MVM PAKS II ZRT.

IMPLEMENTATION OF NEW NUCLEAR POWER PLANT UNITS, AT THE PAKS SITE

ENVIRONMENTAL IMPACT ASSESSMENT STUDY

SIMPLIFIED PUBLIC SUMMARY

MVM PAKS II Zrt. contract number: 4000018343

MVM ERBE Zrt. contract number: 13A380069000

Applicant's data

Applicant's name:	MVM Paks II Atomerőmű Fejlesztő Zártkörűen Működő Részvénytársaság (Nuclear Power Plant Developing Private Company Limited by Shares)
Official abbreviation of the Applicant's name:	MVM Paks II Zrt.
Applicant's registered seat:	7030 Paks, Gagarin u. 1-3. 302/B
Applicant's company registration number:	17-10-001282
Applicant's tax registration number:	24086954-2-17
Applicant's statistical code:	24086954-4222-114-17
Applicant's manager:	Sándor Nagy – CEO
Contact details of the Applicant's contact person:	László Puskás – Head of Department for Licensing and Nuclear Safety
Contact details of the Applicant's contact person:	+36 75 503 730

DATA OF THE PLANNED ACTIVITY

Name of the planned nuclear power plant:	Paks II. Nuclear Power Plant
Abbreviated name of the planned nuclear power plant:	Paks II.
Planned activity:	implementation and operation of two III$^+$ generation pressurized water reactor nuclear power plant units
Purpose of the planned activity:	generation of electric power for public purposes
Gross electrical output of the planned nuclear power plant:	maximum 1200 MWe per unit
Gross thermal output of the planned nuclear power plant:	maximum 3200 MWe per unit
Installation area of the planned nuclear power plant:	site of the Paks Nuclear Power Plant
Planned start of the commercial operation of the new units:	2025 - Paks II Nuclear Power Plant, unit 1
	2030 - Paks II Nuclear Power Plant, unit 2
Planned life of the new units:	at least 60 years

DETAILS OF THE PLANNED INSTALLATION SITE

Parcel number of the planned installation site:	Paks 8803/15
Owner of the planned installation area:	MVM Paksi Atomerőmű Zrt. (MVM Paks Nuclear Power Plant)

DETAILS OF THE EXPERTS (DESIGNERS) WHO PREPARED THE ENVIRONMENTAL IMPACT ASSESSMENT STUDY

The environmental impact assessment study of the planned nuclear power plant units was compiled by MVM ERBE Zrt.

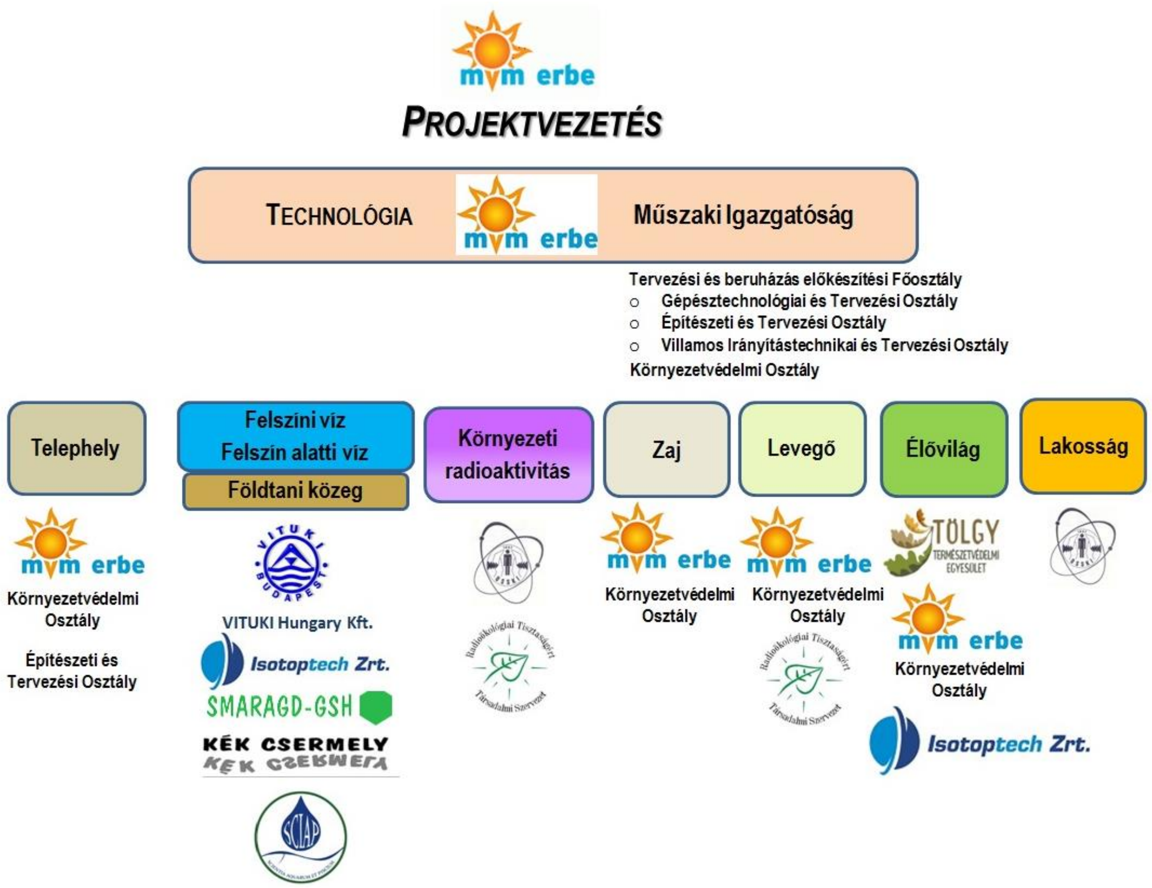
Name of the designer: *MVM ERBE ENERGETIKA Mérnökiroda Zártkörűen Működő Részvénytársaság (MVM ERBE ENERGETIKA Engineering Company Limited by Shares)*
Official abbreviation of the Designer's name: *MVM ERBE Zrt.*
Address of the designer's registered office: *1117 Budapest, Budafoki út 95.*
Designer's company registration number: *01-10-045821*
Head of the designer: *Farkas Dohán - Chief Executive Officer*

The technical conditions of the environmental impact assessment study and licensing for the planned nuclear power plant units are provided by the basic technical parameters elaborated on the basis of the maximum environmental emission values causing maximum environmental load, which are based on the preliminary data reported by the supplier of the units, the published data of nuclear power plants already being built, and the reference data of similar units that have been implemented. On the installation site plan the buildings and structures were arranged on the basis of technological considerations, taking into account those technological units with the maximum spatial requirement. The basic specifications were prepared by MVM ERBE Zrt. (ERBE).

The environmental impact assessment of a nuclear power plant is a highly complex task comprising a large number of specializations, the implementation of which requires broad professional co-operation.

To this end, ERBE used the services of professionally recognized, certified subcontractors with appropriate references for the purpose of assessing the basic condition of the Paks site and then for elaborating the environmental impact assessment programme and compiling the environmental impact assessment study.

The system of professional organizations co-operating in each specialization was as follows.



Projektvezetés–Project management
Technológia–Technology
Műszaki Igazgatóság–Technical Directorate
Tervezési és beruházás előkészítési Főosztály– Department of Design and Project Preparation

- ***Gépésztechnológiai és Tervezési Osztály –Department of Engineering Technology and Design***
- ***Építészeti és Tervezési Osztály – Department of Architecture and Design***
- ***Villamos Irányítástechnikai és Tervezési Osztály –Department of Electrical Control Engineering and Design***

Környezetvédelmi Osztály–Department of Environmental Protection

Telephely–Site

Felszíni víz –Surface water
Felszín alatti víz –Subsurface water
Földtani közeg –Geological medium

Zaj–Noise

Levegő–Air

Élővilág–Wildlife

Hulladékok–Waste

Környezeti radioaktivitás–Ambient radio activity
Lakosság–Population
Élővilág–Wildlife

Környezetvédelmi Osztály–Department of Environmental Protection
Építészeti és Tervezési Osztály–Architecture and Design Department

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ABBREVIATIONS

Abbreviated name	Complete name
ÁNTSz OTH	Állami Népegészségügyi és Tisztiorvosi Szolgálat Országos Tisztifőorvosi Hivatal (National Public Health and Medical Officer Service, Chief Medical Officer)
ÁVIT	Comprehensive Emergency Management and Emergency Response Plan
DBC	Design Basis Condition
DdKTF	Dél-dunántúli Környezetvédelmi, Természetvédelmi Felügyelőség (South-Transdanubian Environmental and Nature Conservation Supervisory Authority)
DdKTVF	Dél-dunántúli Környezetvédelmi, Természetvédelmi és Vízügyi Felügyelőség (South-Transdanubian Environmental, Nature Conservation and Water Management Supervisory Authority)
DDNPI	Duna-Dráva Nemzeti Park Igazgatóság (Danube–Drava National Park Directorate)
DEC	Design Extension Conditions
PCD	Preliminary consultation documentation
UN	United Nations
ERBE	MVM ERBE ENERGETIKA Mérnökiroda Zártkörűen Működő Részvénytársaság (MVM ERBE ENERGETIKA Engineering Company Limited by Shares) MVM ERBE Zrt.
EUR	European Utility Requirements
Euratom	European Atomic Energy Community
EüM	Ministry of Health
rkm	river kilometer, rkm
MCP	Main circulating pump
GCR	Gas-Cooled, Graphite-Moderated Reactor
GM	Ministry of the Economy
ICRP	International Commission on Radiological Protection
IM	Ministry of Industry
INES	International Nuclear Event Scale
IRG	Inert radioactive gas
IRM	Ministry of Justice and Law Enforcement
KHEM	Minister of Transport, Telecommunication and Energy
EIAA – EIAS	Environmental Impact Assessment Analysis – Environmental Impact Assessment Study
KHVM	Ministry of Transport, Telecommunications and Water Management
SFIS	Spent Fuel Interim Storage
KöM	Ministry for Environmental Protection
KPM	Ministry of Transport and Post
KSH NKI	Central Statistical Office Population Research Institute
KvVM	Ministry of Environment Protection and Water Management
MWL	Minimum water level
LOCA	LOss of Coolant Accident
LWGR	Light-Water-Cooled, Graphite-Moderated Reactor
MAVIR	Magyar Villamosenergia-ipari Átviteli Rendszerirányító Zártkörűen Működő Részvénytársaság (Hungarian Electricity Transmission System Manager Private Company Limited by Shares)
MBFH	Magyar Bányászati és Földtani Hivatal (Hungarian Office for Mining and Geology)
MEKH	Magyar Energetikai és Közmű-szabályozási Hivatal (Hungarian Office of Energy and Public Utility Regulation)
MIR	Modernized International Reactor
MKEH	Magyar Kereskedelmi Engedélyezési Hivatal (Hungarian Trade Licensing Office)
MKM	Ministry of Culture and Education
MVM Zrt.	MVM Magyar Villamos Művek Zártkörűen Működő Részvénytársaság (Hungarian Electricity Works Private Company Limited by Shares)
MVM Paks II. Zrt.	MVM Paks II Atomerőmű Fejlesztő Zártkörűen Működő Részvénytársaság (Nuclear Power Plant Developing Private Company Limited by Shares)
IAEA	International Atomic Energy Agency
NBEIT	Comprehensive Emergency Management and Emergency Response Plan
NSR	Nuclear Safety Regulations
OAH NBI	Országos Atomenergia Hivatal Nukleáris Biztonsági Igazgatóság (Hungarian Atomic Energy Authority, Nuclear Safety Directorate)
P	Parliament
OMSz	Országos Meteorológiai Szolgálat (Hungarian Meteorological Service)
Paks Nuclear Power Plant	MVM Paksi Atomerőmű Zártkörűen Működő Részvénytársaság; MVM Paksi Atomerőmű Zrt. (MVM Paks Nuclear Power Plant Private Company Limited by Shares)
Paks II	Paks II Nuclear power plant – planned new nuclear power plant units at the Paks Site
PHWR	Pressurized Heavy-Water-Moderated and Cooled Reactor
PSA	Probabilistic Safety Assessment

Abbreviated name	Complete name
PWR	Pressurized Light-Water-Moderated and Cooled Reactor
TRU	trans-uranium element (with an atomic number higher than 92, i.e. that of uranium)
FSR	Final Safety Report
HPS	Hungarian Power System
VVER	ВВЭР (Водо-Водяной Энергетический Реактор) - Water-Water Power Reactor
WANO	World Association of Nuclear Operators
WENRA	Western European Nuclear Regulators Association
ZMCS	zone emergency cooling systems

1 BASIC INFORMATION REGARDING THE PLANNED PROJECT

The age of large power plants in the Hungarian power system is approaching, or in certain cases has already exceeded, the end of their design life-cycles. In order to manage part of the capacity shortage and in view of the planned life of the existing nuclear power plant units, Hungary has started making preparations for building new nuclear power plant units.

The purpose of the project in the process of preparation is to implement two modern, III^+ generation, pressurized water nuclear power plant units, each having 1200 MW_e capacity and an expected life of no less than 60 years, next to the Paks Nuclear Power Plant, for the generation of public-purpose electricity, **according to the time schedule determined in the National Energy Strategy,** starting commercial operation in 2025 and 2030, respectively, in order to maintain the share – of about 40% – of nuclear power in electricity generation over the long term.

The planned project consists of the following main elements:

- power plant technology,
- cooling water system for the power plant,
- connection to the Hungarian power system.

1.1 ACTIVITIES IN PREPARATION FOR THE PLANNED PROJECT

1.1.1 TELLER PROJECT

Pursuant to Article 7 (2) of Act CXVI of 1996 on Atomic Energy, Parliament's preliminary provisional consent is required to start preparations for the building of any new nuclear facility. In Article 12. f. of its Decision No. 40/2008. (IV. 17.) on energy policy between 2008-2020, Hungary's Parliament requested the Government to "start preparatory work to support decision making about the new nuclear power plant units. Following the laying down of the professional, environmental and social foundations, it should submit its proposals for the need, conditions, type and installation of the power plant to Parliament in due time."

The Teller Project set up by MVM Zrt has prepared expert studies, analyzing the relevant technical, economic, commercial, legal and social considerations. The feasibility of various implementation options were examined, a preliminary environmental assessment was prepared, and the issues related to the disposal of spent fuels and radioactive waste were scrutinized. The findings of these studies were summed up in three decision support documents, which state that the best choice is a modern pressurized water nuclear power plant, which is not a prototype, has already been licensed somewhere in the world, and has a useful life of at least 60 years, to be built at the Paks site.

Relying on the specialists' analyses, Parliament approved with a 95.4% Yes vote on March 30, 2009 the launching of activities to support preparations for the building of new nuclear power plant units at the Paks site.

1.1.2 LÉVAI PROJECT

For the purpose of performing the preparatory activities prescribed in Parliament's decision, MVM Zrt set up the Lévai Project in June 2009. The following main activities were performed in the framework of the Lévai Project:

- ordering the preparation of strategic analyses and inquiries to clarify financing options;
- ordering the preparation of the first draft of a supplier tender documentation;
- examining the connectivity of the new units to the power grid;
- assessing the various cooling water supply options;
- launching the compilation of a preliminary consultation documentation;
- launching inquiries required for the preparation of an environmental impact analysis;
- preparing the compilation of an application for a site permit;
- assessment of the staffing requirements;
- surveying the range of potential domestic suppliers and regional businesses.

1.1.3 MVM PAKS II. ATOMERŐMŰ FEJLESZTŐ ZRT - PROJECT COMPANY

In order to prepare for the building of the new nuclear power plant units, the MVM Group founded MVM Paks II. Atomerőmű Fejlesztő Zártkörűen Működő Részvénytársaság (MVM Paks II. Zrt) on June 26, 2012.

The most important tasks of the project company comprise determining the frameworks of the future implementation, working out the financing details, and laying down the technical conditions (cooling options, environmental impacts). As an important element of the project, the site permit, the operating licence under water law and the implementation permit must be obtained. The project company is engaged in legal harmonization matters as well as the analysis of regional economic and social impacts. A further especially important task is to make sure that building the new nuclear power plant units will boost Hungary's economy as much as possible.

1.1.4 REGULATORY SUPPORT

As a result of the above outlined preparatory activities, several elements supporting the implementation of the new nuclear power plant units have been introduced into the Hungarian regulatory environment.

On October 3, 2011, Parliament adopted the **National Energy Strategy**, which identifies the directions of development and operation in the next decades up to 2050, and declares that – in order to facilitate the achievement of its long-term economic and environmental objectives – the state wishes to maintain the current approximately 40% share of nuclear power in Hungary's power generation.

In order to ensure a balanced development in nuclear power engineering in Hungary over the next thirty years, in its Decree No. 1195/2012. (VI. 18.) the Government established the **Government Commission for Nuclear Energy** chaired by the Prime Minister, for the analysis of strategic questions related to the use and development of nuclear power in Hungary.

In view of the strategic role played by nuclear energy in Hungary's power supply and in guaranteeing supply safety, and with regard to the provisions of the National Energy Strategy adopted by Parliament, in its Decree No. 1196/2012. (VI. 18.), the Government declared the installation of new nuclear power plant units at the site of the Paks Nuclear Power Plant **as a high-priority project for the national economy**, which is essential for the **safe supply of electrical energy**.

1.1.5 SELECTION OF THE UNITS TO BE BUILT

HUNGARIAN–RUSSIAN INTERGOVERNMENTAL CONVENTION

On 14 January 2014, the Hungarian Government entered into an agreement with the Government of the Russian Federation on the renewal of the nuclear co-operation agreement, which was concluded by the two countries several decades earlier. Based on the agreement, two additional 1200 MW units will be built at the site of the Paks Nuclear Power Plant with the Russian Competent Authority acting as the main contractor, for which the Hungarian Government will be granted an intergovernmental loan from Russia.

ACT II OF 2014

During its February 6, 2014 sitting, Parliament approved the agreement concluded between the two governments in ***Act II of 2014*** on the promulgation of the treaty on co-operation between the Government of Hungary and the Government of the Russian Federation in the field of the peaceful use of nuclear energy.

Article 1 – Subject of the co-operation

The Parties shall co-operate in the maintenance of the output of the Paks Nuclear Power Plant, located in Hungary, and in its development, including the design, erection, commissioning and decommissioning of two new units with reactors of the VVER (water cooling, water moderator) type, each having at least 1000 MW built-in capacity, as provided in this Treaty below, in order to replace units 1 through 4, which will be shut down in the future.

1.2 GENERAL DESCRIPTION OF LICENSING THE NEW NUCLEAR POWER PLANT UNITS

Several thousand permits and licences will need to be obtained for the complete licensing of the planned nuclear power plant. The following list highlights only the most important permits and licences, and specifies the relevant issuing authorities.

Radiation protection – *National Public Health and Medical Officer Service (ÁNTSZ) , Chief Medical Officer*

Dose limitation permit

Environmental protection – *South-Transdanubian Environmental and Nature Conservation Supervisory Authority (DdKTF)*

Environmental permit

Water rights –*Fejér County Disaster Control Directorate*

Preliminary water rights licence
Water rights implementation permit
Operating licence under water rights

Nuclear safety – *Hungarian Atomic Energy Authority*

Site inspection and assessment permit
Site permit
Implementation permit
Construction permit
Occupancy permit for buildings and building structures
System-level permits

- Manufacturing permit
- Procurement permit
- Installation permit
- Type permit

Commissioning licence
Operating licence

Power engineering

Power Plant – *Hungarian Office of Power Engineering and Public Utility Regulation*

Preliminary licence for power plants having a significant impact on the operation of the power grid
Implementation permit by the Hungarian Office of Power Engineering and Public Utility Regulation (MEKH)
Electricity generation licence issued by MEKH.

Grid connection (transmission line) - *Baranya County Government Office, Pécs Office of Measures, Standards and Technical Safety*

Permit for preliminary works
Line permit
Operating licence

Technical supervision – *Hungarian Trade Licensing Office*

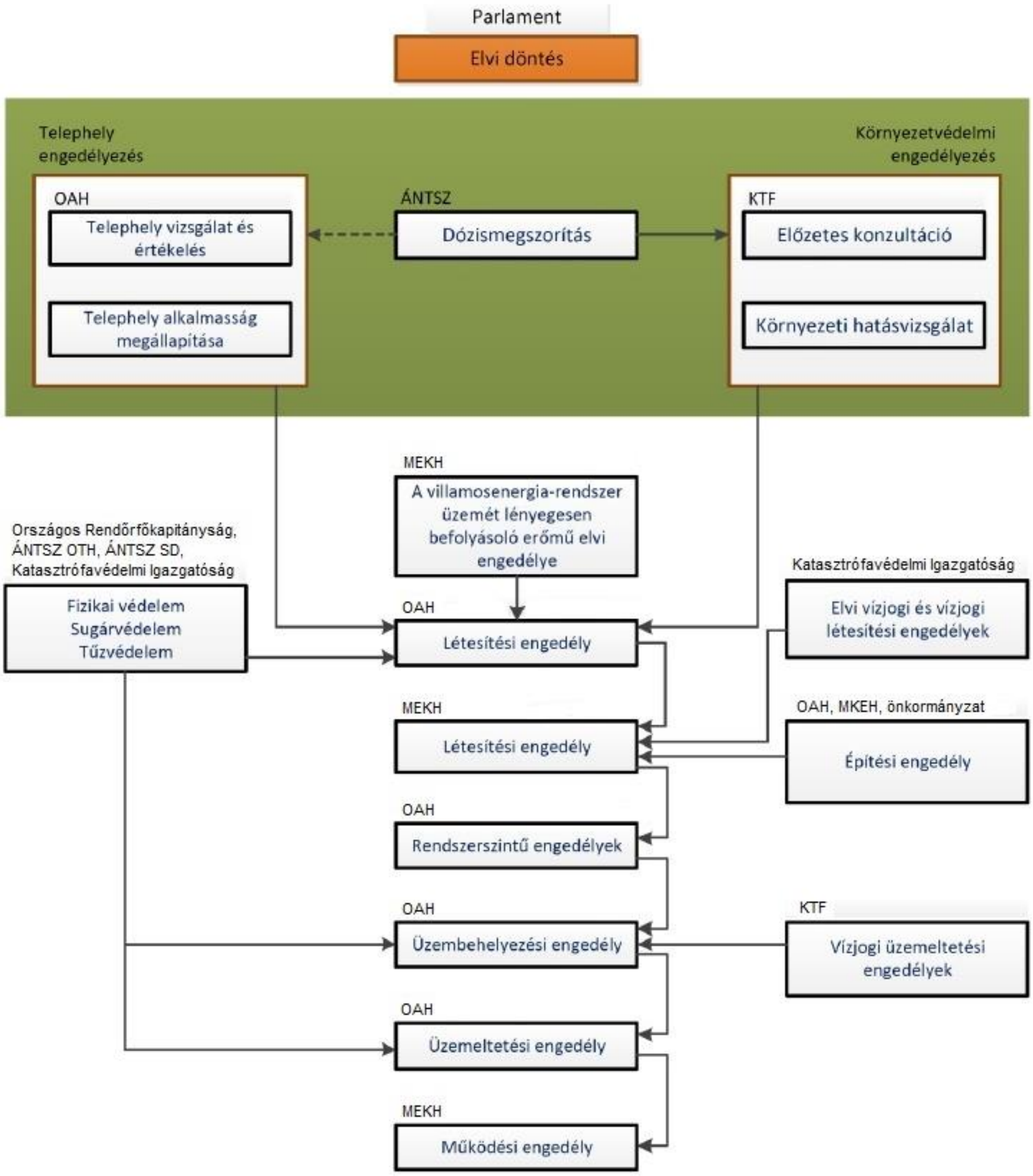
Building permits falling within the competence of the Hungarian Trade Licensing Office (MKEH)
The licences to be obtained from MKEH during implementation (e.g. for pressure vessels, district heating pipes, hazardous waste stores)
Occupancy permits falling within the competence of MKEH

Architecture – *Municipalities*

Building permits falling within the competence of municipalities

Additional licensing and other procedures

Physical security
Procedure as regulated in Article 37 of EURATOM
Procedure as per Article 41 of EURATOM



Parlament–*Parliament*
Elvi döntés–Preliminary decision
Telephely engedélyezés–Site permit
Környezetvédelmi engedélyezés–Environmental licence
OAH - Telephely vizsgálat és értékelés– OAH Site inspection and assessment
Dózismegszorítás–Dosage limit
KTF Előzetes konzultáció– KTF Preliminary consultation
Telephely alkalmasság megállapítása–Implementation of site suitability
Környezeti hatásvizsgálat–Environmental Impact Assessment
Országos Rendőrfőkapitányság–National Police Headquarters
ÁNTSZ OTH, ÁNTSZ SD,
Katasztrófavédelmi Igazgatóság–Disaster Control Directorate
MEKH Villamosenergia-rendszer üzemét lényegesen befolyásoló erőmű elvi engedélye–MEKH Preliminary licence for power plants having a significant impact on the operation of the power system
Katasztrófavédelmi Igazgatóság–Disaster Control Directorate
Elvi vízjogi és vízjogi létesítési engedélyek–Preliminary water rights licence and water rights implementation permit
Fizikai védelem, sugárvédelem, tűzvédelem–Physical protection, radiation protection, fire protection
MEKH Létesítési engedély–MEKH Implementation permit
OAH, MKEH, önkormányzat– OAH, MKEH, municipalities
Építési engedély– Building permit
OAH rendszerszintű engedélyek–OAH system level permits/licences
OAH üzembehelyezési engedély–OAH commissioning licence
KTF vízjogi üzemeltetési engedélyek–Water rights operating licences
OAH üzemeltetési engedély– OAH management licence
MEKH működési engedély–MEKH operating licence

Figure 1: The nuclear power plant licensing procedure

1.3 CURRENT STATE OF ENVIRONMENTAL LICENSING FOR THE NEW NUCLEAR POWER PLANT UNITS

Based on Article 66 (1) of Act LIII of 1995 on the general rules of environmental protection, any activity subject to environmental impact assessment can only be started in possession of the relevant final and non-appealable environmental licence issued by the environmental authority of the affected region.

