E+21

„*“ Reference nuclide

Exposure pathways:	Gamma submersion, inhalation, gamma soil radiation
Remote area transport:	NRPB model
Wind speed:	**10 m/s**
Mixing layer height:	**1000 m**
Soil correction factor:	negligible, b = 1 (see Chapter 8)
Integration time for Gamma soil radiation:	7 d
Breathing rate:	$3.5 \cdot 10^{-4}$ m^3/s for normal activity
Inhalation dose integration time:	50 a
Reference group:	Adults
Underlying equations:	(2.1), (3.1), (4.1) in Chapter 8, Sections 8.2 to 8.4

Note: The partly higher operational intervention levels (released activity) compared with the inventory (assumption: equilibrium core of a power reactor with approx. 3700 MW_{th}) show that at distances of 300 km and more sheltering is no longer necessary.

Bundesministerium
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und Reaktorsicherheit

Compendium of Measures to Reduce Radiation Exposure Following Events with not Insignificant Radiological Consequences

(Catalogue of Countermeasures)

Volume 2

December 2000

Table 7.2-4 Selected radionuclides of the inventory of a 1300-MW_{el} PWR equilibrium core, average burn-up [SSK 13], activity in Bq

Nuclide	Time after end of chain reaction				
	0 h	1 h	6 h	24 h	120 h
Kr 85	2.81E+16	2.81E+16	2.81E+16	2.81E+16	2.81E+16
Kr 85m	1.04E+18	9.06E+17	4.18E+17	2.58E+16	9.16E+09
Kr 87	1.95E+18	1.14E+18	7.49E+16	4.10E+12	0.0
Kr 88	2.77E+18	2.18E+18	6.42E+17	7.92E+15	5.24E+05
Xe 133	7.57E+18	7.57E+18	7.55E+18	7.30E+18	4.72E+18
Xe 135	1.65E+18	2.04E+18	2.94E+18	1.77E+18	2.12E+15
Total Kr-Xe	**1.50E+19**	**1.39E+19**	**1.17E+19**	**9.13E+18**	**4.75E+18**
I 131	3.63E+18	3.62E+18	3.57E+18	3.37E+18	2.42E+18
I 132	5.32E+18	5.29E+18	5.11E+18	4.37E+18	1.86E+18
I 133	7.58E+18	7.44E+18	6.35E+18	3.49E+18	1.42E+17
I 134	8.21E+18	5.74E+18	2.18E+17	1.83E+11	0.0
I 135	7.06E+18	6.36E+18	3.77E+18	5.70E+17	2.43E+13
Total iodine	**3.18E+19**	**2.85E+19**	**1.90E+19**	**1.18E+19**	**4.43E+18**
Sr 89	3.86E+18	3.85E+18	3.84E+18	3.80E+18	3.60E+18
Sr 90	2.22E+17	2.22E+17	2.22E+17	2.22E+17	2.22E+17
Sr 91	4.74E+18	4.41E+18	3.06E+18	8.24E+17	7.48E+14
Y 90	2.32E+17	2.32E+17	2.32E+17	2.30E+17	2.25E+17
Y 91	4.91E+18	4.91E+18	4.91E+18	4.88E+18	4.66E+18
Zr 95	6.42E+18	6.42E+18	6.41E+18	6.35E+18	6.08E+18
Zr 97	6.38E+18	6.13E+18	4.99E+18	2.39E+18	4.65E+16
Nb 95	6.37E+18	6.37E+18	6.37E+18	6.37E+18	6.36E+18
Mo 99	6.86E+18	6.79E+18	6.45E+18	5.34E+18	1.95E+18
Tc 99m	6.01E+18	6.01E+18	5.91E+18	5.10E+18	1.88E+18
Ru 103	5.62E+18	5.61E+18	5.59E+18	5.52E+18	5.14E+18
Ru 105	3.59E+18	3.17E+18	1.45E+18	8.75E+16	2.70E+10
Ru 106	1.38E+18	1.38E+18	1.38E+18	1.38E+18	1.37E+18
Rh 105	3.38E+18	3.38E+18	3.27E+18	2.43E+18	3.73E+17
Sb 127	3.19E+17	3.18E+17	3.08E+17	2.70E+17	1.31E+17
Sb 129	1.14E+18	9.86E+17	4.42E+17	2.46E+16	5.02E+09
Te 127	3.13E+17	3.13E+17	3.11E+17	2.90E+17	1.64E+17
Te 127m	3.88E+16	3.88E+16	3.88E+16	3.88E+16	3.85E+16
Te 129	1.13E+18	1.08E+18	6.25E+17	1.38E+17	9.98E+16
Te 129m	1.69E+17	1.69E+17	1.69E+17	1.67E+17	1.53E+17
Te 131m	5.30E+17	5.20E+17	4.63E+17	3.06E+17	3.33E+16
Te 132	5.24E+18	5.20E+18	4.97E+18	4.24E+18	1.81E+18
Cs 134	3.51E+17	3.51E+17	3.51E+17	3.50E+17	3.49E+17
Cs 136	1.34E+17	1.34E+17	1.32E+17	1.27E+17	1.03E+17
Cs 137	2.99E+17	2.99E+17	2.99E+17	2.99E+17	2.99E+17
Ba 140	6.67E+18	6.65E+18	6.58E+18	6.31E+18	5.08E+18
La 140	6.82E+18	6.82E+18	6.80E+18	6.71E+18	5.74E+18