The activities subject to environmental impact assessment are listed in Annex 1 to Government Decree No. 314/2005. (XII. 25.) on environmental impact assessment and on the unified procedure of licensing the use of the environment. Section 31 of this Decree deals nuclear power plants without any size limitation.

Thus, as a precondition of establishing the two nuclear power plant units of 1200 MW_e electrical output each, the environmental impact assessment prescribed in Government Decree No. 314/2005. (XII.25.) must be conducted, the findings must be summed up in an environmental impact assessment study, an environmental licensing procedure must be conducted on their basis, and as a result of this procedure, an environmental license must be obtained.

During the environmental licensing of the new nuclear power plant units planned to be erected at the Paks site, the licensing authority as the competent body appointed to deal with matters related to the site of the Paks Nuclear Power Plant is the South-Transdanubian Environmental and Nature Conservation Supervisory Authority (hereinafter: DdKTF).

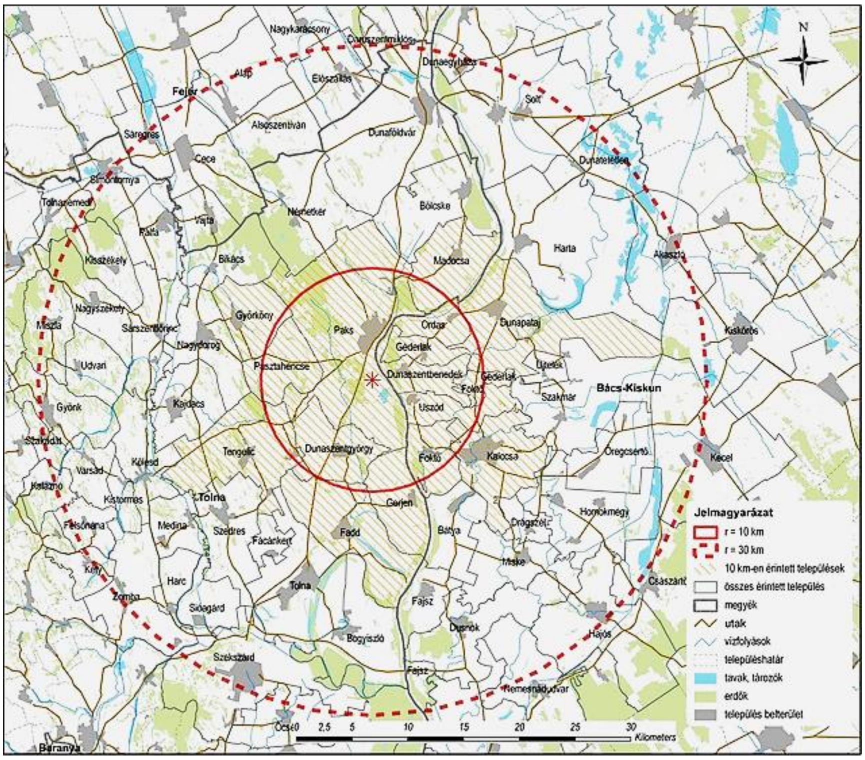
1.3.1 PRELIMINARY CONSULTATION DOCUMENTATION ON THE POTENTIAL 5 UNIT TYPES(PCD)

The environmental licensing procedure started on November 10, 2012 by submission of preliminary consultation documentation No. 6F111121, entitled “MVM Magyar Villamos Művek Zrt, Implementation of New Nuclear Power Plant Units”, and compiled by PÖYRY ERŐTERV Energetikai Tervező és Vállalkozó Zrt. [1-1][1]

The PCD was prepared on the basis of the specification of the 5 unit types that may be installed on the Paks site.

Areas within a radius of 10 km and 30 km were studied in the PCD.

[1]*Download the PCD from the website of MVM PAKS II. Zrt at:*
http://www.mvmpaks2.hu/hu/Dokumentumtarolo/EKD-HUN.pdf
http://www.mvmpaks2.hu/hu/Dokumentumtarolo/EKD-ENG.pdf



Jelmagyarázat–*Legend*
r = 10 km
r = 30 km
10 km-en érintett települések –communities affected within 10 km
összes érintett település–all affected locations
megyék–counties
utak–roads
vízfolyások–water streams
településhatár–location border
tavak, tározók–lakes, reservoirs
erdők–forests
residential area–település belterület

Figure 2: Areas studied in the PCD (10 km, 30 km)[1-1]

In the course of the procedure conducted by the South-Transdanubian Environmental, Nature Conservation and Water Management Supervisory Authority, the following public administrative authorities made comments:

Public administration agency	file number
Tolna County Government Office, Public Health Administration	XVII-R-084/01550-2/2012
Tolna County Government Office, Public Services Department, Cultural Heritage Protection Department, Szekszárd	II-P-18/184-2/2012
Tolna County Government Office, Plant and Soil Protection Directorate	26.2/1271-2/2012
Baranya County Government Office, Forestry Directorate	II-G-033/8061/1/2012
Baranya County Government Office, Construction Office, State Chief Architect	II-D-15/157-2/2012
Pécs District Mining Inspectorate	PBK/3519-2/2012
District administrator of Pusztahencse – Györköny	629/2012
District administrator of Dunaszentgyörgy - Németkér - Gerjen	625-5/2012
Administrator of Bölcske	1985-2/2012
District administrator of Zomba, Harc and Medina, representative office at Medina	819-2/2012
City administrator of Kalocsa	8350-1/2012/H

Table 1: Public administration organizations that commented on the PCD:

The following parties had not made any comment up to the publication date of the Opinion:

Tolna County Government Office, Paks District Land Registrar
Hungarian Atomic Energy Authority
Titular city administrator of Paks
District administrator of the communities Nagydorog, Bikács and Sárszentlőrinc
District administrator of Kölesd, Kistormás, Kajdacs
District administrator of Foktő and Dunaszentbenedek
District administrator of Géderlak, Ordas and Uszód
District administrator of Harta and Dunatetétlen
District administrator of Homokmégy and Öregcsertő
District administrator of Szakmár and Újtelek
District administrator of Miske and Drágszél
District administrator of Sióagárd and Fácánkert
District administrator of Bogyiszló, Tengelic, Szedres, Fadd, Pálfa, Madocsa, Dusnok, Dunapataj, Bátya, Fajsz, Vajta, Tolna, Cece, Dunaföldvár, Előszállás

DdKTVF requested legal aid from the Road, Rail and Waterways Office of the National Transport Authority for reasons of these having competence; the opinion of the Central Transdanubian Environmental, Nature Conservation and Water Management Supervisory Authority, for reasons of having jurisdiction, and a declaration from the Duna-Dráva National Park Directorate. The affected organizations had not made any comment or given any declaration up to the publication of the Opinion.

Publicity

In the course of the procedure, the Energiaklub Climate Policy Institute and Applied Communications requested acknowledgement of its customer status, and on this basis it requested access to the PCD for inspection and formulating an opinion. Based on the statutes of the club, DdKTVF approved its customer status, and provided the Club with access to the electronic version of the consultation application. Up to the publication of the Opinion, Energiaklub had not expressed its opinion on the PCD.

During the procedure, neither DdKTVF nor the administrators of the affected communities received any comment from the public in relation to the preliminary consultation.

In view of all these, DdKTVF published its Opinion under file No. 8588-32/2012 on December 21, 2012, stating the following:

- implementation of the planned nuclear power plant is an activity subject to environmental impact assessment
- based on the available information, in the course of the preliminary consultation, DdKTVF sees **no condition that would prevent** the environmental licensing procedure in relation to the planned project
- the environmental impact assessment study must be prepared in accordance with the content requirements set forth by DdKTVF and in Annexes 6 and 7 to Government Decree 314/2005. (XII.)
- the specialized parts of the environmental impact assessment study may be prepared by licensed experts.

DdKTVF emphasized that the statements made in the Opinion reflect their position and the observations made by the public administrative organizations may differ.

International procedure

The implementation of a nuclear power plant is subject to the provisions of Government Decree 148/1999. (X. 13.) on the promulgation of the Espoo (Finland) Convention on Environmental Impact Assessment in a Transboundary Context, signed on February 26, 1991, and to Council Directive 85/337/EEC on the assessment of the effects of certain public and private projects on the environment, as amended by Council Directives 97/11/EC, 2003/35/EC and 2009/31/EC of the European Community.

In order to start the international procedure, under the Espoo Convention, DdKTVF sent the PCD and its foreign language versions to the Environment Preservation Department of the Ministry of Rural Development, which informed 30 countries of the procedure. The contacted countries and their positions on the procedure are summed up in the following table:

Notified potential participant	Participation	Statement of intention to participate	Observations
Austria	Yes	**wished to participate**	sent comment
Belgium	N/A		
Bulgaria	N/A		
Cyprus	No	did not wish to participate	
Czech Republic	Yes	**wished to participate**	sent comment
Denmark	N/A		
Estonia	No	did not wish to participate	
Finland	N/A		
France	N/A		
Greece	Yes	**wished to participate**	sent comment
Netherlands	N/A		
Croatia	Yes	**wished to participate**	sent comment
Ireland	N/A		
Poland	No	did not wish to participate	
Latvia	N/A		
Lithuania	N/A		
Luxembourg	N/A		
Malta	Yes	**wished to participate**	sent comment
Germany	Yes	**wished to participate**	sent comment
Italy	N/A		
Portugal	N/A		
Romania	Yes	**wished to participate**	sent comment
Spain	No	did not wish to participate	
Switzerland	N/A		
Sweden	N/A		
Serbia	N/A		
Slovakia	Yes	**wished to participate**	sent comment
Slovenia	Yes	**wished to participate**	did not send comment
United Kingdom	N/A		
Ukraine	Yes	**wished to participate**	no comment was sent

Table 2: Countries contacted in the course of the international procedure

A total of approximately 15 thousand letters were received from the other countries, which included questions and comments that may be classified into the following 10 topics:

	Topics
1	Comments related to the energy strategy
2	Comments on serious accidents and malfunctions
3	Questions regarding nuclear safety
4	Remarks related to nuclear damage liability
5	Presentation of the effects of the full fuel cycle on the environment
6	Comments on the management of radioactive waste
7	The aggregate impacts of the two power plants, and the effects of the new power plant on the old one
8	Comments on the content of the environmental impact assessment study
9	Economic considerations
10	Other remarks, comments

Table 3: Questions asked in the course of the international procedure

The responses given in writing to the individual groups of questions are included in the chapter on international affairs.

1.3.2 ENVIRONMENTAL IMPACT ASSESSMENT STUDY (EIAS) OF THE PAKS II NUCLEAR POWER PLANT

The purpose of the environmental impact assessment analysis (EIAS) performed before erecting the Paks II Nuclear Power Plant on the Paks site is to identify and evaluate the environmental impacts of the planned nuclear power plant technology on the individual elements and systems of the environment depending on the condition and load capacity of the design area.

If based on the legislative background and the professional positions, the impact assessment conducted in this system of conditions does not identify any inadmissible use or exposure for any environmental element or system, then *no environmental consideration prevents the installation and operation of the two 1200 MW units.*

1.3.2.1 Design basis condition surveys

In order to provide a baseline for the environmental impact assessment analysis, surveys and analyses have been made from March 1, 2012 on the areas of the planned installation areas of the nuclear power plant units and on the basis of the preliminary estimates of the impact areas, in the following topics in order to assess the current state of the environment and characterize and appraise the baseline condition on this basis.

I. **Characterization of the site**

II. **Weather conditions**
   a) Meteorology
   b) Micro- and mezo-climate in the vicinity of the site

III. **Description of the geological formation and the ground and underground aquatic environment**
   c) Description and characteristics of the geological formation
   d) Description and characteristics of the subsurface aquatic environment
   e) Hydrological characterization of the site
   f) Condition of the Danube and other surface waters
   g) Condition of the river bed and the embankment wall of the Danube

IV. **General characteristics of the ambient radioactivity**

V. **Assessment of noise and vibration exposure**

VI. **Assessment of air quality**

VII. **Wildlife health status**
   h) Exposure of the wildlife to radiation (with human exposure excluded)
   i) Model biomonitoring surveys

VIII. **Population health status**
   j) Definition of the population’s exposure to radiation
   k) Health status of the population living in the surroundings of the site

The baseline measurements, tests and analyses providing the input data for the environmental impact assessment analyses were completed in 2012, thus the relevant closing date is 2012. The closing date of data collection for meteorological analyses differs from this, as it is 2010.

The year 2012 was extremely dry. The findings of biomonitoring surveys reflected the extreme drought recorded in the year reviewed. In order not to record the baseline status of the wildlife under such extremely dry weather conditions, the biomonitoring surveys were repeated in 2013. For this reason high water measurements on the Danube were also carried out in 2013.

In all cases when subsequent onsite surveys were made in 2013 or when analyses were prepared with later dates (e.g. high water measurements on the Danube, analyses of the data from groundwater monitoring wells), the closing date of the affected data is shown for the specialist fields involved.

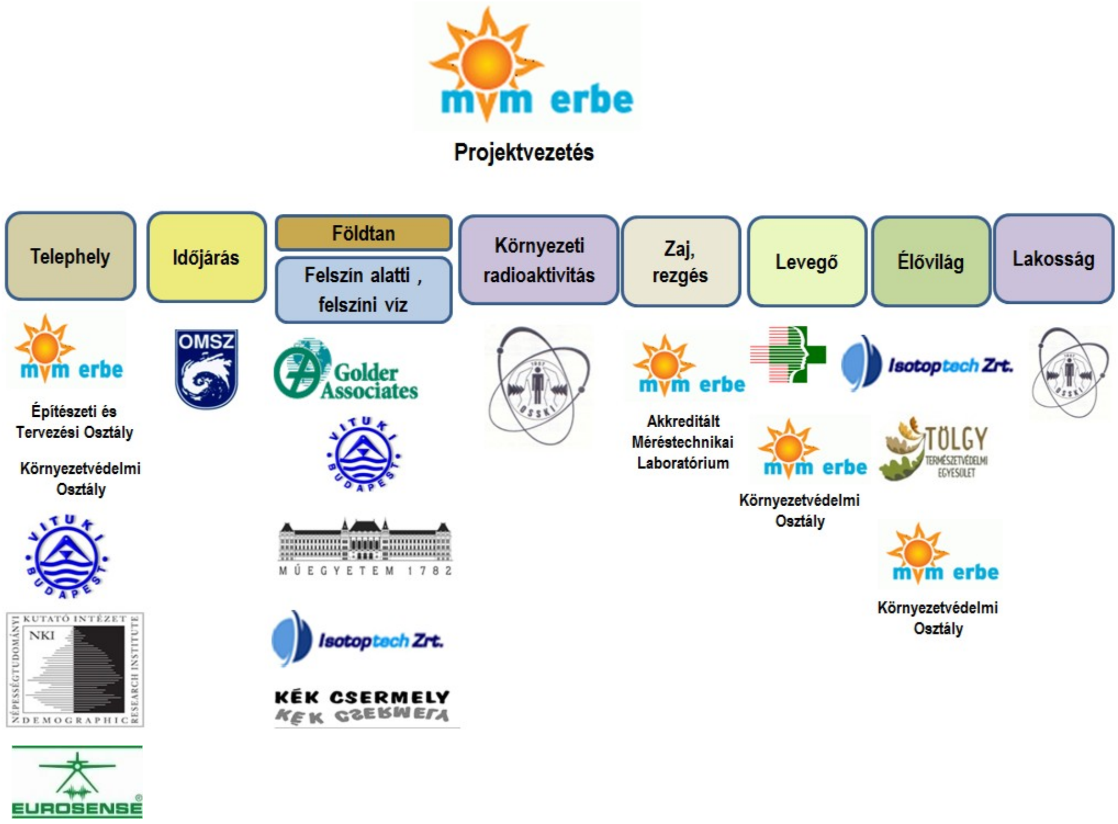
Study areas

In the course of the baseline surveys conducted during 2012-2013, the area marked by a circle of a 30 km radius from the installation site of the new units was taken as the area for the general status survey of the site environs. The majority of the surveys conducted by the various specialist fields were conducted within this boundary. The Danube study areas fundamentally differ in various extent in the individual topics, and in certain cases the full length of the Danube in Hungary was surveyed.

As the hypothetical impact is expected to occur within a circle of a 10-km radius, more detailed analyses were conducted on this territory. Hence the baseline status of the Natura 2000 areas outside the Danube was also surveyed on this part of the area.

The detailed biomonitoring surveys and flora mapping were also performed on the hypothetical direct impact area, i.e. within a circle of 3 km radius. The one-year survey of the baseline air pollution was conducted on the expected direct impact area, adjusted to the location of the points to be protected. The noise and vibration measurements were also performed on these areas. The field surveys aimed at determining the properties of the area, including those for characterizing geological formations and subsurface waters, were also conducted on the planned installation areas and their immediate vicinities.

The following professional organizations contributed to the elaboration and execution of the survey and evaluation programs that provided the basis of the environmental impact assessment analysis:



Projektvezetés–Project management
Telephely–Site
Időjárás–Weather
Földtan–Geology
Felszín alatti víz–Subsurface water
Felszíni víz–Surface water
Környezeti radioaktivitás–Ambient radioactivity
Zaj, rezgés–Noise, vibration
Levegő–Air
Élővilág–Wildlife
Lakosság–Population
Építészeti és Tervezési Osztály–Department of Architechture and Design
Akkreditált Méréstechnikai Labor–Accredited Metrological Laboratory
Környezetvédelmi Osztály–Environmental Department

1.3.2.2 Technical conditions and installation site plan for the environmental impact assessment analysis

Considering data from the already operating Paks Nuclear Power Plant, MVM ERBE Zrt. prepared and laid out the framework of technical conditions and the installation site plan, which makes it possible to assess the environmental impacts of Paks II Nuclear Power Plant and fits the present stage of planning in the depth of its details, based on the data that the supplier of the units provided in advance, data already published from power plants that are being constructed as well as reference data from public databases, presentations and units that have been completed so far, using the figures of highest environmental emissions causing the biggest environmental impact.

On the installation site plan the buildings and structures were arranged on the basis of technological considerations, taking into account the technological units with the known maximum spatial requirement. The specifications for buildings were also given on the basis of data reported by the supplier and taking into consideration the structures of the existing nuclear power plant.

In conformity with procedure presented in the PCD, fresh water cooling was analyzed in detail as the applicable cooling method. The points where water is taken from the Danube and where hot water is discharged into the Danube and the methods applied during these operations differ from those presented in the PCD.

In order to identify the appropriate foundation construction technology, the successive layers obtained by drilling performed in recent years for environmental protection purposes provided the starting data for estimating the expected foundation depths. Later on, all the buildings and structures located on the construction site will have to be dimensioned with a view to fire protection and earthquake resistance. For certain buildings other special sizing considerations also need to be taken into consideration, such as sizing to minimize the impact of aircraft crash, sizing for radiation, noise and vibration protection and the creation of salvage facilities to protect the geological formation and subsurface waters.

The construction licensing documentation, including the structural and architectural design of the buildings and structures will be based on the results of drillings performed during the geological exploration programme and during various geological surveys, as well as specific soil mechanical analyses.

Based on the above, as the work proceeds, changes may be made in the arrangement and in the sizes due to functional, building physics, building structure, earthquake resistance and fire protection considerations and the perhaps as yet unknown considerations of the supplier of the units.

The volume of the necessary supplies was determined on the basis of the technical solutions, basic specifications and the installation site plan prepared for the completion of the EIAA. The sources of the supplies are not yet known; a specific organizational plan will be prepared when the implementation is planned. The sources and volumes of the supplies and the parameters of movements within the area will be specified in that stage of the planning procedure. In the course of preparing the EIAA, calculations were made for every conceivable route within the circle with a radius of 25 km specified by law.

The process and the circumstances for shutdown, decommissioning, and dismantling Paks II – considering the units' expected life of at least 60 years – cannot be defined at the moment.

1.3.2.3 Environmental Impact Assessment Analysis (EIAA) – Environmental Impact Assessment Study (EIAS)

The several months' long process of environmental impact assessment analysis was performed on the basis of the framework of technical conditions and the installation site plan valid in March 2014.

Thus, among the versions taken into consideration in the Preliminary Consultation Documentation (PCD), the Environmental Impact Assessment Study (EIAS), which describes and sums up the results of the Paks II environmental impact assessment, analyzed the assessability of significant environmental impacts of the Russian nuclear power plant technology selected for implementation, its main connections, cooling water intake, discharge of the heated water into the Danube, and the unit line that carries the electricity generated in the power plant, also taking into account the opinions given on PCD.

The environmental impact assessment study did not address any economic or financial matters related to the installation of the planned units.

The impact assessment study of Paks II takes the latter approach: it examines the impact processes and impacts caused by the impact factors in the various stages of the project, and their territorial coverage, i.e. affected zone by the individual environmental elements and systems.

The content of the environmental impact assessment study is structured on the basis of the general descriptions given in Annexes 6 and 7 of Government Decree 314/2005. (XII. 25.) on the procedural rules of performing environmental impact assessment analyses and issuing integrated permits for use of the environment.

Annex 6 - On the general requirements for the content the environmental impact assessment study
Annex 7 - On the general requirements for the content the environmental impact assessment study

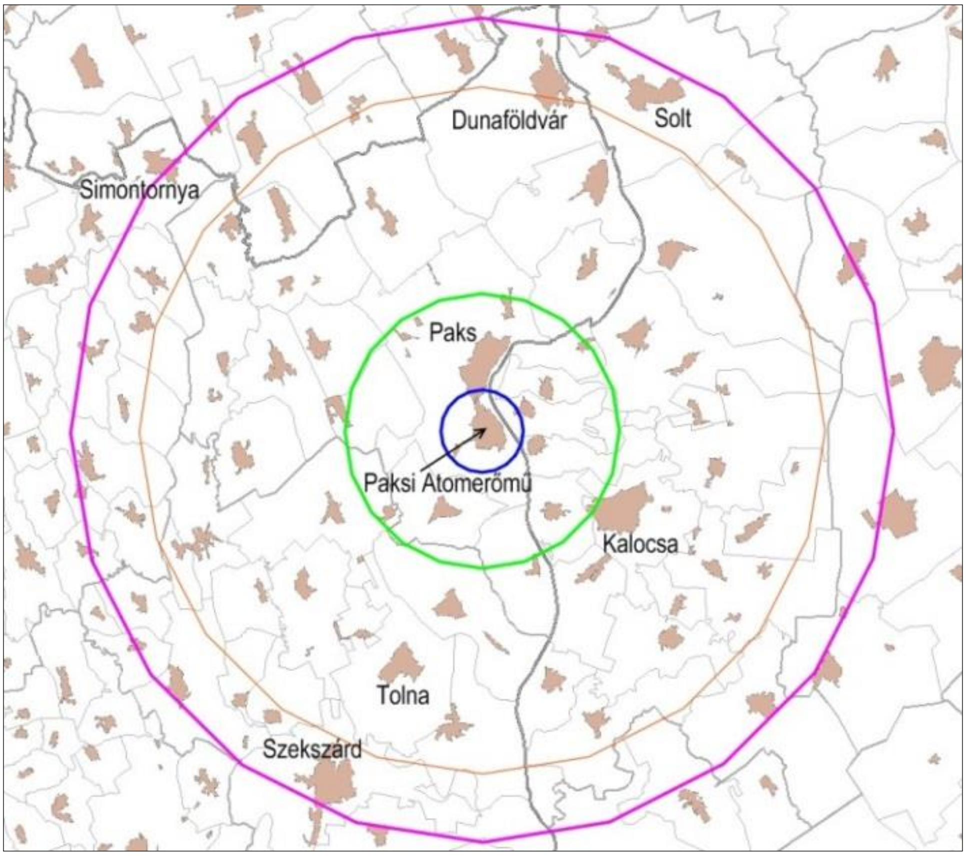
Based on completion of the EIAA and its findings, the EIAS was compiled for those parameters that exert the greatest environmental impact on the individual environmental elements and systems – taking into consideration the given basic condition of the Paks site.

The impact assessment study of Paks II describes and reviews the following topics:

- detailed description of the planned nuclear power plant project and presentation of the basic technological data,
- description of the selected installation area and its immediate and wider environment, location of and the territory required for the activity, and the presentation of the installation site plan
- presentation of the previously examined and considered versions
- specification and calculation of the environmental impacts of the power plant technology on the individual elements and systems of the environment
- delimitation of the areas affected by the planned project
- presentation of cross-border impacts.

Based on all these, the Paks II. Environmental Impact Assessment Study is divided into the following main chapters:

1 Basic information regarding the planned project
2 Forecasts and strategies related to the planned project
3 A general guide to nuclear engineering
4 Description of the planned installation site
5 Possible methods of condenser cooling in the new nuclear power plant units
6 Characteristics and basic specifications of the Paks II Nuclear Power Plant planned to be built on the Paks site
7 Network connection to the Hungarian power grid
8 Potential impact factors and impact matrices of Paks II
9 Social and economic effects
10 Climate profile of Paks and its environs within a 30 km radius
11 Modeling the Danube bed morphology and heat load on the Danube
12 Assessment of water quality in the Danube and other surface waters according to the Water Framework Directive
13 The geological formation and subsurface waters on the site and in its immediate environs
14 Geological formation and subsurface waters in the Danube valley downstream of Paks
15 Noise and vibration
16 Ambient air
17 Non-radioactive wastes
18 Wildlife and ecosystem
19 Radioactive wastes and spent fuels
20 Ambient radioactivity, and exposure of the population living in the vicinity of the site to radiation
21 Exposure of wildlife to radiation in the vicinity of the site
22 Summary impact matrices and aggregate impact areas



blue circle: estimated area of directly affected territories
green circle: estimated area of indirectly affected territories
purple circle: area surveyed for general characterization
orange circle: area of a 25-km radius surveyed for the impacts of supplies

Figure 3*: Various areas surveyed in the EIA [2], [3]*

1.3.3 INFORMATION BY MVM PAKS II

MVM Paks II Atomerőmű Fejlesztő Zrt launched a series of programmes under the title "Business of the Future – Information for Entrepreneurs" with the aim to provide information to Hungarian small, medium-sized and large companies about the project, safety requirements in the nuclear industry, the relevant special technical challenges, the recommended preparatory process, the necessary permits, licences and qualifications.

Briefings were held for the mayors of the region's affected communities, and in order to inform the population an interactive informational lorry is operated as a mobile visitor centre to familiarize the population of Hungary with nuclear energy, its significance, safe and environment-friendly consumption and the importance of its role in Hungarian energy generation. During the preparatory stage of the project, informative materials were compiled for the population about the details of the new project and about the tasks related to licensing and site research, and they were disseminated to every household in the vicinity. We plan to prepare similar informative materials during the next stages of implementation.

The planned project was presented in detail during the "Construction of Paks II – Forum on maintaining nuclear power plant capacity" held at the Budapest University of Technology and Economics, and the timely questions of the projects were addressed at numerous other programmes and scientific forums.

We also regularly provide information on the ongoing work on international forums. One of the most important such events is the Austrian-Hungarian bilateral consultation forum of nuclear authorities, organized every year.

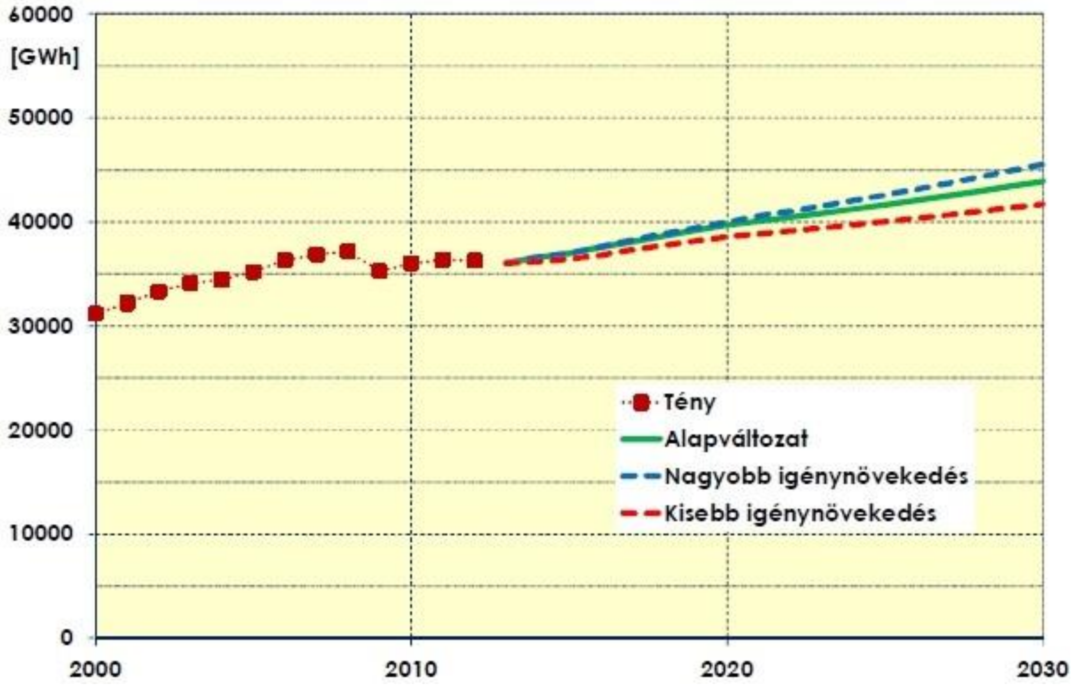
2 FORECASTING ELECTRICITY CONSUMPTION IN HUNGARY

Forecasting long-term developments in the electric power system in Hungary is one of the important statutory tasks of MAVIR Zrt. (MAVIR Hungarian Independent Transmission Operator Company Ltd), the system operator. The system manager must assess the expected future electricity consumption, and must monitor changes in the system-level energy balance, power plant capacity, the public electricity network and consumption.

2.1 FORECASTING ELECTRICITY CONSUMPTION IN HUNGARY UP TO 2030

Since 2012 forecasts on consumer demand and the presentation of medium and long-term capacity development of the Hungarian electric power system have been published in a separate study, based on the electricity consumption and system load data of the past few years and on the economic growth predictions of various economic research institutes. The short-term forecast for the period up to 2018 relies on MAVIR's short and medium-term forecasts, while the period up to 2030 is forecast on the basis of the predictions made in the National Energy Strategy 2030.

The analysis of the period to 2030, included in MAVIR's 2013 consumer demand forecast contains three different scenarios, as illustrated in Figure 4.



Tény – *Fact*
Alapváltozat – Baseline version
Nagyobb igénynövekedés – Faster increase in demand
Kisebb igénynövekedés – Slower increase in demand

Figure 4 *Expected net electricity consumption up to 2030[2-1]*

The **baseline version** compliant with the strategic objectives (marked by a green line in the figure) reckons with an annual 1.5% average increase in the net electricity consumption for the period to follow 2014, and then after 2020 this pace will decline slightly. In addition to the baseline version, as an alternative a **faster demand increase version** *(marked by a blue line)* is also given, with an annual demand growth rate between 1.4–1.7% between 2014 and 2020, slowing to 1.4% by 2030. A **demand slower** than the baseline version *(marked by a red line)* expects demand to grow at 1% p.a. between 2014 and 2020, and a gradual decline to 0.8% p.a. by 2030.

The net electric power consumption is expected (according to the baseline version) to be about 40 TW_h and may increase to 44 TW_h by 2030.

The total electric power consumption (including consumption by the Hungarian power plants as well as system loss) may reach 47.6 TW_h in 2020 and – according to the baseline version – 54.7 TW_h in 2030.

3 GENERAL GUIDE TO NUCLEAR ENGINEERING

3.1 NUCLEAR POWER GENERATION IN THE WORLD

In 2012 the world's total electric power generation was 22,668 TW_h, of 2,461 TW_h was generated by nuclear power plants, i.e. 10.9% of the generated electric power came from nuclear power plants (source: IEA: Key World Energy Statistics 2014). Nuclear power plants typically have a more pronounced role in the electric power generation systems of developed regions, such as Europe, North-America and Japan.

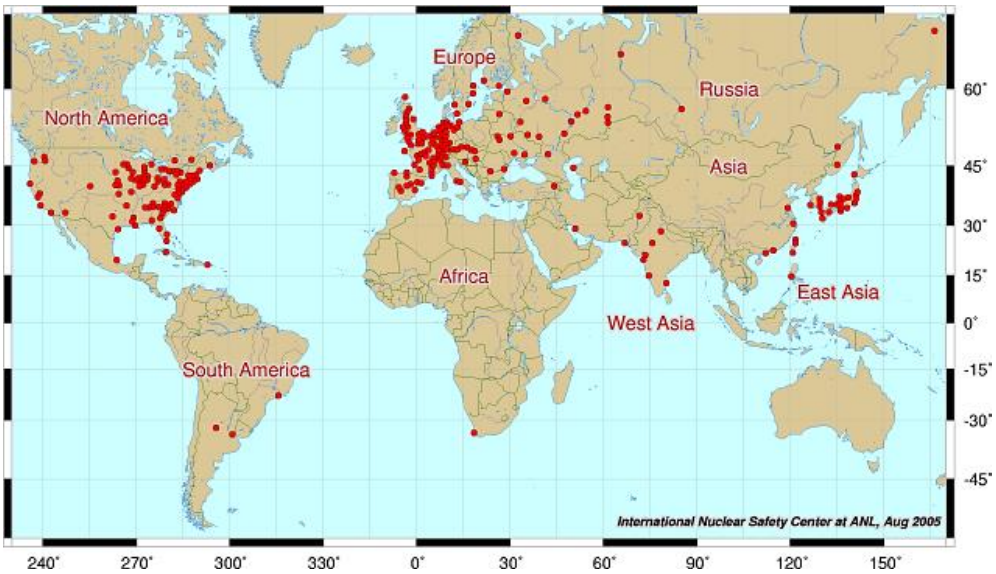


Figure 5 Geographical location of the nuclear power plants of the world [4]

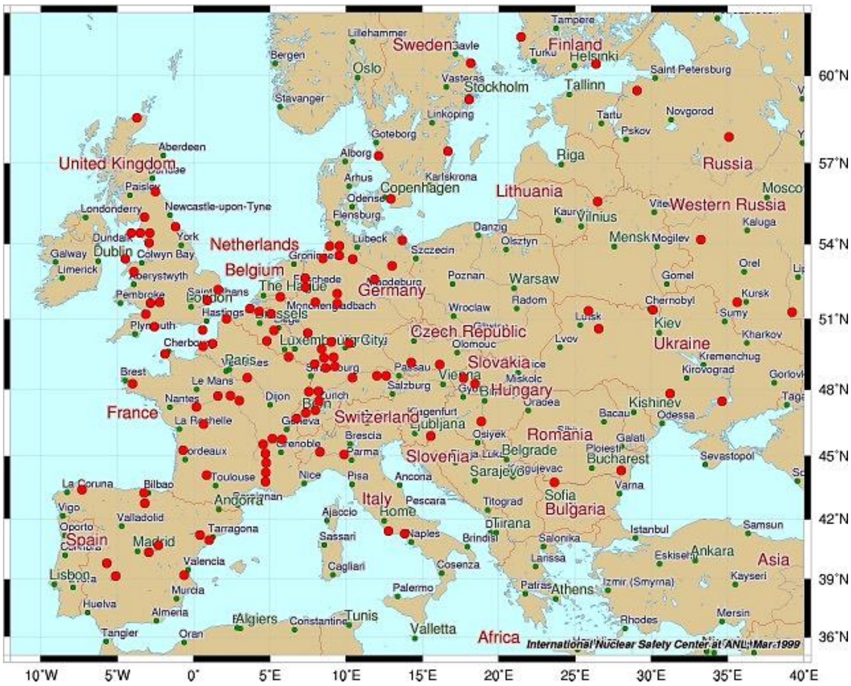


Figure 6: Geographical location of nuclear power plants in Europe [5]

The majority (62.2%) of the currently operating 434 nuclear power plant units work with pressurized water reactors. The overwhelming majority of power plants in the process of construction are also pressurized water reactors (82.6%).

3.2 GENERAL INTRODUCTION INTO PRESSURIZED WATER REACTOR (PWR) UNITS

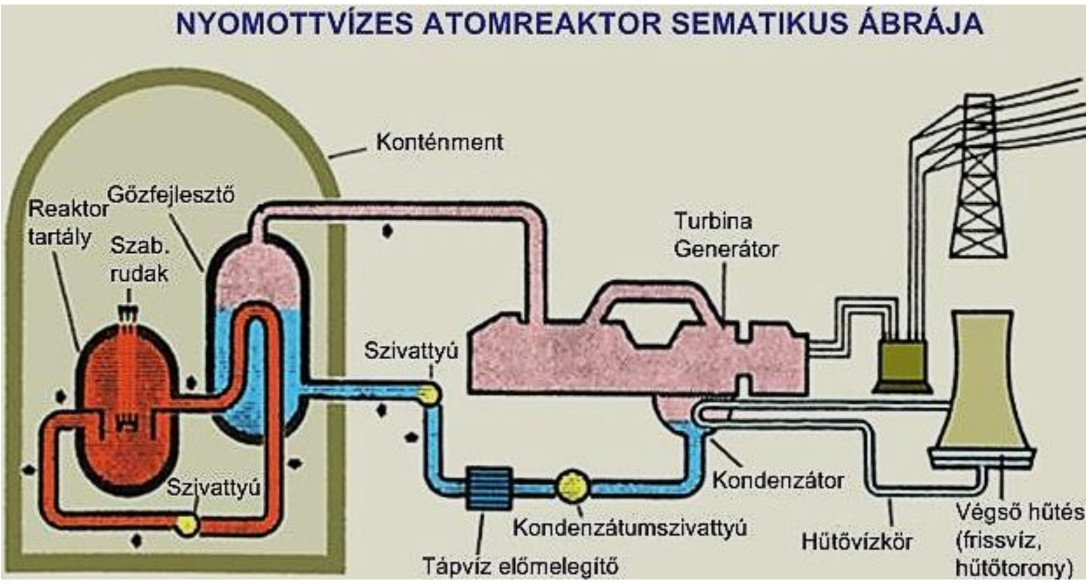
3.2.1 POWER GENERATION PROCESS IN UNITS OPERATING WITH PWR REACTORS

The basis of nuclear energy generation is the regulated and self-sustaining chain reaction based on the fission of atomic nuclei. An extremely large amount of energy is released: the power of a single gramme of ^{235}U released in a fission process corresponds to the energy obtainable from burning about 3 tons of high-quality coal. This released energy constantly increased the temperature of fuel fills, and thus in order to provide for permanent and sustainable energy generation, this heat needs to be removed. Heat is removed by a coolant, which is, in the case of PWR reactors, light water (H_2O). Removed heat energy is used for the generation of electric power.

Pressurized water reactors consist of two closed circuits: the primary and the secondary.

The **primary circuit** consists of a pressurized water, light-water cooled and moderated nuclear reactor, the circulating loops (main water circuit), the main circulating pumps, the heat transfer tubes of the steam generators and the expansion tank. The reactor vessel is a cylindrical pressure tank with a hemispheric bottom and a demountable hemispheric top, which contains the reactor core. In addition to these, the nuclear steam generator, called reactor, connects to numerous other auxiliary systems that have safety functions, improve power plant efficiency and constantly clean the water circuits. The main water circuit absorbs the heat released in the active zone of the reactor, carries it away and transfers it to the secondary circuit in the steam generators. The main function of the steam generator is to use the heat transferred by the primary circuit and generate steam with the parameters suitable for driving the turbines. This equipment is a cylindrical, vertically or horizontally positioned vessel in an airtight space called containment structure, and contains heat exchanger pipes and a built-in steam separator.

The **secondary circuit** is fundamentally the feedwater-side part of the steam generators, and consists of the main steam system, the various high and low pressure parts of the turbine, the condenser and the feedwater system. The function of the secondary circuit is to transform the steam power generated in the steam generator into rotational motion to drive the generator. The bled "exhaust" steam is re-transformed into water (condensed) by using an ultimate heat absorber, which may be sea water, river water or, in the case of tower cooling, air, depending on the features of the particular site.



Nyomottvizes atomreaktor sematikus ábrája–General schematic structure of a PWER reactor
Konténment–Containment
Reaktor tartály–Reactor vessel
Szab. rudak–Control rods
Gőzfejlesztő–Steam generator
Szivattyú–Pump
Turbina generátor–Turbine generator
Tápvíz előmelegítő–Feedwater pre-heater
Kondenzátumszivattyú–Condensate pump
Kondenzátor–Condenser
Hűtővízkör–Coolant circuit
Végső hűtés (frissvíz, hűtőtorony) – Final cooling (fresh water, cooling tower)

Figure 7*: General schematic structure of a PWR reactor[6]*

3.2.1.1 Fuel

The nuclear fuel is found in the active zone.

Natural uranium typically consists of two isotopes: ^{235}U, which splits as a result of the low-energy (or "thermal") neutrons (natural uranium contains only 0.72% ^{235}U), and the isotope ^{238}U, which splits as a result of high-energy (or "fast") neutrons (99.275% of natural uranium is of this kind). No self-regulating chain reaction can be made in a reactor fuelled purely by ^{238}U.

The PWR units fundamentally use enriched uranium-based fuel (UO_2), and the Paks Nuclear Power Plant currently uses this type. This fuel is made by processing and then enriching raw uranium.

3.2.2 CHARACTERISTIC FACILITIES OF PWR-TYPE UNITS

3.2.2.1 Facilities in the main building

NUCLEAR ISLAND

Containment structure: In the interest of safe operation, the primary circuit systems typically (e.g. in the case of the EPR-1600 and the VVER-1200 types) are placed in a double-walled containment structure. The function of the internal containment structure is to retain the radioactive substances that escape in the course of any breakdowns considered during design, and to transfer the released heat.

The internal containment structure is surrounded by an external screening building to ensure increased protection against external impacts (e.g. a major earthquake, hit by aircraft, flood).

Safety system buildings: for the sake of multiple redundancy, there are several safety systems in nuclear power plants (e.g. malfunction zone cooler), and the appropriate operation of any single one of them is sufficient for handling malfunctions. In order to provide for an appropriate spatial separation, they are usually placed in separate buildings or building parts.

Auxiliary building:houses the auxiliary systems of the primary circuit.

Nuclear maintenance facility: a building used for the performance of maintenance related to the primary circuit, and for decontamination.

Waste management building: the liquid and solid radioactive waste generated during unit operation is treated in this building.

Fuel building: used for the management and storage of fresh and spent nuclear fuel

TURBINE ISLAND

Turbine building: The turbine building contains the secondary circuit equipment that transform the heat transferred from the steam generator into mechanical and then electric power, condense the steam that leaves the turbine, and return it to the steam generator.

Water treatment plant: a facility used for the generation of extra water in the quality and quantity appropriate and required for the primary and secondary circuits.

Electric switchboard room: *a building that houses electrical switchboards, control engineering equipment and communication devices.*

Transformer area: *this is the outdoor place of unit transformers and other power plant transformers.*

3.2.2.2 Associated facilities

- ✓ *Spent fuel interim storage:* a building used for the interim storage of the spent fuel generated during the operation of the nuclear power plant (prior to any further processing or final placement without processing)
- ✓ *Diesel generators:* Diesel generators ensure direct current charge in the case of a breakdown (in the interest of appropriate physical separation, they are placed in different buildings).
- ✓ *Healthcare facility:* a facility that contains the healthcare centre, the primary access system, and the offices required for work with the primary circuit.
- ✓ *Water intake plant:* supplies the industrial water required for the power plant. Most of the water taken from the Danube is used for cooling.
- ✓ *Chemical depository:* a building for storing the chemicals required for operation.
- ✓ *Storage room for industrial gases:* a building that contains the gases required for operation.
- ✓ *Nuclear maintenance facility:* A building used for the performance of maintenance related to the secondary circuit.

- ✓ *Fire service facilities:* a building within the boundaries of the power plant, serving as a branch office of the fire service, and containing the fire water and fire fighting systems.
- ✓ *Electric substation:*ensures transfer of the electric power produced by the generators to Hungary's national grid.
- ✓ *Waste storage: serves as a store for non-radioactive waste generated in the nuclear power plant.*
- ✓ *Civil defence shelter:*protects the operating and hazard control staff during emergencies.
- ✓ *Protected control point* (with reserves): provides a working environment for emergency control in the event of emergencies, and protects the troubleshooting and cleanup staff.
- ✓ *Environmental monitoring systems:* include the system of environmental sampling and measurements.
- ✓ *Infrastructure:* access roads and railway rails to the power plant, drinking water and sewage systems, etc.
- ✓ *Physical defence systems: reception desks, access systems, fences etc.*

4 NUCLEAR SAFETY

In designing, installing and operating the new nuclear power plant units, the first and foremost priority is to ensure nuclear safety.

4.1 BASIC PRINCIPLES OF NUCLEAR SAFETY

Nuclear safety is a key aspect of nuclear power.

Nuclear power plants must comply with three basic safety requirements:

I. The nuclear chain reaction must stop in the case of abnormal operation.
II. When the chain reaction is stopped, the stable and safe cooling of fuel cells must be ensured.
III. Quantities of radioactive pollutants over the limit must be prevented from escaping into the environment.

The safety of a nuclear power plant is ensured by applying the principle of defence in depth, with an emphasis on the prevention of emergencies.

The basic principles for and the five levels of such a multi-level protection were developed by the International Atomic Energy Agency. National nuclear safety authorities strive to apply these principles in their own regulations to the maximum possible extent. Defence in depth is applied in each facility according to its local characteristics.

The following are the basic goals of defence in depth:

- ❖ preventing accidents through conservative engineering,
- ❖ preventing abnormal operation through constant monitoring,
- ❖ preventing the escalation of any abnormal operation and reducing its consequences through *integrated defence devices*,
- ❖ in the case of events beyond the design basis, having proper tools and defined measures for reducing their consequences.

The safety of nuclear power plants is ensured by the complex system of engineering solutions and operating requirements.

Defence in depth defines five hierarchic levels of safety related events, equipment and procedures. Each level is aimed at preventing the occurrence of the next one.

Level	Objective	Implementation
Level I	Preventing abnormal operation	High quality, conservative planning
Level II	Detecting abnormal conditions and preventing abnormal operation	Proper operation of supervisory and control systems
Level III	Management of design-basis emergencies	Safety systems and procedures
Level IV	Management of serious accidents, moderating their severity and easing their consequences	Complementary tools, measurements, actions as well as accident management guides
Level V	Reducing the consequences of radioactive emissions outside the facility	Accident prevention emergency response plans

Table 4: Five levels of protection built on one another

- Level I is related to the engineering process, where the power plant must be designed in a conservative manner, with operation and safety reserves, using solutions that minimize the possibility of human error (automation, clear-cut handling). In this phase, all external events must be defined that should not be able to endanger the operation of the nuclear power plant (earthquakes, extreme weather etc.).
- Level II is about having those tools and procedures at hand through which the power plant can be kept within the designed operating envelope, so that safety barriers are not crossed. These include continuous measurements (of pressure, temperature, circulation etc.), as well as periodical tests and trials, maintenance work and inspections.
- Level III involves systems and measures that ensure the operation of safety functions in emergencies included in the design-basis conditions). Some events (such as inherent material faults or natural disasters) cannot be prevented even by the most careful engineering, installation and operation. This level involves the automatic stoppage of the chain reaction, while ensuring the continued cooling of the fuel and keeping radioactive emissions below the limit values, for all of which the corresponding safety systems must be set up.
- Level IV represents very low probability events extending beyond designed-for emergencies. At this level, safety systems cannot completely fulfill their role and there is a risk of zone meltdown and radioactive pollution. Despite their low probability, the severity of possible consequences makes it necessary for nuclear power plants to have the tools that hinder the escalation of such accidents, reduce their impacts and provide time for other measures to be taken (such as delivering additional equipment to the site, helping the population shutter up or move away).
- Level V kicks in when all previous levels have failed. This involves the escape of significant amounts of radioactive pollutants into the environment, which, in turn, requires the intervention of authorities in accordance with emergency scenarios developed for such events.