Table 7.2-9 Cumulative release fractions, oriented on the core inventory according to the German Risk Study, Phase B [DRSB]

	Released fraction of the core inventory								
	Kr-Xe	I	Cs	Te	Sr	Ru[1)]	La[2)]	Ce[3)]	Ba
Global containment failure ER-CF	1	(0,5	to	0.9)	$4 \cdot 10^{-1}$	$1 \cdot 10^{-5}$	$2 \cdot 10^{-2}$	$4 \cdot 10^{-2}$	$3 \cdot 10^{-1}$
Primary system leak in the annulus (without hydrogen deflagration in containment and annulus) ER-PLA	1	$3.7 \cdot 10^{-1}$	$3.7 \cdot 10^{-1}$	$2.3 \cdot 10^{-1}$	$1.7 \cdot 10^{-1}$	$2.5 \cdot 10^{-6}$	$6.4 \cdot 10^{-3}$	$1.4 \cdot 10^{-2}$	$1.1 \cdot 10^{-1}$
Steam generator tube leak without sufficient water in the defective steam generator ER-SG LP*a	$1.7 \cdot 10^{-1}$	$1.5 \cdot 10^{-1}$	$1.5 \cdot 10^{-1}$	$5.0 \cdot 10^{-2}$	$6.7 \cdot 10^{-5}$	$8.8 \cdot 10^{-8}$	$7.0 \cdot 10^{-9}$	-	$1.4 \cdot 10^{-3}$
Steam generator tube leak with sufficient water in the defective steam generator ER-SG LP*b	$1.7 \cdot 10^{-1}$	$2.5 \cdot 10^{-2}$	$2.5 \cdot 10^{-2}$	$1.5 \cdot 10^{-2}$	$1.3 \cdot 10^{-5}$	$1.7 \cdot 10^{-8}$	$1.3 \cdot 10^{-9}$	-	$2.7 \cdot 10^{-4}$
Increased containment leakage ($10\ cm^2$) via annulus and auxiliary building ER-leakage LP*	1	$7.8 \cdot 10^{-3}$	$3.5 \cdot 10^{-4}$	$2.1 \cdot 10^{-3}$	$1.5 \cdot 10^{-4}$	$3.6 \cdot 10^{-7}$	$5.6 \cdot 10^{-6}$	$1.3 \cdot 10^{-5}$	$1.3 \cdot 10^{-4}$
Controlled pressure relief at 0.6 MPa and release via the stack ER-pressure relief ND*	$9.0 \cdot 0^{-1}$	$2.0 \cdot 0^{-3}$	$3.3 \cdot 10^{-7}$	$3.5 \cdot 10^{-6}$	$2.0 \cdot 10^{-7}$	$6.4 \cdot 10^{-10}$	$6.3 \cdot 10^{-8}$	$2.0 \cdot 10^{-8}$	$1.7 \cdot 10^{-7}$

1) „Ru“ also stands for Rh, Co, Mo, Pd, At, Tc

2) „La“ also stands for Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Hf, Ta, W, Re, Os, Ir, Pt, Au, Ac, Zr, Nb, Y

3) „Ce“ also stands for Th, Pa, U, Np, Pu, Am, Cm, Bk, Cf, Es, Fm, Md

Note: In Phase B of the Risk Study, the nuclide groups shown above were partly extended and newly structured. This was done in connection with the investigations concerning the behaviour of the radionuclides in the accident atmosphere in the light of detailed analyses and new findings compared with Phase A. This concerns in particular the less volatile radionuclides.