Basic Design Principles

- Criteria for choosing the geographical location of the site
- Evaluating the potential dangers of operation
- Defining the design basis and analyzing its events

  Fundamental requirements include the following:

  - *Ability to be driven to subcritical state*
  - *Removal of residual heat*
  - *Keeping radioactive emissions under the limit values*
- Minimizing anomalies beyond the design base
- Keeping radiological exposure at the lowest reasonable level

SYSTEM OF ENGINEERED BARRIERS

The ***system of engineered barriers*** serves to prevent radioactive pollutants from getting out into the environment, or reduce their escape. These barriers set up one after the other are designed to block pollutants from spreading further once they escaped from the previous level. The four physical barriers are:

1. the fuel matrix (UO2),
2. the fuel casing (the airtight casing of the fuel cells),
3. the pressure barrier of the primary circuit (of the reactor vessel and other systems included in the primary circuit),
4. the safety mantle called containment structure (airtight, usually with a double wall).

Üzemanyag mátrix–Fuel matrix
Üzemanyag burkolat–Fuel casing
Primerköri nyomáshatár–Primary circuit pressure limit
Konténment–Containment structure

Figure 8: Engineered barriers in the case of nuclear power plant units[7]

DOUBLE-WALLED CONTAINMENT STRUCTURE

The containment structure is a component of outstanding significance in defence in depth, as this is the last barrier in the internal space of the nuclear power plant between radioactive substances and the environment.

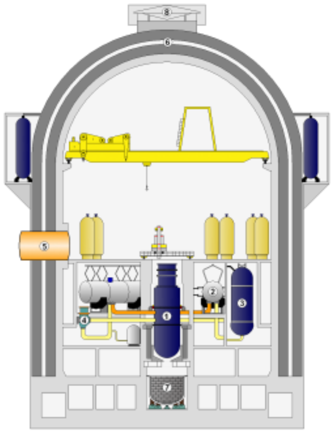


Figure 9: Cross-section of the double-walled containment structure [7]

Permanent and safe cooling of the reactor fuel must be ensured under any condition whatsoever. In the case of any pipe burst, cooling is ensured by the emergency cooling system, in a passive or active manner. If the pressure falls, the passive cooling system feeds water into the reactor and ensures cooling until the pumps start operation. The active emergency cooling system consists of a high-pressure and a low-pressure part, and reserve coolant is stored in large tanks to replace evaporated water.

Most safety systems need electric power to operate. These systems must remain serviceable in the case of a power loss. This is ensured by emergency Diesel generators, which automatically start when needed and provide uninterrupted power to consumers which are of key importance for the safety of the nuclear power plant.

One structure used widely for handling meltdowns in the course of serious accidents is the “core catcher”: the melting of the concrete below the reactor vessel is prevented by rooms built at the bottom of the core that facilitate the spread of the melt, or by substances are placed under the vessel which the core melt can not penetrate.

Reinforcement of the containment structure and maintenance of structure integrity over the long term are of outstanding significance. Containment structure integrity is also protected by the procedures applied for the treatment of the hydrogen gas – explosive when it reaches certain concentration if mixed with the containment air – generated in the course of hypothetical grave accidents. In the passive process, the hydrogen released to the air is continuously transformed into water steam by catalytic recombination systems, while in the active process, “hydrogen igniters” are applied, which deliberately ignite the hydrogen gas accumulated in the containment structure before the hazardous concentration is reached to prevent reaching the explosive concentration.

In most countries current requirements demand that the containment structure withstand even a direct hit by a large passenger airplane.

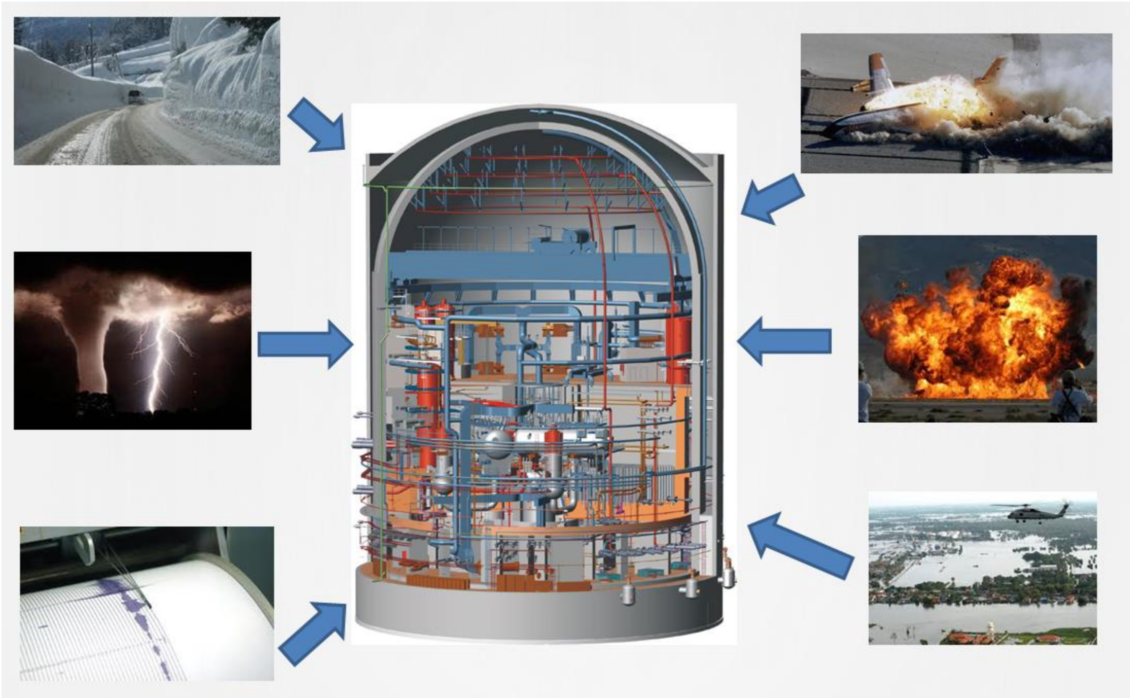


Figure 10*: The first containment structure provides protection against external impacts[7]*

The most important guarantee for the safety of the nuclear power plant is called ***inherent safety.*** In certain accident situations, inherent physical and heat engineering processes and barriers operate in the reactor which slow down and finally stop unfavourable developments. This inherent safety ***is always ensured irrespectively of the operability of the safety and defence devices.*** This reactor feature is type-specific. Pressurized water reactors, currently the most wide-spread type in the world, fall into this category. The VVER-440 reactors of the Paks Nuclear Power Plant are also of this type. (The other type, developed and built in the former Soviet Union, is the RBMK type, which does not meet all the conditions an inherent safety. The reactors of the nuclear power plant at Chernobyl, where an accident happened on April 26, 1986, belong to this type. It was proven that one of the fundamental reasons of the accident was the lack of inherent safety. For this reason, the disaster of the Chernobyl nuclear power plant does not mean that other types of reactors are unsafe. Due to the lack of inherent safety, Chernobyl type reactors have been shut down nearly everywhere in the world.)

Another important guarantee of protection against nuclear power plant accidents is the application of ***external safety devices***, which prevent the progress and deterioration of various accident situations, and complement inherent safety. Within the framework of these external safety devices, an increasing role is played by the ***passive defence systems***, which can operate without any external power supply.

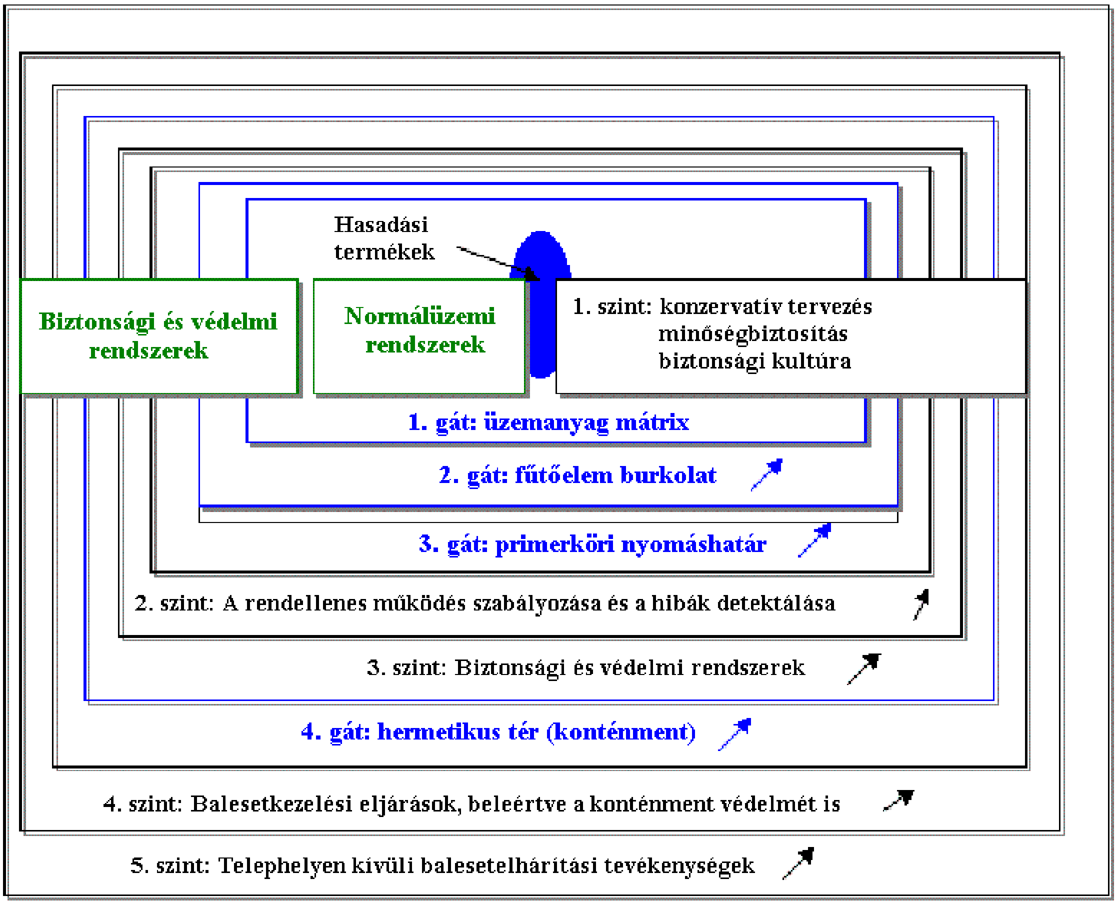
As a result of the above, nuclear power plants can be built today with a probability of grave accidents affecting the environment being less than 10^{-6} per reactor year.

The probability of a potential risk must be kept at the lowest possible level in accordance with the ALARA (As Low as Reasonably Achievable) principle, to guarantee the best reasonably achievable safety.

The fundamental goal of defence in depth is to maintain the integrity of the physical barriers with the help of automatic or manual safety and protection systems against inherent or external events which jeopardize their integrity.

HIERARCHY OF SAFETY AND PROTECTION SYSTEMS

The five levels of defence in depth, applicable to new units, the four physical barriers and the relationship between automatic and manual interventions are plotted in the following figure.



Hasadási termékek–Fission products
Biztonsági és védelmi rendszerek–Safety and defence systems
Normálüzemi rendszerek–Normal operation systems
1.szint: konzervatív tervezés, minőségbiztosítás, biztonsági kultúra–Level 1: conservative design, quality assurance, security culture
1. gát: üzemanyag mátrix–Barrier 1: fuel matrix
2. gát: fűtőelem burkolat–Barrier 2: fuel casing
3. gát: biztonsági és védelmi rendszerek–Barrier 3: Safety and defence systems
4. gát: hermetikus tér (konténment) –Barrier 4: Containment (airtight area)
4. szint: balesetkezelési eljárások, beleértve a konténment védelmét is–Accident management procedures, including containment defence
5. szint: telephelyen kívüli balesetelhárítási tevékenységek–Accident prevention activities outside the site

Figure 11*: Protection barriers, defence in depth levels and the hierarchy of interventions[3-14]*

In the case of new units, breakdowns that were previously classified as “design extension conditions” (such as multiple failures) are now part of the design basis. For this reason, the content of the “design extension” category differs between current and new reactors. In the case of the currently operating reactors, in depth protection deals with nuclear fuel mainly in those operational states when the fuel is in the reactor. In the case of new units, it includes all the possible states of the nuclear fuel (including those situations where the fuels are stored in the spent fuel pool).

In the course of developing III^{+} generation reactors, key design objectives included preventing serious accidents and reducing the consequences of extremely low probability accidents. The applied design and technological solutions ensure that no radioactive substances are released to the environment even if serious accidents happen, and thus III^{+} generation units do not have any significant impacts on the population and the environment of the power plant even in the case of serious accidents.

Stress Test

Following the accident caused by an earthquake and an unprecedented tidal wave in the Fukushima nuclear power plant, in March 2011 the European Council called for a targeted safety survey in all nuclear power plants of the European Union. In the course of the survey the safety of nuclear power plants and their ability to withstand extreme natural impacts, such as floods, earthquakes, extreme weather were assessed. The operators of the nuclear power plants carried out self-assessment against the specified criteria, and submitted the results to their respective national nuclear authorities for approval. The national authorities prepared national reports, which were assessed by international expert groups, holding on-site consultations in several cases.

Besides those member states of the EU where nuclear power plants are in operation, Ukraine and Switzerland also took part in the surveys. The survey, which was conducted in 17 countries, finally came to the conclusion that European nuclear power plants had sufficient safety reserves and they found no deficiencies in any of the nuclear power plants that would make it necessary to shut them down. At the same time, the report by the European Commission included several recommendations concerning increased safety, for the implementation of which the member states developed programs.

The targeted safety survey of the European Union concerning the Paks Nuclear Power Plant clearly had positive findings. The report emphasized good practices that should be modelled by others in several areas. No critical or significant deficiencies were found and some of the recommendations concerned developments in progress.

Based on the recommendations of the stress test, Paks Power Plant developed a programme to enhance safety, with periodic reports on its implementation. Similar programs are implemented in other power plants of the EU and the relevant reports will be summarized for EU level assessment. [9], [10], [11]

SAFETY ANALYSES

Safety analyses using *deterministic* and *probabilistic* methods as well as ***safety reports*** prepared on their basis are of basic importance in nuclear safety licensing.

The most serious consequence of a breakdown in a nuclear power plant is contaminating the environment with radioactive material, which can mainly happen in the wake of serious damage done to the active zone, especially in a meltdown, if the contamination is not held back by the containment structure. Therefore ***Probabilistic Safety Analyses*** (PSA) primarily deal with the probability of ***zone damage***. This requires the examination of all the possible chains of events that can lead to zone damage with the help of deterministic analyses and calculating their probability individually. Their sum total characterizes the safety of the nuclear power plant. This analysis also reveals the weak points of the nuclear power plant from the point of view of safety. The results make it possible to create means and equipment to enhance safety. Safety analyses are conducted at various levels.

The purpose of probabilistic safety analyses is the calculation of the probable frequency of level 1 events (involving zone damage) and level 2 events (involving heavy release of radioactive material).

4.2 NUCLEAR SAFETY REQUIREMENTS

Article 2 of Act CXVI of 1996 on Atomic Energy (as effective on July 16, 2014) stipulates:

> *"Article 29 – nuclear safety: "Ensuring proper operating conditions, preventing accidents and mitigating the consequences of accidents in every phase of the life cycle of the nuclear facility, to protect employees and the public against the hazards resulting from the ionizing radiation of nuclear facilities."*

Act CXVI of 1996 on Atomic Energy specifies the general requirements for the peaceful use of nuclear energy, and lays down the rights and obligations of the parties involved in nuclear energy use. The regulations on the execution of the Atomic Energy Act assign the matters related to nuclear safety and nuclear safety licensing to the competence of the Hungarian Atomic Energy Authority.

During the licensing of new nuclear power plant technology, special attention shall be paid to checking whether the planned nuclear power plant to be established meets the nuclear safety requirements.

Nuclear power plants are engineered, and their equipment and safety systems are designed so that even in the case of an accident, the safety of the power plant's surroundings should be guaranteed as much as possible. The continuous supervision of safe operation and the development of measures aimed at increasing safety are basic requirements for the operators. The supervisory authority allows the commissioning and operation of a reactor, or actions to be carried out on certain parts of the reactor only if there is proof that the safe operation of the reactors can be guaranteed.

Compliance with the geological and nuclear safety requirements must be confirmed in the framework of a site licensing procedure to be conducted by OAH on the basis of the Nuclear Safety Regulations (NSR) attached as annexes to Government Decree No. 118/2011. (VII.11.) on the nuclear safety requirements of nuclear facilities and the related activities of authorities.

OAH determines the adequacy of the site and the geological base data related to the site according to the results of highly detailed assessments. The site assessment programme was developed to meet the latest international requirements (post-Fukushima). The site assessment programme was evaluated by the experts of the International Atomic Energy Agency (IAEA) within the framework of an independent supervisory procedure.

In accordance with the effective statutory regulations (NSR), the power plant units to be established in the Paks site are to be protected against the impact of large-sized, civilian aircraft. There are extremely stringent quality control criteria in place regarding the equipment and buildings of the power plant units. As the supplier of the units undertook to meet the European Utility Requirements (EUR); they will employ various architectural and other technical solutions during implementation to ensure facility protection, even in the case of an aircraft impact.

Building and system-level permits are to be acquired for ABOS class buildings, structural parts, systems and system elements that affect the nuclear safety of the nuclear power plant.

The safety requirements applicable to the nuclear facilities to be installed in Hungary are fundamentally determined in Hungarian statutory regulations. However, it is also advisable to take into consideration the relevant international safety regulations, the IAEA safety directives, the American ASME standards, as well as the EUR recommendations in order to ensure a uniform level of nuclear safety conformance for the different reactor types built in different countries.

A requirement concerning the unit type to be erected is that during the licensing procedure carried out before implementation, it must be evidenced that the emission recommendations applicable to the unit type in case of various design breakdowns conform the Hungarian and international regulations in effect at the time of licensing.

NUCLEAR SAFETY REGULATIONS (NSR)

NSR, the domestic classification (Annex 10 to Government Decree No. (118/2011. (VII. 11.), Operational state 163) defines the individual operational states of new nuclear units according to the following:

Design Basis (DB)				Design Extension (DE)	
Normal operational condition	**Design Basis Conditions**			**Design Extension Conditions**	
Normal operation	Expected operational events	Design basis failures		Design extension failures	Serious accidents
		Low-frequency design basis condition failures	Very low probability design basis failures		
DBC1	**DBC2**	**DBC3**	**DBC4**	**DEC1**	**DEC2**
Frequency (probability) (f [1/year])					
1	$1 > f > 10^{-2}$	$10^{-2} > f \geq 10^{-4}$	$10^{-4} > f \geq 10^{-6}$		

Table 5: Classification of individual operational states according to the probability of occurrence

NORMAL OPERATION

121 Normal operation (DBC1)

*"The **operation** of a nuclear facility by observing the Operational Conditions and Limits approved by the nuclear safety authority, including, in the case of nuclear reactors and nuclear power plants, **load changes, shutdown, start-up, fuel rod replacement, maintenance, tests, and other planned operations**."*

DESIGN BASIS CONDITIONS

*179 **Expected operational event (DBC2)***

"A process triggered by an initial event assumed in the design basis condition and analyzed according to the principle of single failure, and covered by these analyses, which is highly likely to take place during the operating time of the nuclear power plant."

*159 **Design basis failures (DBC3 and DBC4)***

"A process triggered by an initial event assumed in the design basis condition and analyzed according to the principle of single failure, and covered by these analyses, which has a low probability of occurrence during the operating time of the nuclear power plant, and which results in fuel rod damage of only the type and extent defined in the designs."

DESIGN EXTENSION CONDITIONS (DEC)

155 Design extension failure (DEC1)

A process that falls outside the scope of expected operational events and service breakdowns, which cannot be excluded, but may only occur as a consequence of several unrelated failures, and which may have more serious consequences than the processes belonging to the design basis conditions, causing zone damage without meltdown.

*145 **Serious accident (DEC2)***

A state of accident that involves significant damage to the reactor zone and includes meltdown, which has more serious external affects than design basis and design extension conditions.

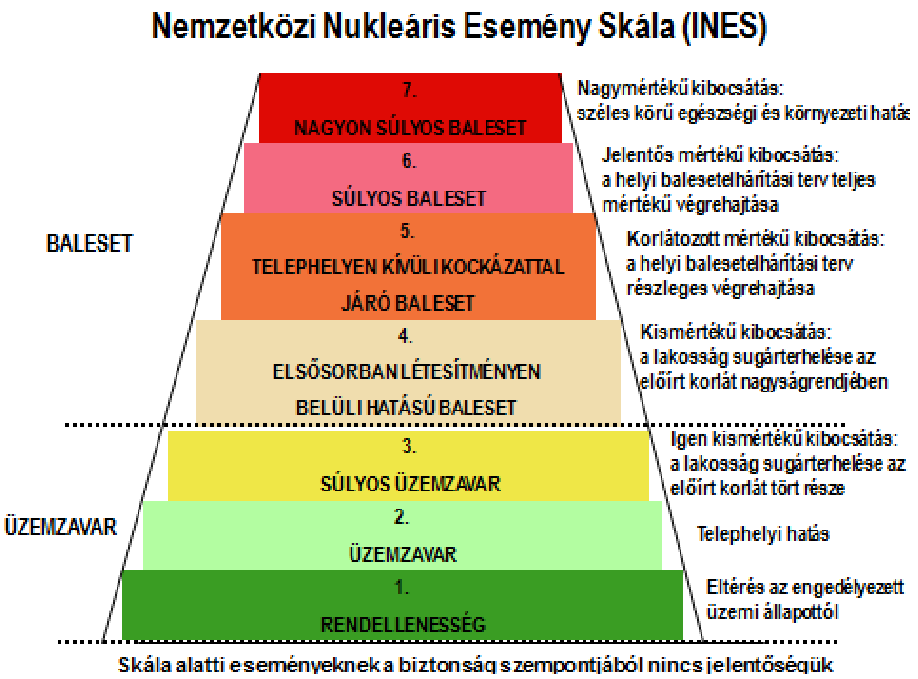
4.3 INTERNATIONAL NUCLEAR EVENT SCALE

In order to facilitate the spread of information concerning nuclear events and to promptly and **adequately inform the public, the social and political organizations and the media,** the Nuclear Energy Agency (NEA) of the Organization for European Co-operation and Development (OECD) and the International Atomic Energy Agency (IAEA) developed the International Nuclear and Radiological Event Scale (INES).

The INES scale is intended to **inform and notify the public using a comparative scale** about the quality and the severity of the events, incidents and accidents and their impacts on safety in nuclear power plants or other nuclear facilities.

The INES scale rates events on a scale of seven levels, differentiating three levels in the case of incidents (operational failures) and four levels of accidents.

The International Nuclear and Radiological Event Scale is shown in the following figure.



Baleset– accident
7. Nagyon súlyos baleset – major accident
Nagymértékű kibocsátás: A helyi balesetelhárítási terv teljes mértékű végrehajtása–Significant emission: widespread health and environmental effects
6. Súlyos baleset –serious accident
Jelentős mértékű kibocsátás: A helyi balesetelhárítási terv teljes mértékű végrehajtása – Significant emission: full implementation of planned local countermeasures
5. Telephelyen kívüli kockázatokkal járó baleset – accident with wider consequences
Korlátozott mértékű kibocsátás: a helyi balesetelhárítási terv részleges végrehajtása – Limited emission: implementation of some planned local countermeasures
4. Elsősorban létesítményen belüli hatású baleset –accident with local conseuqences
Igen kismértékű kibocsátás:a lakosság sugárterhelése az előírt korlát tört része – Minor emission: radioactive exposure of population within specified limits
3. Súlyos üzemzavar –serious incident
Igen kismértékű kibocsátás: a lakosság sugárterhelése az előírt korlát tört része – Very small emission: radioactive exposure of population only a fraction of the specified limits
2. Üzemzavar – incident
Telephelyi hatás – Impact within the facility
1. Rendellenesség –anomaly
Eltérés az engedélyezett üzemállapottól – Diversion from the normal operating conditions
Skála alatti eseményeknek a biztosnág szempontjából nincs jelentőségük – Events under the scale have no safety-related significance.

Figure 12 International Nuclear and Radiological Event Scale (INES)

Deviations from the normal operational level are rated by levels 1-7 on the INES scale, and there are three levels of operating failures and four levels of accidents.

The accident that took place in the Chernobyl nuclear power plant in 1986 is classified as level 7 on the INES scale. The accident seriously affected people's health and the environment. One of the main considerations in developing the criteria for rating on the INES scale was to clearly distinguish less serious events with less extensive impacts from this very serious accident. Thus, they rated the accident that happened at Three Mile Island (TMI) nuclear power plant in 1979 as level 5 on the INES scale.

Events of any level on the scale have to be reported to the National Nuclear Energy Office (OAH) and the Vienna headquarters of the International Atomic Energy Agency (IAEA) and also to other organs designated by local and international treaties, within the specific timeframe required for the given level.

The events are rated in Hungary by the operative technical personnel of the Paks Nuclear Power Plant according to Guide no. 1.48. of the OAH and based on the Nuclear Safety Regulations (NSR), which is approved by the OAH. The Information and Visitor Centre of the Paks Nuclear Power Plant issues a short, clearly understandable public announcement about all event on the scale and forwards it to the Hungarian Press Agency.

Table 6 shows the general criteria of nuclear event rating, and Table 7 gives examples for the application of the INES criteria for rating events in nuclear facilities.

Description and INES level	People and environment	Engineering control in the facility and radiological barriers	Defence-in-depth
Major accident INES 7	Major release of radioactive material with widespread health and environmental effects requiring implementation of planned and extended countermeasures		
Serious accident INES 6	Significant release of radioactive material likely to require implementation of planned countermeasures.		
Accident with wider consequences INES 5	Limited release of radioactive material likely to require implementation of some planned countermeasures. Several deaths from radiation.	Severe damage to reactor core. Release of large quantities of radioactive material within an installation with possible exposure of (one or more members of) the population. This could arise from a major criticality accident or fire.	
Accident with local consequences INES 4	Minor release of radioactive material unlikely to result in implementation of planned countermeasures other than local food controls. At least one death from radiation.	Fuel melt or damage to fuel resulting in more than 0.1% release of core inventory. Release of significant quantities of radioactive material within an installation with a high probability of significant public exposure.	
Serious incident INES 3	Exposure in excess of ten times the statutory annual limit for workers. Non-lethal deterministic health effect (e.g., burns) from radiation.	Exposure rates of more than 1 Sv/h in an operating area. Severe contamination in an area not expected by design, with a low probability of significant public exposure.	Near accident at a nuclear power plant with no safety provisions remaining. Lost or stolen highly radioactive sealed source. Misdelivered highly radioactive sealed source without adequate procedures in place to handle it.
Incident INES 2	Exposure of a member of the public in excess of 10 mSv. Exposure of a worker in excess of the statutory annual limits.	Radiation levels in an operating area of more than 50 mSv/h. Significant contamination within the facility into an area not expected by design.	Significant failures in safety provisions but with no actual consequences. Found highly radioactive sealed orphan source, device or transport package with safety provisions intact. Inadequate packaging of a highly radioactive sealed source.
Anomaly INES 1			Overexposure of a member of the public in excess of statutory annual limits. Minor problems with safety components with significant defence-in-depth remaining. Low activity lost or stolen radioactive source, device or transport package.
No safety significance (Below scale/INES 0)			

Table 6: General criteria of rating nuclear events [12]

Description and INES level	People and environment	Engineering control in the facility and radiological barriers	Defence-in-depth
Major accident **Level 7**	Chernobyl 1986 Widespread health and environmental effects. Environmental release on a significant part of the zone inventory.		
Serious accident **Level 6**	Kyshtym, Russia, 1957 Significant release of radioactive material to the environment after the explosion of a high-activity waste container.		
Accident with wider consequences **Level 5**	Windscale Pile, UK, 1957 Release of radioactive material to the environment, after the reactor zone caught fire.	Three Mile Island, USA, 1979 Severe damage to the reactor zone.	
Accident with local consequences **Level 4**	Tokaimura, Japan, 1999 Lethal exposure of workers owing to a critical event in the nuclear facility .	Saint-Laurent des Eaux, France, 1969 Melting of one of the fuel channels in the reactor, without release outside the facility.	
Serious incident **Level 3**	No precedent.	Sellafield, UK, 2005 Release of significant amount of radioactive material contained within the facility.	Vandellos, Spain, 1989 Near-accident due to fire, which stopped the safety system in the reactor.
Incident **Level 2**	Alucha, Argentine, 2005 Exposure of a worker in excess of the statutory annual limits in an energetic reactor.	Cadarche, France, 1993 Radioactive contamination within the facility into an area not expected by design.	Forsmark, Sweden, 2006 Impaired safety functions and the failure of the emergency power supply system with a common cause in the nuclear power plant.
Anomaly **Level 1**			Damage done to the operation limits in a nuclear facility.

Table 7: Examples of rating events in nuclear facilities to illustrate the INES criteria [12]

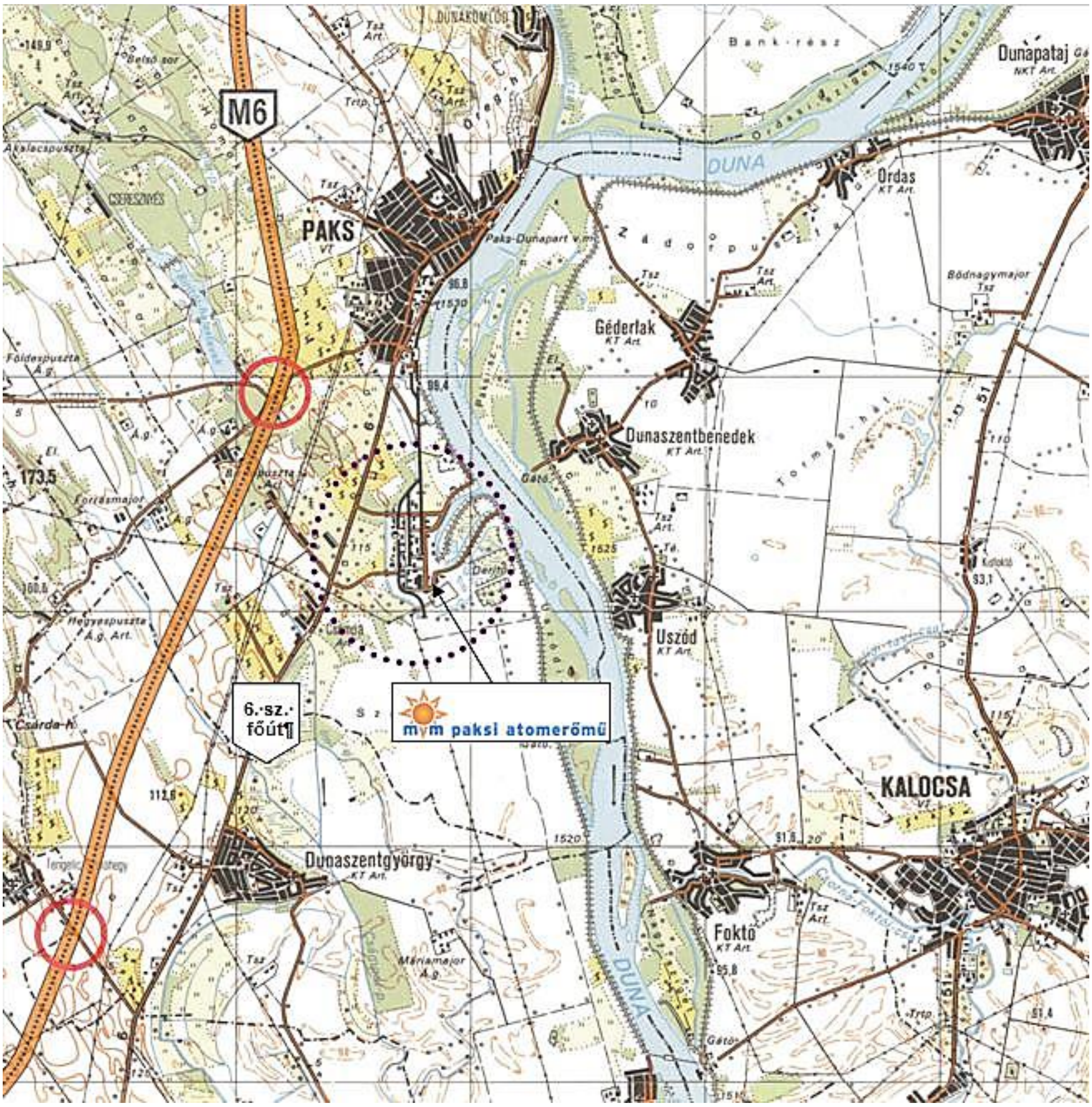
The two tables above do not contain the level 3 serious failure that took place on April 10, 2003 in unit 2 of the Paks Nuclear Power Plant or the extremely serious, level 7 accident that took place on March 11, 2011 in units 1, 2 and 3 of the Fukushima Daiichi Nuclear Power Plant in Japan.

5 DESCRIPTION OF THE PLANNED INSTALLATION SITE

The planned installation site of the new Paks II nuclear power plant units falls within the boundaries of the site of the Paks Nuclear Power Plant.

The site of the Paks Nuclear Power Plant is located in Tolna County, 118 km south of Budapest.

The plant lies 5 km south of the centre of Paks, 1 km west of the River Danube and 1.5 km east of Main Road No. 6. The following figure shows the location of the site and its immediate environs.

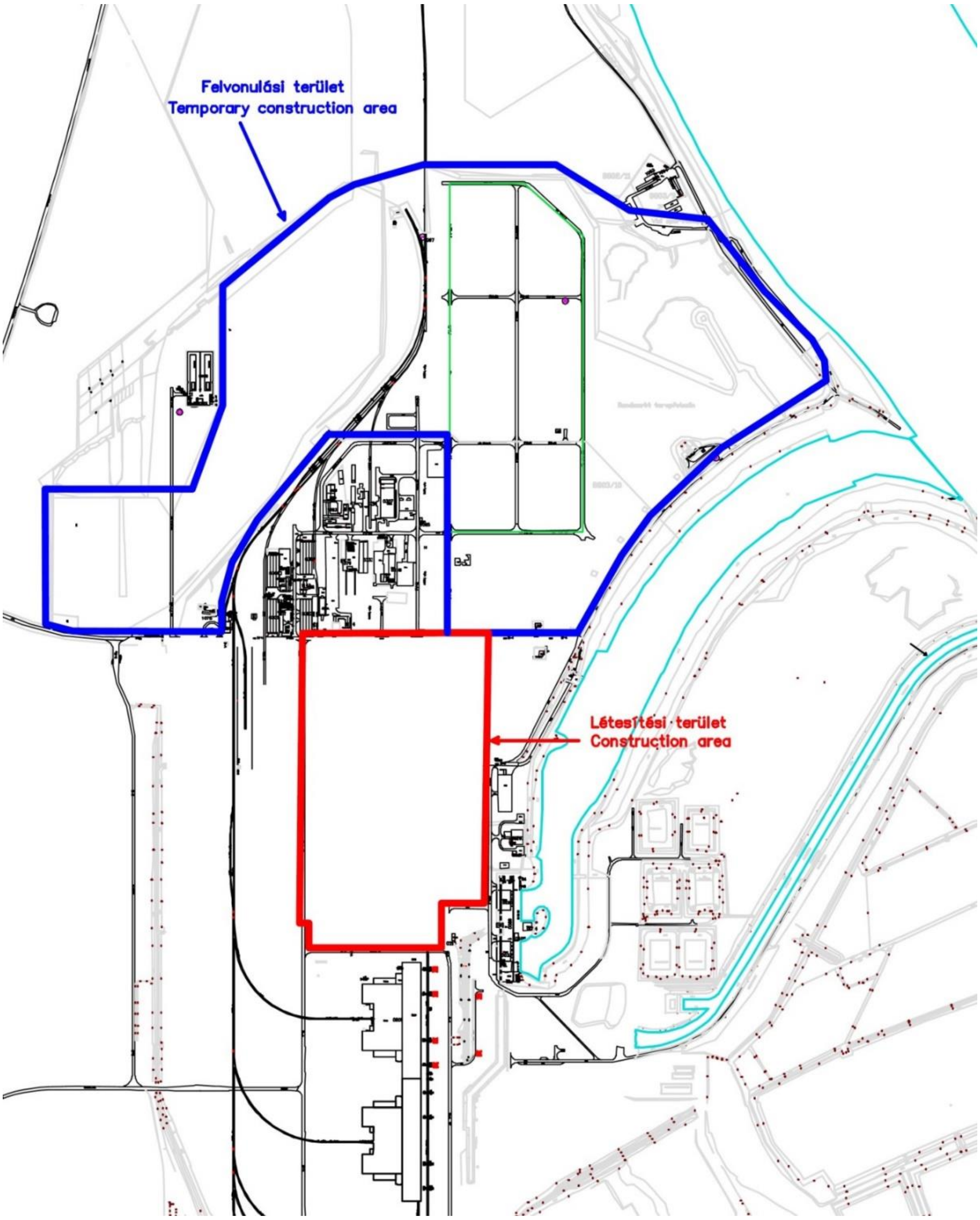


MVM Paksi Atomerőmű – MVM Paks Nuclear Power Plant

Figure 13*: General map of the Paks Plant [13]*

5.1 PAKS II INSTALLATION AREA WITHIN THE BOUNDARIES OF THE SITE OF THE PAKS NUCLEAR POWER PLANT

For the purposes of implementing the new nuclear power plant units, the areas north of the existing units of the Paks Nuclear Power Plant can be taken into account. The area delineated by the red line, shown in the figure below, will be the operating area of the new units and the one delineated by the blue line will serve as a temporary construction site.



Legend
Red line: operating geographical scope
Blue line: temporary construction area

Figure 14 *The Paks site with the location of the planned new nuclear power plant marked*

The total area is 105.8 ha, of which operating facilities and the temporary construction will occupy 29.5 ha and 76.3 ha, respectively. The operating area will accommodate the power plant units, the auxiliary equipment and systems providing support as well as other buildings, and the temporary construction site will offer a suitable location for construction in the implementation phase.

Figure 15*: Location of the planned units [14]*

5.2 INFRASTRUCTURAL CONNECTIONS OF THE INSTALLATION SITE

Source: Analysis of the Items Beyond the Contractor's Scope for the new nuclear power plant units to be established at the Paks site, 2013, MVM ERBE Zrt.

A task of major importance in the preparatory phase of the investment is studying the accessibility of the designated development area and the feasibility of the supply of a large amount of equipment. The area earmarked for the construction of the new units is accessible by road, rail and water; however, the physical condition of the current infrastructure does not make or only partially makes daily commuting or the supply of a large amount of equipment possible in the installation period.

Both the operating and the temporary construction sites of the new nuclear plant are accessible via the M6 motorway (Paks southern exit) and Main **Road** No. 6. There are separate driveways leading to the northern gate and the southern gate of the nuclear power plant. Several options for accessibility by road have been studied in advance:

- implementation of a new access road branching off the exit of the M6 motorway;
- upgrading the road network connecting the neighbouring settlements (Tengelic, Kölesd, Nagydorog, Németkér and Bölcske) with Main Road 6, to 2 x 1 lane of standard width;
- widening and upgrading the current dirt road to Gerjen.

The Gerjen-Paks Nuclear Plant road and a boat or ferry service on the River Danube can plug the city of Kalocsa and its surroundings into the construction project.

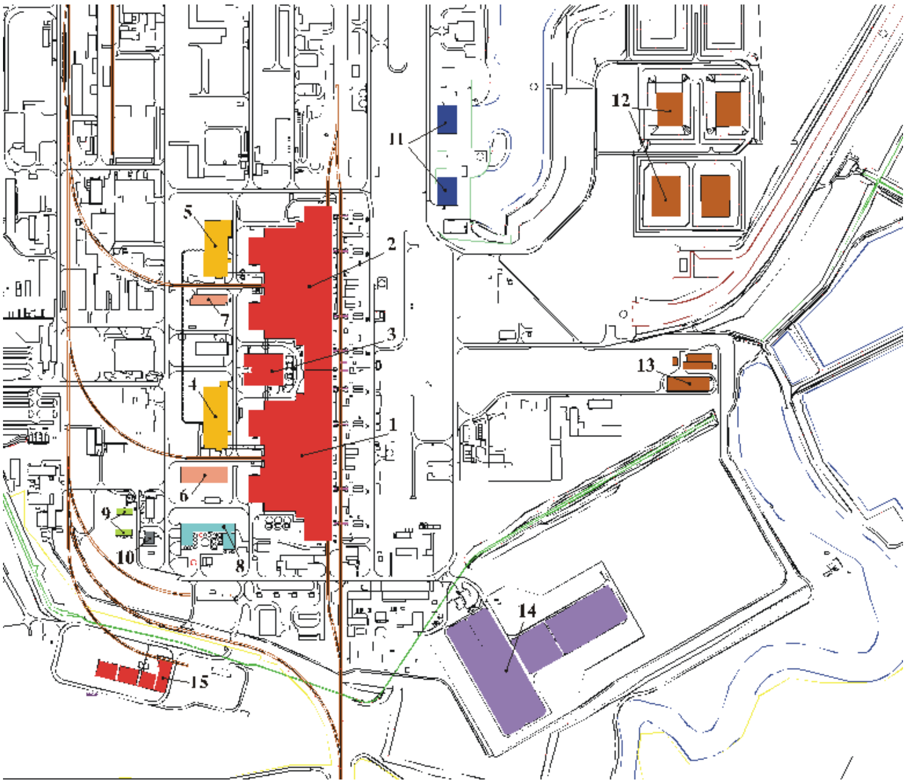
Regarding **rail** links, the current railroad runs along the area mentioned in the direction of Pusztaszabolcs (Pusztaszabolcs-Dunaújváros-Paks, Hungarian Rails' partially electrified 79 km single-track railroad). The original section was upgraded during the construction of the Paks Nuclear Power Plant and is suitable for engines with an axle load of 20 tons; nevertheless, the section needs further upgrading. Alternatively, a new track needs to be established.

Regarding access by **water**, the Paks Nuclear Power Plant already has a port, however, it needs to be upgraded with a portal jib-crane and perhaps extended.

The operating and temporary construction sites of the new nuclear plant will be located north of the current units of the Paks Nuclear Plant. Currently, no direct water supply or waste water disposal is available. Therefore, this issue needs to be addressed.

5.3 THE PAKS NUCLEAR POWER PLANT AND ITS ASSOCIATED FACILITIES

Figure 16*: View of the twin units of the Paks Nuclear Power Plant[13]*



Legend:
1 Main operating building I
2 Main operating building II
3 Sanitary facility and laboratory
4 Auxiliary building I
5 Auxiliary building II
6 Diesel engine room I
7 Diesel engine room II
8 Chemical water pre-treatment room
9 Hydrogen – nitrogen tanks
10 Hydrogen plant
11 Water intake plants I and II
12 Sludge tanks
13 Waste water treatment plant
14 Transformer station
15. Spent Fuel Interim Storage (SFIS)

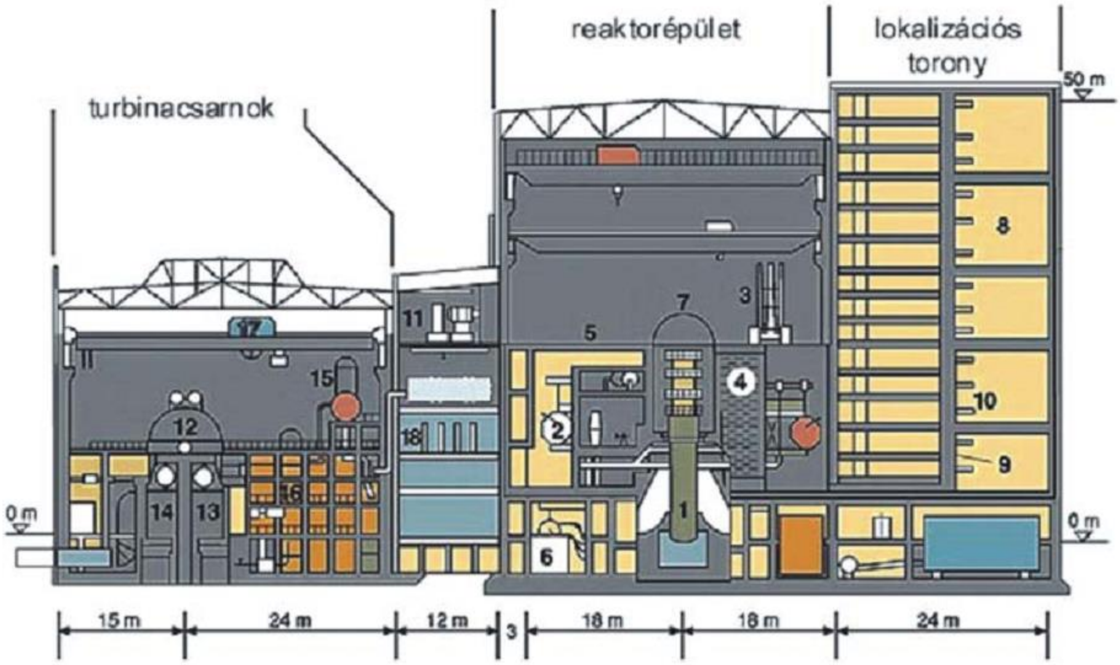
Figure 17*: Paks Nuclear Power Plant and its associated facilities at the Paks site[15]*

5.3.1 PAKS NUCLEAR POWER PLANT

The Paks Nuclear Power Plant has a key role in Hungary's supply of power. Its four units were commissioned between 1982 and 1987, with one pressurized, water-cooled and water-moderated VVER-440 reactor of the V-123 type in each unit. The initial nominal capacity of the units was 440 MW_e. This was increased to 500 MW_e in a capacity boosting program, as a result of which the total nominal capacity of Paks increased to 2000 MW_e. The heat output of each unit is 1485 MW_{th} and the total heat output of plant is 5940 MW_{th}.

The Paks Nuclear Plant operates as a base load power plant with an output load kept as steady as reasonably possible. In 2013 it generated 15,369.6 GWh electricity accounting for 50.7% of Hungary's gross domestic electricity output.

The nuclear power plant technology can be divided into a primary and a secondary circuit. The primary circuit comprises the core with the main water circuit and the related primary circuit systems and other auxiliary systems. The main equipment of the primary circuit is a vertical cylindrical reactor, housing the active zone. The reactor is fueled by 42 tons of uranium-dioxide. The pressurized nuclear reactor is moderated and cooled by light water (H_2O). High pressure and high temperature primary circuit water transmits heat from the reactor to the secondary circuit via the heat transmission pipes of a steam generator. In the secondary circuit the heat generated in the reactor is transformed into kinetic and then electrical energy. In the steam generator water evaporates and reaches the turbines via the main steam system. The steam exiting the turbines condenses on the heat transfer surfaces of the condensers cooled with water from the River Danube and returns to the steam generators. The Paks Nuclear Plant uses the water of the River Danube for cooling and discharges it back to the Danube after warming it up. The main transformers (2 for each unit) transform the electricity generated to 400 kV.



Turbinacsarnok – Turbine building
Reaktorépület – Reactor building
Lokalizációs torony – Localization building

Figure 18 *East-west cross-section of the Paks Nuclear Power Plant[16]*

Fuel management and storage

The used or spent fuel assemblies, i.e. those no longer fit for use in the reactors, must be kept in a sub-critical condition, must be shielded for protection against radiation, and must be cooled to carry away their remaining heat. After their removal, the spent fuel assemblies are temporarily stored in a fuel pond, with an independent cooling circuit, in the immediate vicinity of the reactor.

Following their storage for 3 to 5 years in the fuel pond, the spent fuel cassettes are transported to the Spent Fuel Interim Storage (KKÁT/SFIS) in order to free up the fuel pond for uninterrupted reactor operation.

Security zone of the Paks Nuclear Power Plant

The minimum width of the security zone of the Paks Nuclear Plant is 500 m calculated from the following elements and structures:

- the walls of the rooms comprising emergency cooling water pumps at water intake plants,
- the walls of the ducts where emergency cooling water pipes run and the pipes themselves where they are buried in the ground,
- the walls of the turbine engine room,
- the walls of the desalinated water pump rooms,
- the walls of the electrical cross bus line galleries,
- the walls of the reactor halls, including the walls of the localization towers,
- the outermost points of the subterranean fuel tanks of diesel generators,
- the walls of diesel engine rooms,
- the walls of the auxiliary buildings, and
- the walls of the reinforced concrete tube bridge.

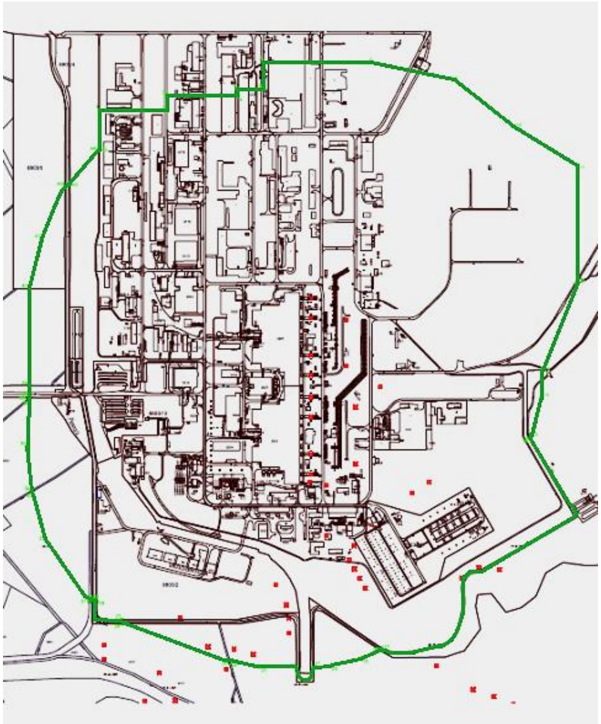


Figure 19*: Security zone of the Paks Nuclear Power Plant[15]*

5.3.2 400 kV SUBSTATION

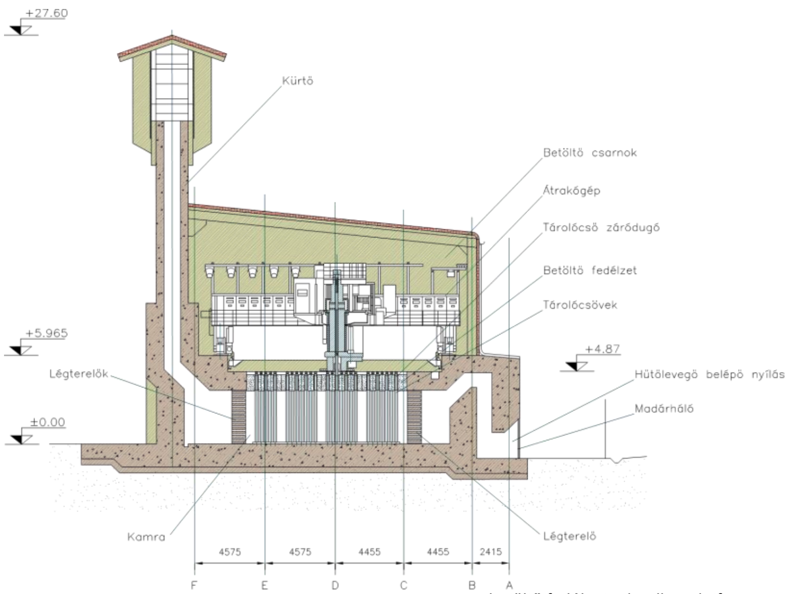
The electricity generated by the turbines of the Paks Nuclear Plant is transformed by the main transformers to 400 kV. The main transformers are connected via a 400 kV overhead electrical power line to a 400 / 120 kV substation, constituting part of the national grid, in the south east of the Paks Plant. The 400 kV transmission lines running from the substation provide the main routes of the delivery of the electricity generated. The 400 kV station section is connected to a 120 kV substation and, hence, the 120 kV long-distance transmission line via two 400 / 120 / 18 kV, 250 / 250/ 75 MVA booster transformers. The 400 kV substation uses SF6 gas-insulated switchgear technology in a one-and-a-half breaker arrangement. The 120 kV part is a traditional substation with 2 main and 1 auxiliary bus lines.

5.3.3 SPENT FUEL INTERIM STORAGE (SFIS)

The spent fuel generated during the operation of the power plant must be temporarily stored prior to any further processing or final placement without reprocessing. Following their storage for 3 to 5 years in the fuel pond, the spent fuel cartridges are moved to the Spent Fuel Interim Storage (SFIS) located next to the Paks Nuclear Power Plant.

The SFIS is a modular interim storage facility, with a storage capacity that can be expanded by the addition of new storage capacities. Pursuant to Act CXVI of 1996 (Atomic Energy Act), the interim storage of spent fuels is assigned to Radioaktív Hulladékokat Kezelő Közhasznú Nonprofit Kft. The SFIS was built in the neighbourhood of the Paks Nuclear Power Plant, it is a separate nuclear facility independent of the operator of the power plant, which has its own separate Final Safety Report and operating licence.

The cross-section of the storage chamber that contains the storing tubes and ensures natural draught is illustrated in the following figure.



kürtő – flue
légterelők – air baffles
betöltő csarnok – load chamber
átrakodógép – transfer machine
tárolócső záródugó – plug of storage tube
betöltő fedélzet – loading platform
tárloócsövek – storage tubes
hűtőlevegő belépő nyílás –cooling air inlet
madárháló – catch net
kamra – chamber

Figure 20: Cross-section of the SFIS[15]

SFIS security zone

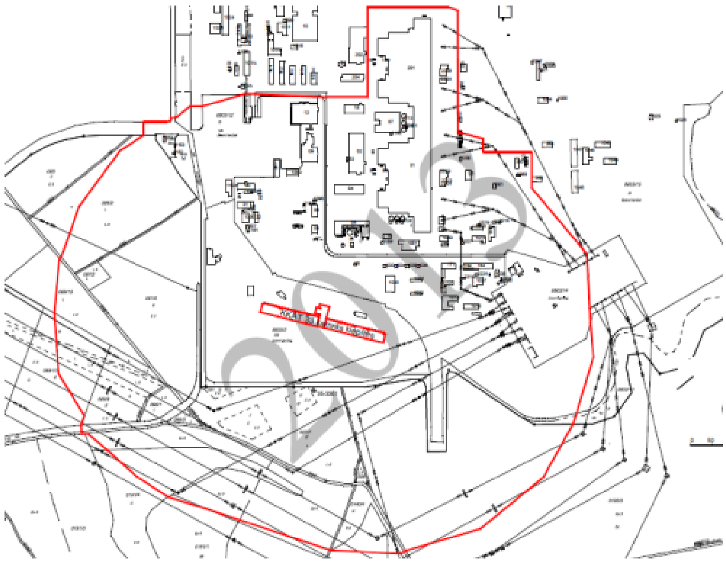


Figure 21: SFIS security zone[15]

5.4 MONITORING SYSTEMS IN THE NEIGHBOURHOOD OF THE PAKS NUCLEAR POWER PLANT

Just as all power generating facilities, the Paks Nuclear Power Plant continuously monitors its characteristic environmental emissions that are necessary concomitants of is technology, as well as their appearance in the environment (immission), and furnishes a summary report of them, cf. the 2013 environmental report of the MVM Paksi Atomerőmű Zrt.

5.4.1 CONTROL OF TRADITIONAL ENVIRONMENTAL CONDITION INDICATORS

5.4.1.1 Control of waste water and used water emission

Waste and used water is monitored in compliance with the Self-revision Plan approved by DdKTVF.

- V1 sampling and remote metering station: sampling from the cold-water conduit
- V2 sampling and remote metering station: sampling from the warm water conduit
- V4 sampling station (sample pumped from the cassette of the energy dissipation device): sampling the mixture of used water and purified waste waters returned to the Danube; conventional emission limits apply at this point
- Expansion area pump shaft: Quality of waste water transferred to the Paks city waste water treatment plant (with a set threshold).
- Other sampling places: before and after the communal waste water treatment plant, at the caustic sludge pool and the chemical waste water pool

5.4.1.2 Exposure of the Danube to heat

Inspection of compliance with the heat load limits applicable to the Danube is performed according to the Self-Revision Plan approved by DdKTVF. According to the provisions of this Plan, the temperature of the water removed from and returned to the Danube is continuously measured, and if the temperature of the water discharged to the Danube exceeds 25 °C, the temperature of the Danube water 500 m downstream of the warm water discharge point is also measured.

5.4.1.3 Groundwater monitoring

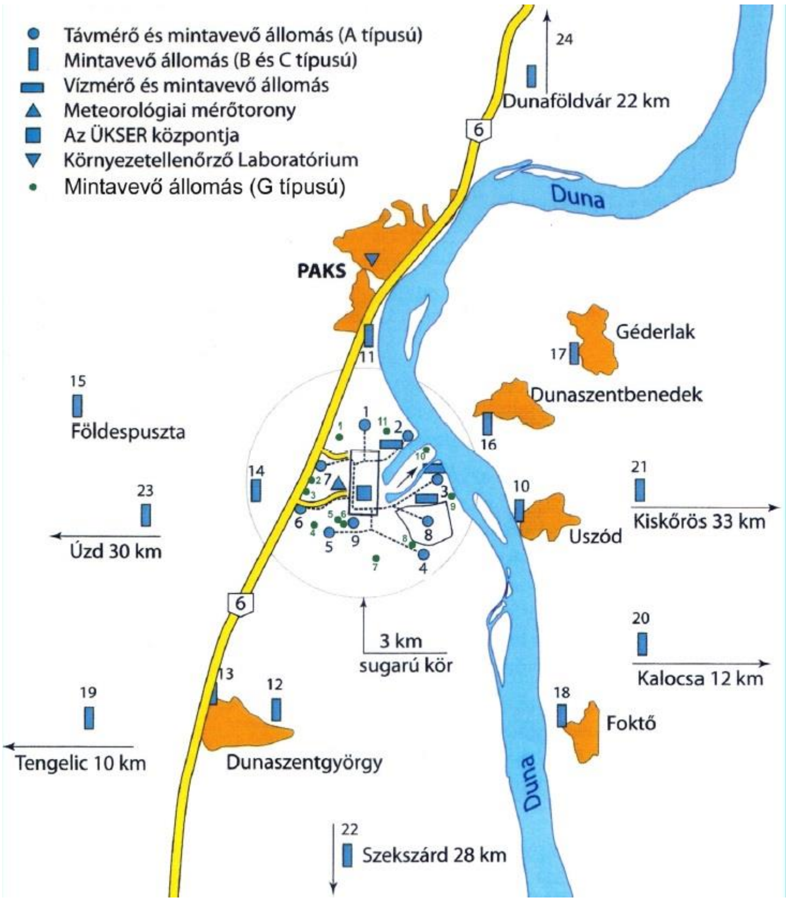
In order to monitor potential sources of environmental pollution, the Paks Nuclear Power Plant operates a groundwater monitoring system, as required by its environmental licences. In the system set up for monitoring conventional emissions, the following parameters are measured and analyzed at the following sampling points:

- At wells in the neighborhood of the operational hazardous waste collection site: pH, total salt, total oil, KOI_{ps}, Fe, Mn, Cu, Zn, Pb, Cr, Ni values,
- At the sludge area wells:
  pH, conductivity, total hardness, total salt content, ammonium, total oil, KOI_{ps}, NO_3^-, Fe, Mn, Cu, Zn, Pb, Cr, Ni, Cl^- values,
- At the wells located next to the oil tanks: pH, oil content, NO_3^-, ammonium, Cl values,
- At the monitoring wells designated on the operating area: pH, ammonium, nitrate, KOI_{ps}.

5.5 OPERATIONAL ENVIRONMENTAL RADIATION PROTECTION CONTROL SYSTEM (PERMS)

The environs of the Paks Nuclear Power Plant have been monitored since 1978 by measuring the radioactivity of samples taken from the environment, from baseline surveys to continuous operational metering.

The territorial arrangement of the radiological and environmental monitoring system of the Paks Nuclear Power Plant is shown in Figure 22.



Távmérő és mintavevő állomás (A típusú) – Remote measuring and sampling station (type A)
Mintavevő állomás (B és C típusú) – Sampling station (type B and C)
Vízmérő és mintavevő állomás – Water metering and sampling station
Meteorológiai mérőtorony – Meteorological monitoring tower
Az ÜKSER központja – PERMS centre
Környezetellenőrző Laboratórium – Environmental Monitoring Laboratory
Távmérő állomás (G típusú) – Sampling station (type G)

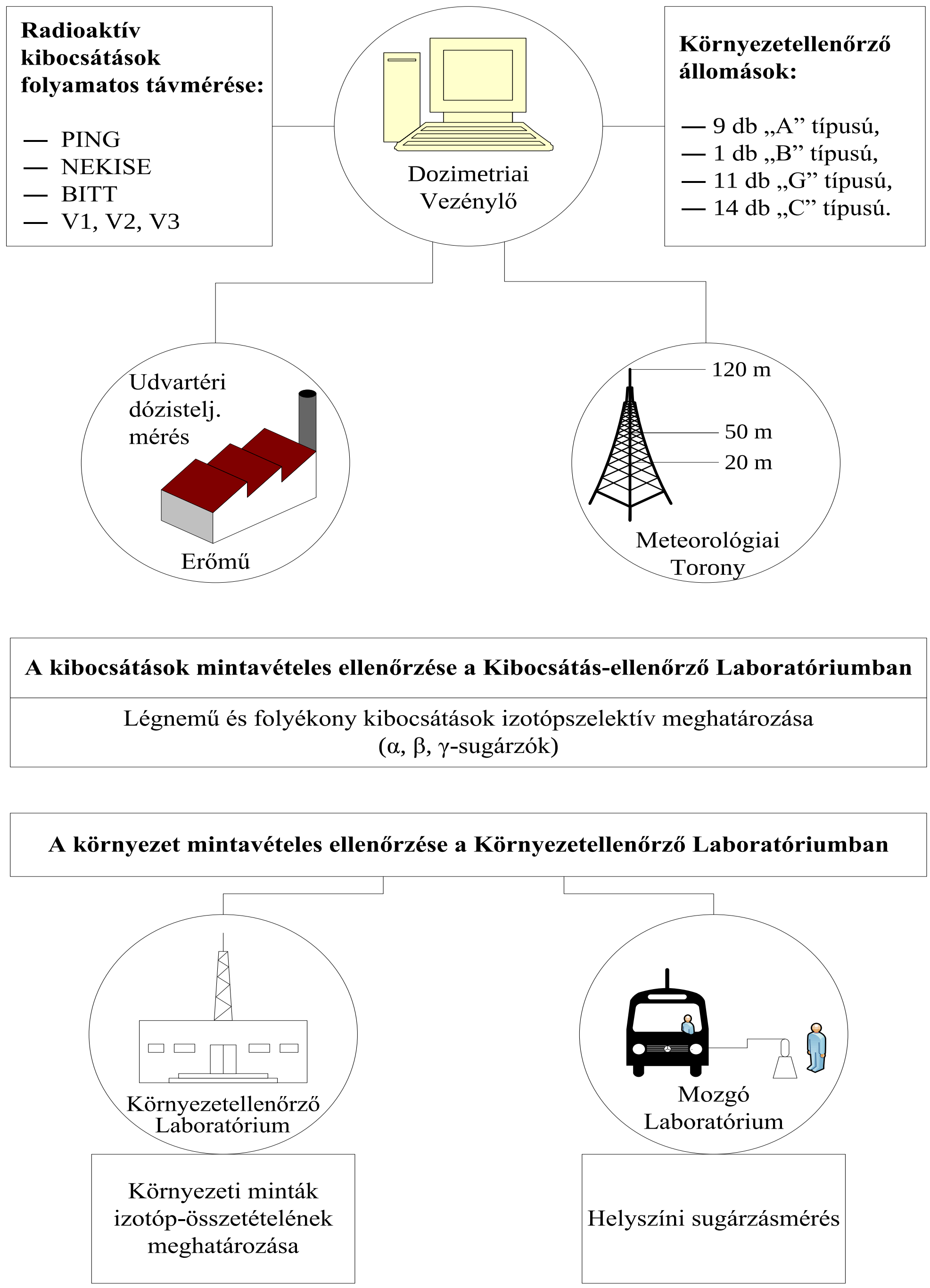
Figure 22: Geographic location of the radiological and environmental monitoring system of the Paks Nuclear Power Plant [17]

These measurements were performed by the Paks Nuclear Power Plant, various authorities and other institutions.

The fundamental purpose of nuclear environmental monitoring is to survey the nuclear power plant's emission of radioactive substances, the appearance of the latter in the environment, and to identify environmental radiation levels.

The continuous monitoring of the vicinity of the Paks Nuclear Power Plant must be performed by the Operational Environmental Radiation Protection Control System (PERMS). The summary report of the findings related to the measured ambient radiation and radioactive concentration based on sampling from the individual environmental media is published each year under the title "Radiation Protection Activity in the Paks Nuclear Power Plant".

The structure of the two-level radiological and environmental monitoring system of the Paks Nuclear Power Plant is shown in the following figure.



Radioaktív folyamatok folyamatos távmérése – Continuous remote monitoring of radioactive emissions
Dozimetriai Vezénylő – Dosimetric control room
Környezetellenőrző állomások – Environmental monitoring stations:
- 9 of type A
- 1 of type B
- 11 of type G
- 14 of type C

Udvartéri dózisteljesítmény mérés – Doseage metering on the courtyard
Meteorológiai Torony – Meteorological tower
Erőmű – Power plant
A kibocsátások mintavételes ellenőrzése a Kibocsátás-ellenőrző laboratóriumban – Monitoring emissions by sampling in the Emission Monitoring Laboratory
Légnemű és folyékony kibocsátások izotópszelektív meghatározása (α-, β- és γ- sugárzók) – Isotope-selective definition of aeriform and liquid emissions (α-, β- and γ- emitters)
A környezet mintavételes ellenőrzése a Környezetellenőrző Laboratóriumban - Environmental monitoring by sampling in the Environmental Monitoring Laboratory
Környezetellenőrző Laboratórium – Environmental Monitoring Laboratory
Mozgó Laboratórium – Mobile Laboratory
Környezeti minták izotóp-összetételének meghatározása – Definition of the isotope-composition of environmental samples
Helyszíni sugárzásmérés – On-site radiation measurement

Figure 23: Structure of the two-level radiological and environmental monitoring system of the Paks Nuclear Power Plant[18]

Emissions and the condition of the environment are assessed by monitoring at two levels:

- by continuous measurement
  - *The online remote monitoring networks measure the most significant radioactive emissions (aeriform and liquid) and environmental radiation volumes on an continuous basis.*
- by sampling
  - *The Emission Monitoring Laboratory uses isotope selective, high-precision laboratory investigation methods to improve the accuracy of the remotely measured values of the samples taken from the emitted media.*
  - *The Environment Monitoring Laboratory measures the isotope selective radioactive concentration, the gamma radiation dose and the dose rate of the various environmental samples taken from of the environment within 30 km of the plant.*

Both laboratories are accredited by the National Accreditation Board.

5.5.1.1 Radioactive emissions and their control

In 2004 the emission limitation system prescribed by Decree No. 15/2001. (VI.8.) of the Minister for the Environment entered into force. It compares both aeriform and liquid emissions to the isotope specific emission limits derived from the dose limits (90 μSv/year) set for the Paks Nuclear Power Plant.

In 2013, the Paks Nuclear Power Plant used 0.26% of the emission limit, in other words, 0.26% of the permitted values were emitted.

Utilization of the limits on liquid emissions was 1.77 10^{-3}, i.e. 0.18%, while 7.7710^{-4} or 0.08% of the aeriform emission limit was used.

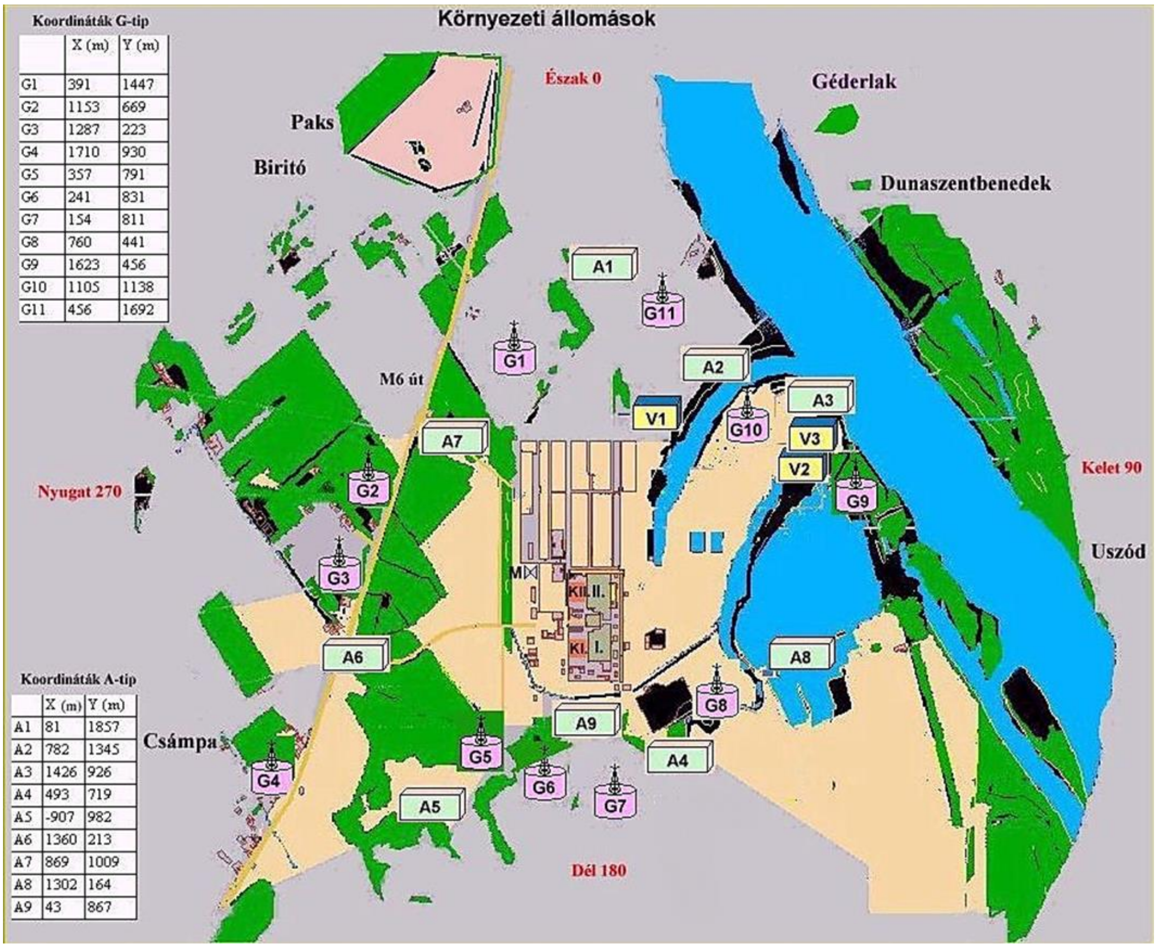
Utilization was similar in the previous years: 2012 - 0.26%, 2011 - 0.20%, 2010 – 0.25%, 2009 - 0.22%.

5.5.1.2 Assessment of the state of the environment

The state of the environment is assessed by analyzing the results of the following measurements:

- measuring the radioactive concentration of the air, fall-out, the soil, groundwater and natural vegetation (grass),
- measuring activity in surface waters (Danube, fish ponds, catch drain), water, sludge and fish samples,
- measuring activity concentration in certain food samples (milk),
- measuring the ambient gamma radiation dose and dosage rate.

The following figure shows the location of remote measuring stations that monitor the state of the environment in the vicinity of the Paks Nuclear Power Plant.



Környezeti Állomások – Environmental stations
Koordináták G-típ – Co-ordinates type G
Koordináták S-típ – Co-ordinates type S

Figure 24: Type "A" and type "G" remote measuring stations monitoring the condition of the environment in the vicinity of the Paks Nuclear Power Plant [19]

5.5.1.2.1 Remote measuring systems

Remote metering systems within a 1.5-km radius of the Paks Nuclear Power Plant

- 9 type "A" measuring and sampling stations (A1-A9)
    - gamma dose rate measuring (on-line)
    - (online) measuring the total beta activity concentration in aerosols
    - (online) measuring the radio-iodine elementary and organic phases
    - taking aerosol and iodine samples for laboratory measurements (weekly and monthly)
    - [2] Fall-out, wash-out sampler (monthly)
    - T/^{14}C sampler (T: aqueous vapour and hydrogen), ^{14}C: CO_2, and $CO_2 + C_nH_m$); (monthly)
- 11 stations of the type "G" (G1-G11)
    - gamma dose rate measuring (online)

[2] *The fall-out of radioactive isotopes in the air may take place by deposition (gravitational precipitation), or as a result of the erosion effect of falling rain or snow. These processes are collectively termed 'fall-out'.*

Remote metering systems within a 30-km radius of the Paks Nuclear Power Plant

- One measuring and sampling station of the type "B" (B24) – ***Control station at Dunaföldvár***

  For the purpose of determining the control or background level, the same measurements are performed as on the type "A" stations.
- 15 stations of the type "C"
  - dose measurements performed by thermo-luminescent detectors (TLD) (monthly)
  - fall-out sampling and analysis (periodically)

5.5.1.2.2 Sampling, laboratory tests

- water samples at water sampling points V1, V2 and V3 (daily sampling for total gamma, total beta, and monthly or quarterly sampling for isotope selective measurements)
- water samples and sludge samples
  - Danube, fish ponds, catch drain, lime sludge pool (quarterly)
  - Danube Backwater at Fadd (monthly)
- soil and grass samples from the vicinity of remote monitoring stations (periodically)
- milk samples from the dairies at Dunaszentgyörgy and Tengelic (monthly)
- fish samples from angling ponds (quarterly)

5.5.1.2.3 Measurement of groundwater tritium activity concentration

To measure the tritium content of the groundwater under the main building, the Paks Nuclear Power Plant runs a monitoring system in order to meet the requirements of Section 13-2 a) of resolution HA-4797 (IBJ tasks) of OAH.

Fundamentally, the tests are based on the network of groundwater monitoring wells surrounding the nuclear power plant, consisting of nearly 140 wells, of which 52 are sampled monthly or annually by the Radiation and Environmental Protection Department. The tritium activity concentration measurement of the samples was supplemented by total beta and gamma spectrometry measurements whenever tritium concentration exceeded 500 Bq/dm^3. Within the framework of environmental monitoring, continuous water samplers were installed in 25 wells for the main purpose of detecting other radioactive substances that might be present (gamma spectrometry once in 2 months, ^{14}C once in 4 months, ^{89,90}Sr once in 4 months, Pu-TRU trans-uranium once in 8 months from large-volume (20 liter per month) average samples), in addition to monitoring tritium.

The annual additional exposure to radiation from groundwater tritium is about 0.01 nSv/year, practically negligible in comparison to the exposure to electromagnetic fields arising from natural background radiation, which is about 20% higher (2,4 mSv/) in Hungary than the global average (2,4 mSv/year), as it is 3, or at certain places 4 mSv/year.

5.5.1.3 Additional exposure of the population to radiation

Based on the 2013 emission and meteorological data of normal operation, the annual additional exposure of the population to radiation, resulting from the normal operation of the plant, is shown in the following table.

Dose limit	μSv/year	90
Population dose	μSv/year	4.83 10^{-2}
Limit utilization	%	5.37 10^{-2}

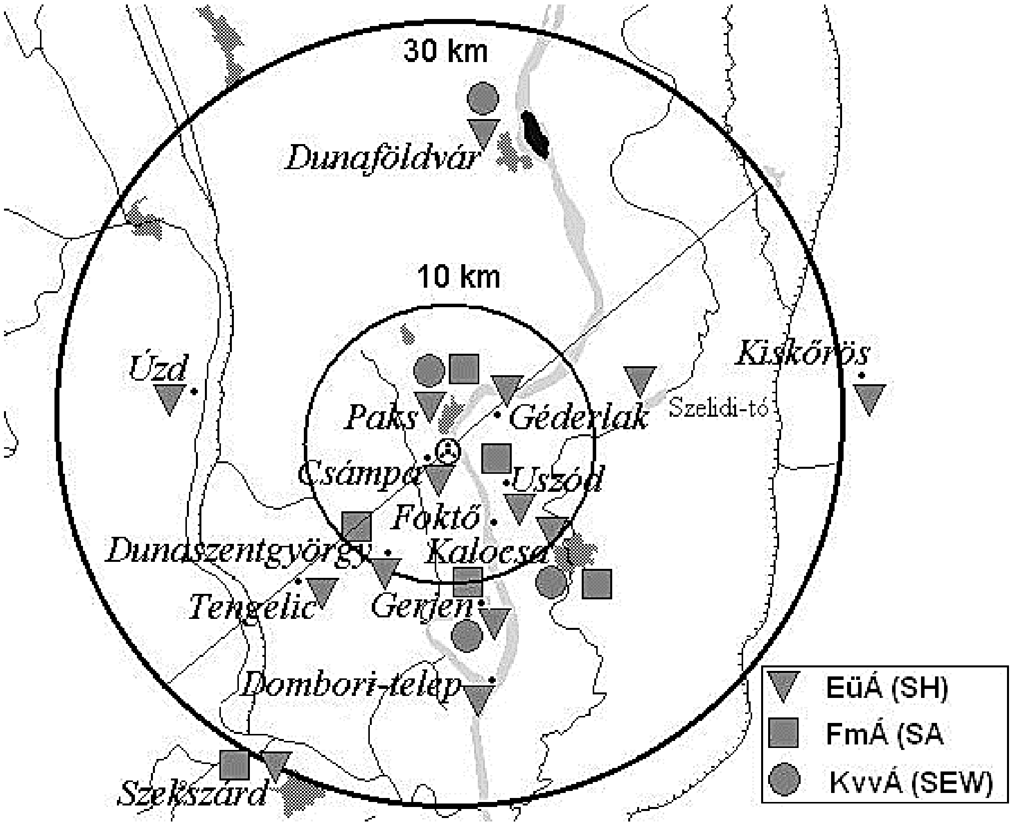
Table 8: Dose limit utilization at the site of the Paks Nuclear Power Plant – 2013 [19]

According to calculations, as a result of the normal operation of the Paks Nuclear Power Plant, the 2013 additional exposure to electromagnetic fields was 48.3 nSv, which is 0.0537% of the 90 Sv permitted annual dose limit.

This additional radiation exposure is identical to the effective dose received during about half an hour in the open air, thus it does not impose practically any health hazard, and the population was exposed to a negligible amount of additional radiation.

5.6 JOINT ENVIRONMENTAL RADIATION MONITORING SYSTEM (JERMS)

The Joint Environmental Radiation Monitoring System (JERMS), run by the authorities to check the radiation protection of the power plant operates in parallel with the measurements performed by the Paks Nuclear Power Plant.



Note:
EüÁ – healthcare
FmÁ – agriculture
KvVÁ - environment and water management

Figure 25: Official measuring points within 30 km of the Paks Nuclear Power Plant [4-13]

The following ministries are members of the JERMS:

Ministry of Human Resources (EMMI), Healthcare Division (EüÁ)
Ministry of Agriculture (FM)
Agriculture Division (FmÁ)
Environment and Water Management Division (KvVÁ)

In the framework of inspections by the authority, in addition to the survey of atmospheric and aquatic environmental emissions, laboratory analyses are also made of the Danube water and sludge, soil, plant and milk samples.

In addition to measuring the dose rate of ambient radiation, the authorities have been measuring the following activities since 2001:

- atmospheric aerosol,
- fallout, dry-out
- surface waters (rivers, natural and artificial lakes, channels)
- drinking water (wells, depth)
- deposit (rivers, natural and artificial lakes)
- soil and grass samples (irrigated and non-irrigated arable land, garden, meadow and road-side)
- leaf vegetables (kitchen garden indicator plants, raw kitchen garden food, fruits)
- meats (pork, beef, lamb, poultry, game, fish)
- raw milk.

In the course of the impact assessment of the environs of Paks II, the data measured by JERMS were analyzed in detail in the chapter entitled “Environmental Radioactivity”.

Under the title *Report of the Joint Environmental Radiation Monitoring System,* JERMS publishes annual reports of its activities performed in the scope of its regulatory inspection of the neighbourhood of the Paks Nuclear Power Plant. The reports containing the findings recorded between 1999-2012 are public and can be downloaded from the JERMS website:

(http://www.hakser.hu/eredmenyek/eredmenyek.html).

5.7 NATIONAL ENVIRONMENTAL RADIOLOGICAL MONITORING SYSTEM (NERMS)

Under Government Decree 275/2002. (XII.21.) Korm. the core responsibility of the National Environmental Radiological Monitoring System (NERMS) includes the collection of countrywide measurement results of natural and man-made environmental radiation to which the population is exposed, and of the concentration of radioactive materials in the environment.

The following are measured:

- ambient radiation dose rate,
- activity concentration of radioactive isotopes,
  - in the environmental elements (air, soil, surface waters, natural and agricultural plants, wild fauna and livestock),
  - in the animal and plant-based foods consumed by the population and their raw materials,
  - in drinking water,
  - in construction materials and raw materials,
- activity concentration of radon and its daughters in the open air and inside buildings,
- internal radioactive pollution of the human body.

Conclusion of the 2012 NERMS Report

Source: [4-15]2012 Report of the National Environmental Radiological Monitoring System (Hungarian abbreviation: NERMS)[12/27/2013]

The 2012 Report of the National Environmental Radiological Monitoring System (NERMS) summarizes the results of measurements conducted in Hungary as follows:

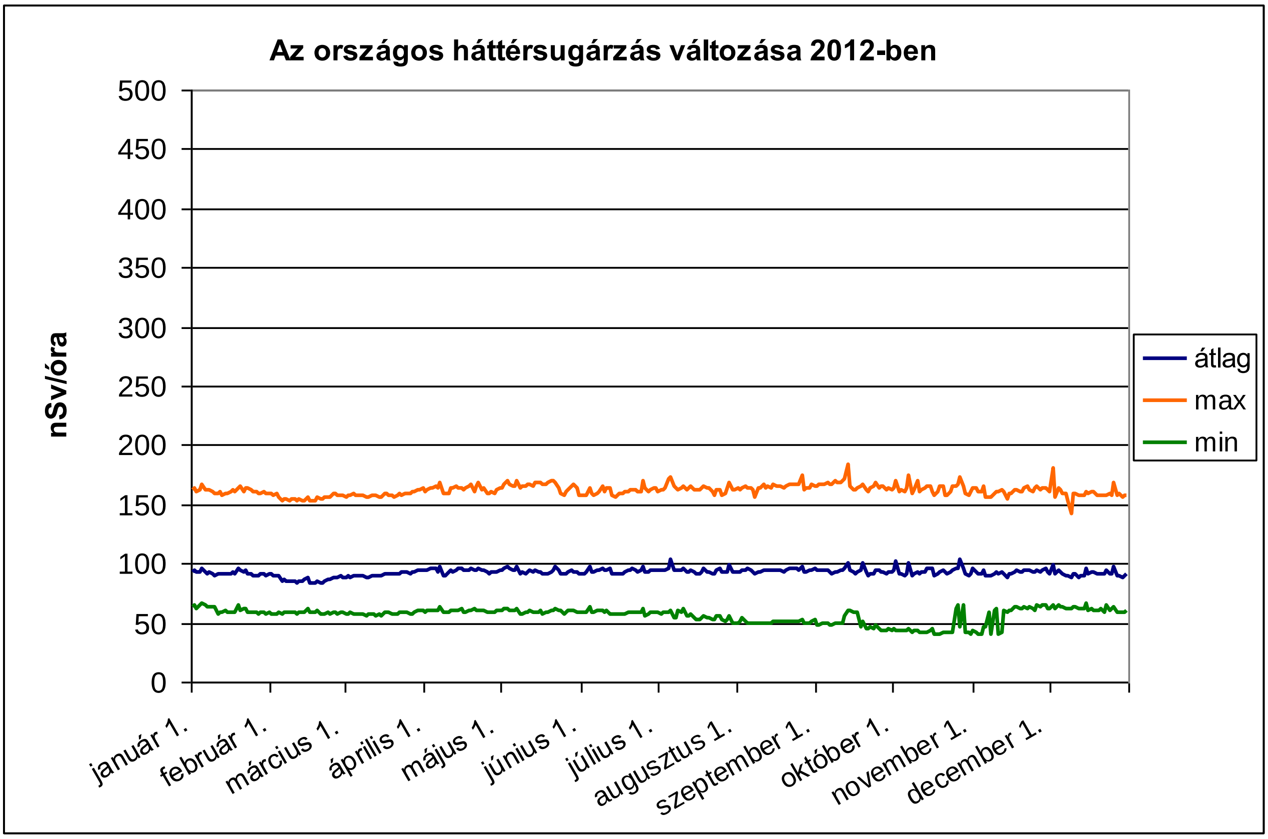
> *“It must be emphasized that while according to the relevant regulation of the European Union {*Post-Chernobyl 733/2008/EC, Council Regulation No 733/2008 of 15 July 2008 on the conditions governing imports of agricultural products originating in third countries following the accident at the Chernobyl nuclear power station (codified version); Council Regulation (EC) No 1048/2009 extends its validity until March 31, 2020) (OJ L-201 of 30/07/2008, page 1)*} the maximum permitted levels of accumulated*

maximum radioactive level in terms of caesium-134 and -137 is 600 Bq/kg (370 Bq/kg for milk and milk products and in foodstuffs intended for the special feeding of infants), the highest values measured in 2012 in processed foodstuffs in Hungary remained below 40 Bq/kg.

"Finally we mention that the exposure of the population to radiation from man-made sources – other than those used for medical purposes – can be estimated between 3 to 6 μSv in recent years in Hungary, while exposure to radiation from natural sources is higher by nearly three orders of magnitude."

"In summary it can be stated that according to both national and facility-specific environmental monitoring results, the activities subject to licensing have negligible impacts on the environment and on the population, and the radioactive isotope concentration values remain below the detection limit for many kinds of samples."

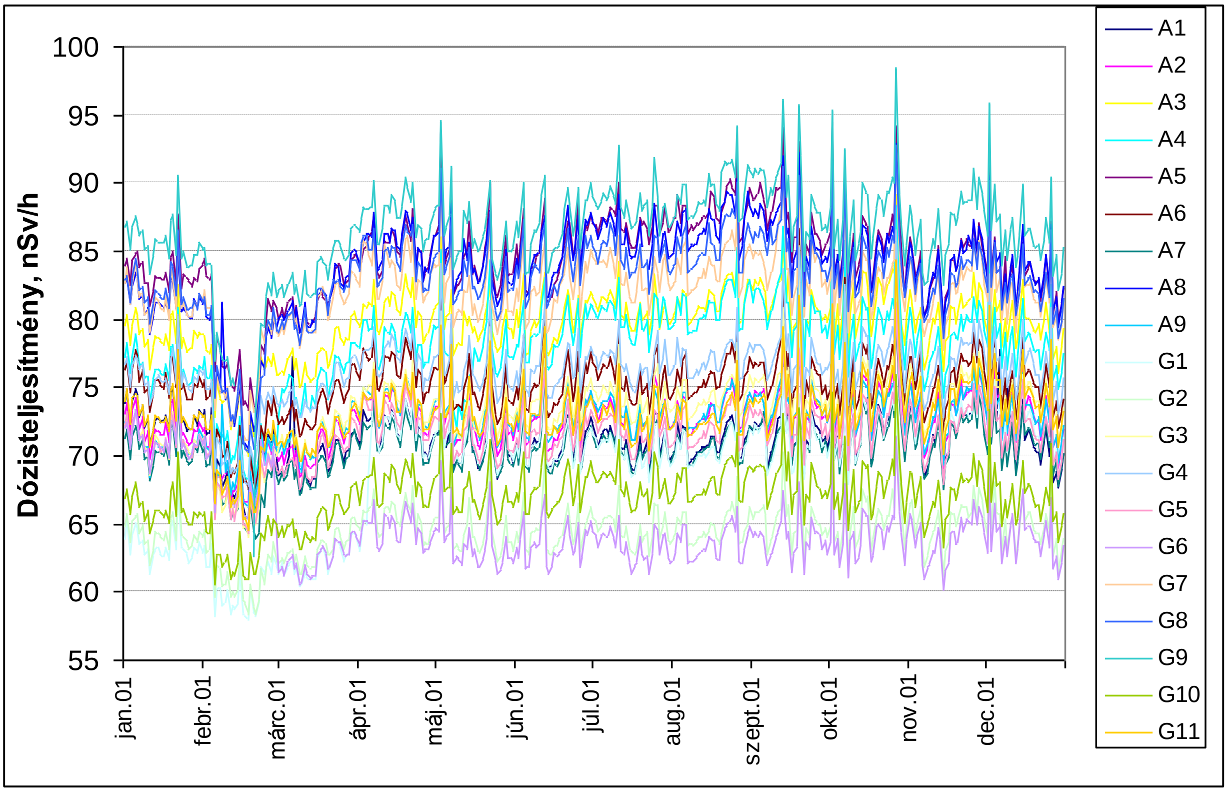
In order to characterize the conditions prevailing in Hungary, the following figure shows changes in the national average and daily maximum and minimum gamma dose rates for the purpose of characterizing the conditions prevailing in Hungary.



Az országos háttérsugárzás változása 2012-ben – Changes in the background radiation, 2012
nSV/óra – nSv/h
átlag – average
max. – maximum
min. – minimum
január 1 – January 1 – február 1 – February 1 március 1 – March 1 április 1 – April 1 május 1 – May 1 június 1 – June 1 július 1 – July 1
augusztus 1 – August 1 – szeptember 1 – September 1 október 1 – October 1 november 1 –November 1 december 1 – December 1

Figure 26: Changes in the national average, maximum and minimum gamma dose rates in 2012 [22]

The daily dose rates measured by the dose rate probes included in the environmental monitoring system of the Paks Nuclear Power Plant in 2012 at type "A" and "G" environmental monitoring stations show environmental dose rates fluctuating between 58 and 98 nSv/h in the ambience of the Paks Nuclear Power Plant. These values represent the lower range of all values measured in Hungary. The temporal changes in the measured values are shown below.



Dózisteljesítmény, nSv/h – Dosage rate nSv/h

Figure 27: 2012 daily dose rates of the Paks Nuclear Power Plant, measured at its environment monitoring stations

5.8 SUMMARY OF THE TOPOGRAPHIC FEATURES AND CHARACTERISTICS OF THE PAKS SITE

The Paks site has numerous favourable features for the implementation of new nuclear power plant units:

- a nuclear power plant has been operating at the Paks site for over 30 years,
- the population living in its vicinity has accepted the existence and operation of the Paks Nuclear Power Plant,
- the site and environs of the Paks Nuclear Power Plant is a meticulously investigated and studied area,
- the impacts resulting from the operation of the Paks Nuclear Power Plant are continuously monitored by a monitoring systems operating on the site and in its environs,
- the site is directly on the bank of the Danube,
- the Danube is available as a cooling water resource,
- the required infrastructure is established and is available at the site,
- the site is easy to access by road and rail,
- part of the construction materials and large equipment can be transported by water,
- due to the special layout of the surface of the area, flood and excess surface water control are ensured,
- the meteorological properties are favourable,
- population density is below the national average in the 30 km vicinity of the power plant, with the exception of the city of Paks,
- the national electricity grid is readily accessible,
- qualified and skilled manpower experienced in work at the nuclear power plant is available in the region,
- Due to its natural and infrastructural resources, Paks offers a good opportunity for the accommodation of the people engaged in the building and later in the operation of the new plant.

Compliance with the geological and nuclear safety requirements will be evaluated in detail and certified by the Hungarian Atomic Energy Authority in the framework of a site licensing procedure to be conducted on the basis of the Nuclear Safety Regulations (NSR) attached as annexes to Government Decree No. 118/2011. (VII.11.) on the nuclear safety requirements of nuclear facilities and the related activities of authorities.

6 POSSIBLE CONDENSER COOLING METHODS OF THE NEW NUCLEAR UNITS

6.1 COOLING REQUIREMENTS AND OPTIONS FOR ELECTRICITY PRODUCING POWER PLANTS WITH CONDENSERS

In the case of condenser cooled power plants of all types the laws of physics dictate that the majority of heat emitted by the fuel – or the fuel rods in the case of nuclear power plants – that cannot be utilized for electric power production be discharged into the natural environment, which acts as the final heat absorber. The reason for this is that the condenser cannot be cooled below the actual ambient temperature. This also explains the efficiency of this cyclical process.

In the case of modern nuclear power plants with current state of art technology, about 65-67% of the heat released in the reactor is eventually released into the environment, at a temperature close to the actual ambient temperature.

In addition to electric power generation, there is also heat produced in the primary and secondary circuits of nuclear power plants that cannot be used for electric power production, and which is carried off by the cooling systems. The waste heat produced in the primary circuit of power plants is carried off by the so-called emergency cooling water system; the condensation heat to be extracted from the condenser in the secondary circuit is carried off by the condenser cooling water system; and the heat generated in the technological systems of the secondary circuit is carried off by the technological cooling water system.

More than 95% of cooling demand in a nuclear power plant is met by cooling the condenser.

Primarily, the following choices are considered to absorb the generated heat, depending on the amenities of the site:

- a high-yield river;
- a bigger lake;
- the sea.

In cases where there is a large amount of water available in the vicinity of a power plant, cooling is achieved by streaming the cooling water directly through the condenser; this is the so-called fresh water cooling method. The warmed-up cooling water is discharged into the sea or river.

When the amount of available fresh water is insufficient for cooling, wet or dry cooling towers are used. The water inside the cooling towers recirculates between the cooling tower and the condenser. In this case, the majority of the heat to be discharged is carried off by the evaporation heat of the cooling water, and the rest of the heat is absorbed by the air through heat transfer.

Nearly 75 percent of the currently operating nuclear power plants utilize fresh water cooling, and the rest of them use cooling towers.

In the case of the planned new nuclear units, the main technology and the majority of auxiliary systems and facilities have a relatively low dependency on the installation environment; however, the cooling system must be chosen in a project specific manner, taking the features of the actual environment into consideration. The cooling method affects the technical and economical features and the environmental impact of the planned new nuclear units.

6.2 GENERAL REGULATION AND LIMITS APPLICABLE TO HEAT LOAD ON THE AQUATIC ENVIRONMENT

The warm water discharged into the aquatic environment (thermal discharge) may affect the recipient aquatic life, including fish and other aquatic organisms. The adverse effects on the aquatic flora and fauna can be mitigated by reducing the temperature of the water before being discharged, as well as by increasing mixing and heat loss. These effects can be regulated by the criteria governing the heat discharge limit values and the mixing zone.

6.2.1 GENERAL REGULATORY FRAMEWORK OF EXPOSURE OF AQUATIC ENVIRONMENT TO HEAT

6.2.1.1 European Union

Thermal discharge is limited by Annex I to Directive 2006/44 (EC) of the European Parliament and the Council:

- in the case of cyprinid waters, the temperature measured downstream of a point of thermal discharge (at the edge of the mixing zone) must not exceed the unaffected temperature by more than 3%
- thermal discharges must not cause the temperature downstream of the point of thermal discharge (at the edge of the mixing zone) to exceed 28°C.

Due to the uneven mixing of the discharged water in the recipient water, zones of higher temperature may be formed inside the mixing zone. The main factors affecting the mixing zone include temperature, speed and the amount of discharged water.

6.2.1.2 Hungary

The general rules are set forth in Government Decree 220/2004. (VII. 21.) on the protection of surface water quality and Decree 28/2004. (XII. 25.) KvVM on the emission limits of water pollutants and the rules governing the application of these limits. The limit values for the thermal load of the aquatic environment must be specified based on independent analysis, taking into account the sensitivity and load bearing capacity of the recipient water, with a view to preserve the desirable chemical and ecological balances. No limitation is given on heat emission and exposure to heat in Decree 10/2010. (VIII. 18.) VM on surface water contamination limits and the rules governing their application.

Table I of Annex 4 in Decree 6/2002. (XI.5.) of the Minister of Transport and Water Management (KvVM) on the contamination of surface waters designated as drinking water sources or reserves as well as surface waters protected for fish sets the following limits:

Quality parameters		Trout waters	Barbel waters	Bream waters
Temperature*	°C	18	25	30
Temperature change**	°C	1.5	3	5

Note:
temporary deviations from the water contamination limit value are allowed Article 12 (1)
**: temperature measured downstream of a point of thermal discharge (at the edge of the mixing zone) must not exceed the unaffected temperature by more than the value indicated above.

Table 9*: Water contamination limit values for fish waters*

To this date, only a few surface waters have been categorized; these are listed in Annex 7 to Decree No. 6/2002. (XI. 5.) of the Minister of Transport and Water Management. The Danube is not included here, thus according to the relevant statute *(as of June 7, 2014),* it does not qualify as a fish water. The classification of the Danube, or some of its sections, as a fish water of some type should be based on ecological impact assessment studies.

Licensing practice

During the licensing procedure of traditional power plants, the authorities specify the allowed difference between the temperature of the removed and returned water (ΔT_{max}), the maximum allowed temperature of the water to be discharged (T_{max}), the increase in temperature after mixing (ΔT) and the place of measurement.

6.2.2 LEGISLATION APPLICABLE TO THE HEAT PRODUCTION OF NUCLEAR POWER PLANTS

6.2.2.1 Member States of the European Union

If a few Member States are picked and inquired without attempting to be exhaustive, the following requirements may be found.

Finland

There is no separate regulation for thermal discharge by nuclear power plants in Finland; limits are set by the competent authorities in accordance with the local characteristics of each project.

The two nuclear power plants currently in operation, Olkiluoto and Loviisa, use sea water cooling. Discharge limit value for Olkiluoto is 30°C (weekly rolling average), measured at a distance of 500 meters from the discharge channel.

For Loviisa, the limit value is 34°C (hourly average), measured at the discharge point.

Germany

In Germany the difference between the temperatures of the intake and discharge water may not exceed 10 °C. The maximum temperature of the removed and returned water depends on the cooling method; 30 °C in the case of fresh water cooling, 33 °C in the case of open-system cooling towers and 35 °C in the case of closed-system cooling towers.

The amount of water taken from the sea must not exceed 1/3 of the lowest water yield

Sweden

There is no separate regulation for water removal; limits for the amount of water that may be removed and for the thermal discharge are set by the competent authorities in accordance with the local characteristics of each project.

Typically, the amount of water removed by nuclear power plants does not exceed 200 m3/s (per site), and the allowed temperature increase is 10°C.

6.2.2.2 Hungary

Statutory regulation applicable to heat production by a cooling system operating with fresh water

High priority facilities, and more specifically, nuclear power plants, are subject to a special regulation set forth in Decree 15/2001. (VI. 6.) of the Minister for the Environment on the emission of radioactive elements to the air and to waters during the application of nuclear power, and on their control.

Article 10 (1): At high priority sites the following rules must be observed for protecting surface waters and water bearing formations against thermal contamination:

a) the temperature difference between the water to be discharged and the recipient water must not exceed 11°C, or 14°C if the temperature of the recipient water is less than +4°C;

b) the temperature of the recipient water measured anywhere in a section 500 meters downstream of the point of discharge must not exceed 30°C.

Based on Article 66 (1) of Act LIII of 1995 on the general rules of environmental protection, other heat load limits required for protecting water quality are determined by the supervisory authority in the course of licensing the use of the environment.

Statutory regulation applicable to heat production by cooling tower cooling systems

There is no statutory regulation in effect that would limit atmospheric thermal load, and there is no known atmospheric purity protection metric or limit value for the assessment of the effects of vapor formation and condensation.

6.3 COOLING METHODS TO BE TAKEN INTO CONSIDERATION REGARDING THE PAKS SITE

The cooling tower options applicable to the envisaged new nuclear power plant units of Paks were analyzed in separate studies. The purpose of these investigations was to select a cooling method that can be built and operated economically with the best possible technology and efficiency under the circumstances and environmental conditions, and which complies with the environmental regulations during its planned lifetime.

The results of the analyses revealed that the two cooling methods feasible at Paks are fresh water cooling and cooling tower cooling. These two options, i.e. the **fresh water cooling system** utilizing the water of the Danube and the **wet cooling tower cooling system**, which can operate independently of the Danube in air cooling mode, were analyzed in depth.

6.3.1 FRESH-WATER COOLING

In the case of fresh water cooling – the method currently used at the four existing units of Paks – the waste heat is removed by circulating Danube water through the condenser. For this cooling solution, water is removed by pumps at the water intake plant from the Danube, and fed through appropriate filters and pipelines to the unit's turbine engine room. The cooling water flows through the condenser, and the warmed cooling water is released back into the Danube through the warm water channel and the return structure.

The fresh water cooling system has been analyzed from the standpoints of technology, economics, and environmental protection. The analyses essentially explored the possibilities of removing the cooling water from the Danube and feeding it to the cooling water unit, as well as the technical solutions of returning the warmed cooling water to the Danube.

6.3.1.1 Alternative cooling water supply solutions

For the technology, the aim is to supply an adequate amount of cooling water, taking into consideration the characteristics of the Danube, the different water levels, water yields and water temperatures. Water may be sourced either from the Danube bank or the river bay of the existing cold water channel of the Paks Nuclear Power Plant. As the site of the Paks Nuclear Power Plant was chosen so that further units may be built there, cost-effectiveness criteria for cooling water supply dictate making use of the amenities of the site and the existing facilities as much as possible.

From the aspect of environmental protection, it is also advisable to use the existing facilities, with modifications applied where necessary. In order to limit the encroachment of new routes and facilities on Natura 2000 classified areas, efforts shall be made to make sure that Natura 2000 areas are affected as little as possible.

The most important alternatives studied for cooling water intake and supply are the following:

- Cooling water supply using a Danube bank water intake structure
- Cooling water supply using a bay water-intake structure

Evaluation

Cooling water supply from the bay is more favourable from the aspect of construction and operation than the two stage fresh water cooling system.

From the aspect of environmental protection, the option with the lowest self-consumption and the one resulting in the smallest amount of lost electric power is the most favourable, as any electric power lost to self-consumption must be produced in another power plant. The most favourable considered alternative is the bay cooling water supply.

In terms of environmental impacts, in the case of the two-stage cooling water supply, a narrow section of Natura 2000 area is affected due to the water intake on the Danube bank, which presents yet another disadvantage compared to the river bay cooling water supply.

Based on survey results and in light of the technological, financial, environmental and nature conservation considerations, the bay cooling water intake and supply alternative was chosen.

6.3.1.2 ALTERNATIVE SOLUTIONS FOR THE DISCHARGE OF HEATED COOLING WATER INTO THE DANUBE

During the analysis and comparison of the different options of passing the warmed cooling water (henceforth: warm water) from the units to the spillway, and onward from there to the Danube, then discharging it into the river, the primary aim was to stay clear of the safety systems of the current operating units of the Paks Nuclear Power Plant.

Regarding the discharge of warm water from the spillway to the Danube, we also investigated the use of the existing warm water channel. The results show that it is preferable to make use of the existing warm water channel.

The alternatives of discharging warm water into the Danube are as follows:

- discharge into the Danube on the left bank,
- discharge into the Danube beyond the shipping lane, at the bottom of the bed,
- discharge into the Danube on the right bank (selected solution).

Based on currently known conditions, discharging the warm water on the left bank of the Danube was discarded due to unfavourable mixing and significant investment costs compared to the other two alternatives.

Discharging the warm water beyond the shipping lane of the Danube is possible, and mixing is favourable in this case, but this solution requires a few significant technical interventions, and installing the structure that handles the deepening of the river bed is very expensive. Based on currently known conditions, discharging the warm water beyond the shipping lane of the Danube is only a secondary solution to the warm water discharge on the right bank of the Danube.

The following are the most important alternatives that can be considered for carrying warm water to the Danube on the right bank and that were analyzed in detail:

- discharge through the existing energy dissipation device and the southern side-channel branching from the new warm-water channel,
- discharge through the existing energy dissipation device and through the northern channel branching, through a new baffle structure (selected solution)

Evaluation

In terms of construction and operation, discharge of the warm water of the new nuclear units into the Danube is more favourable via the northern side channel of the existing warm water channel than via the southern one.

In terms of environmental protection, the more favourable alternative is the one that ensures a more thorough mixing of the discharged warm water with the Danube water. In this respect the northern branching off is a considerable better solution, because in this section mixing conditions are better.

If impacts on nature are considered, the northern side channel is the more favourable solution again, because only a narrow belt of Natura 2000 classified area is affected, resulting in a considerable advantage compared to the southern side channel.

Based on the conducted survey, and in light of the technical, financial, environmental and nature conservation considerations, discharge through the northern side channel branching from the existing warm water channel was chosen.

By establishing the northern side channel and a new warm water discharge structure (e.g. recovery power plant) in the area encircled by the existing cold water channel and the existing warm water channel, it is possible to improve the mixing of the warm water discharged into the Danube, along with minimizing the affected size of Natura 2000 areas.

6.3.1.3 Discharge of warmed-up cooling water in summer

In summer, when the water temperature of the Danube exceeds 25°C, and water yield is low, it might be necessary to apply an additional solution in order to observe the T_{max}=30 ^{o} temperature limit value specified for the Danube section 500 meters downstream of the warm water discharge point, especially in view of the increase in the water temperatures of the Danube over time, as a result of climate change.

In order to meet environmental regulations, the following possibilities were analyzed:

- Limiting the electrical output of the unit
- Mixing in cold cooling water
- Supplemental cooling.

The analyses assumed a 3°C temperature drop (basically resulting from mixing) between the warm water discharge point and the section 500 meter downstream therefrom, which allows a maximum of 33 °C warm water temperature at the discharge point.

Limiting the electrical output of the unit

In the case of this alternative cooling scenario, compliance with the maximum temperature limit permitted at the point of discharge is maintained through the limitation of the output power of the nuclear power plant units. By reducing electrical output, the amount of heat to be removed from the condenser, and therefore – in the case of an unchanged cooling water mass flow – the rate of warming of the cooling water is reduced.

Adding cold cooling water

In the case of this cooling alternative, maintaining the maximum allowed temperature of the warmed cooling water is achieved by mixing the excess Danube water that bypasses the turbine condensers from the cold water channel into the warm water channel. The excess cooling water required for mixing in cold water is supplied by the excess pump located in the water inlet plant, which can also be replaced by the pumps in the existing water inlet plant after the units currently operation are shut down. The cooling water warmed up in the condenser and the necessary amount of cold water mixed in is returned into the Danube via the existing warm water channel and an adequately sized structure that improves mixing at the discharge point.

Supplemental cooling

When supplemental cooling is applied, the maximum allowed temperature of the warmed cooling water is maintained by the cooling of the warmed cooling water that leaves the turbine condensers in a cellular cooling tower with induced draught. The volume passed through the supplemental cooler can be optimized. The cooling water that has passed through the condenser and cooled down in the supplemental cooling water is returned to the Danube through the existing warm water channel and an appropriate structure that improves mixing.

Evaluation

Each of the studied supplemental solutions are suitable for maintaining the temperature of the warmed cooling water below 33 °C, as required for discharge into the Danube.

The minimum allowed partial load of the units puts a limit on reducing the output of Paks II units, while cold water mixing may be limited by the available yield of the Danube and the total amount of cooling water extraction for Paks and Paks II, and the expandability of jointly used structures and aftercooling may be limited by noise. However, under our basic assumptions, technical limitation factors do not render any of the alternatives unfeasible.

The analyses show that the technical, financial and environmental considerations bring forward different benefits in each of the outlined three solutions, but according to current knowledge, temporary limiting of the electrical output of the units is an optimal solution, both on the basis of the results of life cost calculations, and in terms of environmental protection, as it does not entail either additional environmental emission or encroachment on additional areas.

6.3.2 TOWER COOLING

If a wet cooling tower cooling system installed near the existing cold water channel of the power plant is used for the new units, their heat is predominantly discharged into the air. The water taken from the Danube and treated by chemicals is only needed to replace the water lost by evaporation, entrainment and elutriation.

In the case of a wet cooling tower system, the cooling water passed through the surface condenser of the steam turbine is returned to the cooling tower, then with the help of the water distributing sprinkler system, it is evenly dispersed on the fill media. The water film formed on the fill media cools down again, as a result of evaporation into the countercurrent ambient air. In order to dramatically reduce entrainment in the course of passing through the wet fill formation, all modern wet cooling systems have fill media and apply an entrainment separator above the nozzles. From the fill media the cooled water is returned to the cooling water pool, from where the circulating pumps carry it back to the condensers. Evaporation increases the salt content of the cooling water. For this reason, in order to avoid excessive concentration, a part of the cooling water is elutriated and replaced by treated fresh water. Water lost by entrainment must also be replaced. In order to avoid the deposition of salt on wetted surfaces, the cooling water used in the cooling system is treated by chemicals, and to prevent the growth of algae and the settlement of mussels, biocides are added to the water.

6.3.2.1 Analysis of tower cooling alternatives

Separate surveys were carried out for the analyses of the cooling tower options applicable with the new nuclear power plant units planned to be installed on the Paks site [5-4], [5-6], [5-7]. The various alternatives were analyzed in detail according to the considerations of technical, financial, environmental and social acceptability. In the course of the assessments the following technical alternatives were analyzed in detail within the category of tower cooling systems:

- Natural draught wet cooling tower (approx. 186 m high),
- Natural draught wet cooling tower limited to 100 m height,
- Natural draught wet tower cooling, with additional fan cooling,
- Hybrid (dry/wet) tower cooling

The most important technical characteristics of the analyzed alternatives are summed up in the following table for 2 x 1200 MW_e capacity.

for units of 2 x 1200 MW electrical capacity	Natural draught	Natural draught with limited height	Natural draught with an additional fan	Hybrid (dry / wet) tower cooling
Number of cooling towers	2x1	2x5	2x1	2x1
Cooling tower height [m]	186	100	70	60
Base diameter of the cooling tower [m]	136.5	88	150	160
Cooling tower throat diameter [m]	77.5	60	95	74
Net area occupied by the cooling towers (for two units) [m^2]	30,000	61,000	36,000	40,000
Accelerated coolant volume rate of flow M^3/h	2 x 136,820	2 x 5 x 27,364	2 x 136,820	2 x 136,820
Additional coolant [m^3/h]	≈ 2 x 2,900	≈ 2 x 2,900	≈ 2 x 2,900	≈ 2 x 2,600

Table 10: Technical data of wet cooling towers

6.3.2.1.1 Waste heat emission

Based on the literature, cooling tower waste heat and moisture emission are likely to have mainly local impacts on the atmosphere, under certain weather conditions the probability of certain weather phenomena (relative humidity increase, reduced visibility, fog, drizzle, icing, hoar-frost) may increase, cloud, rain and snow formation may be affected, the place of shower formation and the time of rainfall may change. Over the longer term, they might slightly affect the micro-climate of the emitter. Cooling towers have no currently known global impact.

The protective forest planted in the vicinity of the industrial area and a green surface of a higher biological activity can offset part of the heat island impact. In addition to climate related considerations, these solutions are recommended because they are suitable for the reduction of other environmental exposures (air contamination, noise) and the for the partial concealment of the facility. In winter situations preventive anti-skid road treatment and the operative use of warning weather forecasts may reduce the damages caused by increased icing.

Tower cooling systems may emit waste waters as a result of the continuous elutriation of cooling tower pools, and waste water release by the replacement cooling water preparatory technologies. The emitted waste waters contain the salts of the chemicals required for the treatment of the coolant circulating in the tower cooling system and the chemicals and regenerates used for the development of replacement coolant.

6.3.2.1.2 Landscape protection analysis of the studied cooling solutions

The landscape protection considerations and the compatibility of the considered cooling solutions with the landscape were analyzed in the first half of 2012, for the then worst case, which was 2 x 1600 MW. The findings of the analysis are also valid for the currently studied 2 x 1200 MW units, with the difference being that 2x7 natural draught wet cooling towers would be needed for 2 x 1600 MW, while only 2 x 5 such towers are required for 2 x 1200 MW.

Natural draught wet tower cooling

In respect of impacts on and compatibility with the landscape, two 186 m high natural draught wet cooling towers would be highly unfavourable in terms of their impacts on the landscape, but the same can be said of the natural draught wet tower cooling solution with up to 100 m high towers.

Fitting natural draught wet cooling towers into the landscape is practically impossible, as they have the most powerful visual impact, and examples for structure of such a number and size are not found anywhere in Hungary or abroad.

Natural draught wet tower cooling, with a maximum 100 m high cooling tower

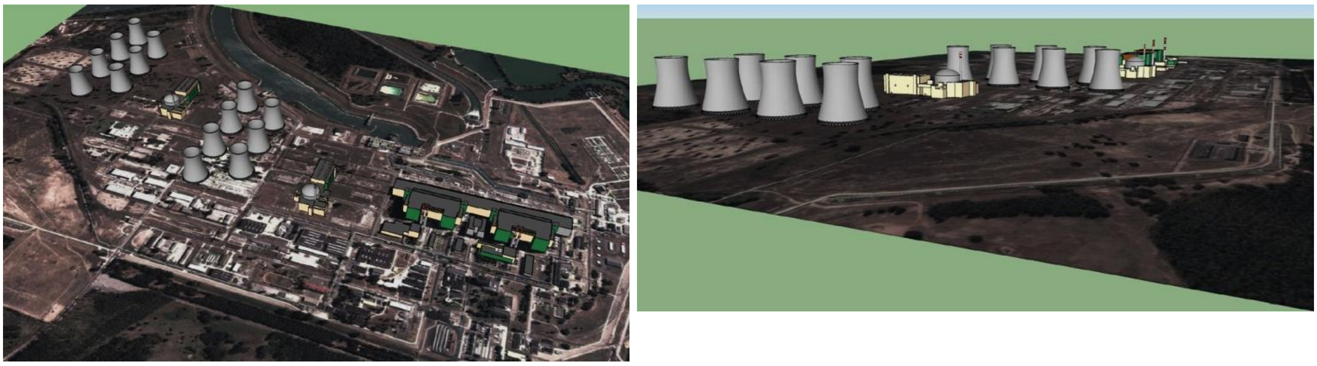


Figure 28: Natural draught wet cooling tower, maximum 100 m high – visual design (bird's-eye view and side view)

The two natural draught wet cooling towers with additional fans and the two hybrid wet cooling towers with additional fans can be adjusted to the landscape, they do not show any significant difference. The slightly lower hybrid cooling tower is more favourable because of the lower visibility of the vapor cloud, but it has a larger footprint.

Natural draught wet tower cooling, with additional fan cooling

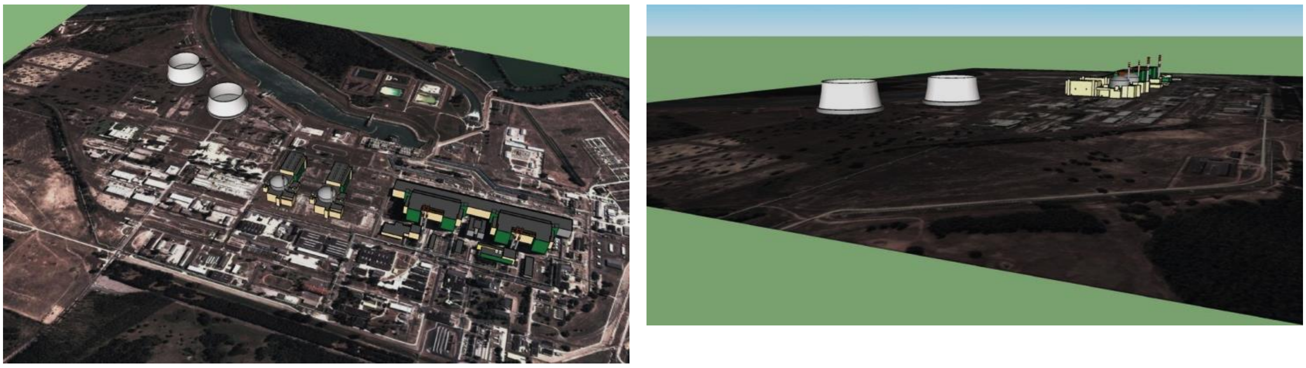


Figure 29: Natural draught wet cooling tower, with additional fan cooling – visual design (bird's-eye view and side view)

Hybrid (dry/wet) tower cooling

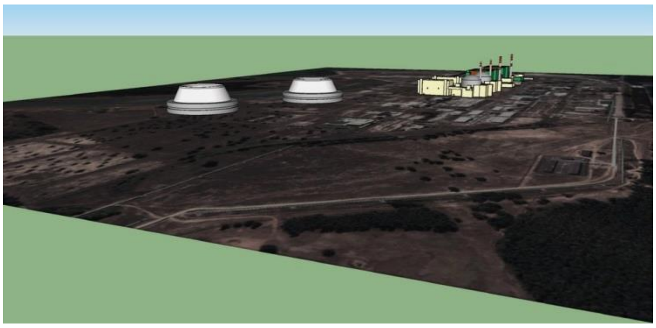


Figure 30*: Hybrid cooling tower with additional fan – visual design*

6.3.3 COST-BENEFIT ANALYSIS OF FRESH WATER AND TOWER COOLING METHODS

The project costs and operating costs of the two alternatives can be estimated but the social/economic and environmental effects are difficult to assess and the benefits are hard to quantify. For that reason, the engineering solutions that have been chosen for both options offer more or less the same level of risks and ensure compliance with the relevant environmental regulations. The two alternatives have different environmental impacts but may be regarded as having the same level of social impact. Consequently, with the level of risk being similar and compliance with the relevant regulations ensured, the lowest-cost solution can be chosen.

Based on the analyses performed, it can be concluded that both the wet tower cooling system and the fresh water cooling system are feasible; compliance with the current environmental regulations can be ensured through the application of adequate engineering solutions; the risks posed by the various alternative solutions are manageable; and the various alternative solutions can be ranked in terms of their cost effectiveness.

From an engineering perspective, with the application of the fresh water cooling system the planned new power plant units would offer a higher level of efficiency and electricity yield than with the tower cooling variant. Also, due to its similarities to the existing units, the fresh water cooling system has the additional advantage of readily available operational experience.

The icing caused by the water vapour emitted by cooling towers in winter time might damage the built environment and poses risks to the environment in general.

As far as construction is concerned, the freshwater cooling system basically consists of types of structures that have already been built in Hungary. A wet tower cooling system applying natural draught technology has not yet been constructed on such a scale in Hungary.

From an environmental perspective, the fresh water cooling system requires no – or very little – chemical use, while the tower cooling system involves substantial chemical use for the processing of replacement cooling water and the chemical conditioning of the cooling water circulated in the cooling system.

From the point of view of the impact on the natural environment, the cooling towers comprising the tower cooling system are less compatible with the landscape character due to the higher number of towers, even if tower height is limited. The noise load, as well as the project cost and operating cost of cooling towers with fan-assisted draught inducers are significantly higher.

From an economic perspective, it can be concluded that the total life-cycle cost of the tower cooling system is higher than that of freshwater cooling.

As a result of the analyses performed, the technology chosen – similarly to that of the four existing units – is the freshwater cooling system. [28]

7 CHARACTERISTICS AND SPECIFICATIONS OF THE PAKS II NUCLEAR POWER PLANT PLANNED TO BE BUILT AT THE PAKS SITE

7.1 HISTORY OF THE RUSSIAN VVER UNITS

The Russian manufacturer's currently available III^{+} generation unit model is VVER-1200.

The unit's thermal capacity is 3200 MW, with a gross electric capacity of 1200 MW, and a district heating capacity of 300 MW.

There unit is available in several versions, the difference between the types being in the different philosophy of safety systems designed by different head designers (MIR-1200 – St Petersburg design, AES-2006 – Moscow design).

The VVER-1200 unit is better in terms both of its economy (unit capacity, efficiency) and availability (92% utilization factor, 60 years operating life). Besides safety changes, the main circulating pumps have been improved (through eliminating oil lubrication), a new fuel has been introduced that burns out[3] reactor poisons, and the reliability of steam generators has been upped. The newly constructed units use integrated, digital control technology.

Through consistent application of the internationally accepted safety norms and EUR recommendations the VVER-1200 unit has practically been elevated to the level of AP1000 and EPR reactors.

3*Reactor poisons absorb neutrons (and thus reduce the multiplicator effect) without contributing to the chain reaction.*

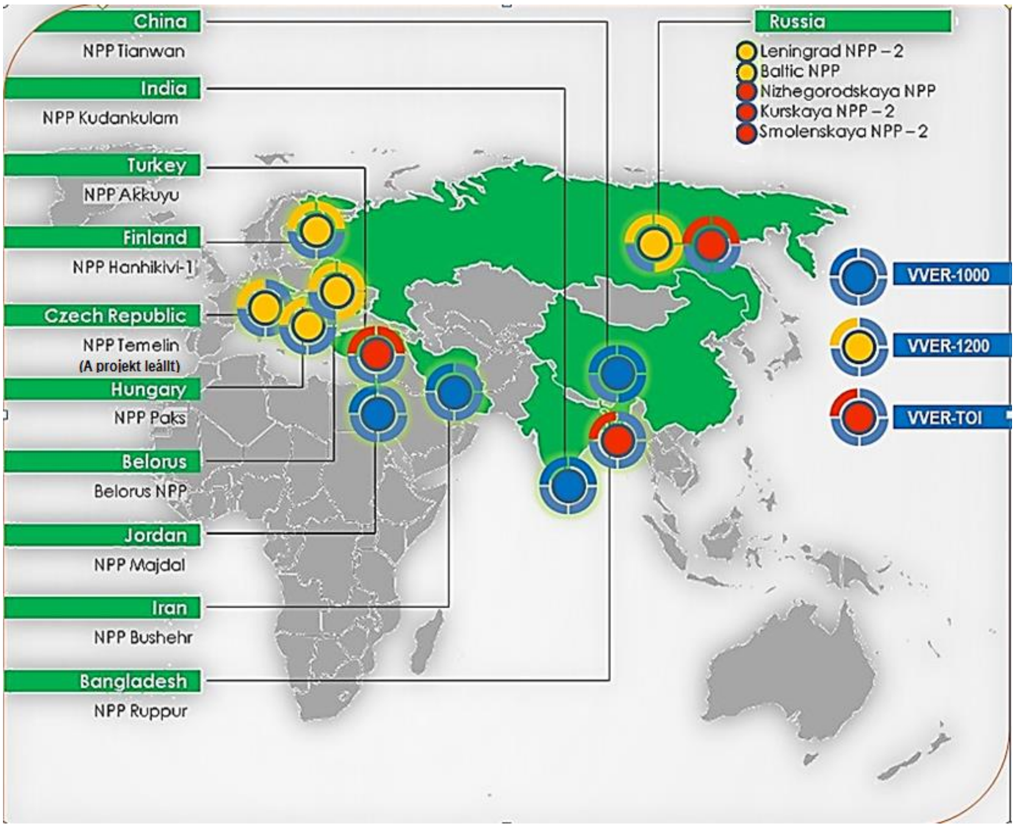


Figure 31*: Russian VVER units under construction and planned [7]*

In the Russian Federation two VVER-1200 units are being built at the Leningrad Nuclear Power Plant (Sosnovij Bor) and another two at the Novovoronezh Nuclear Power Plant and are expected to start operation in 2018 or 2019.

The Russian Federation plans to expand its nuclear generation capacity significantly with VVER-1200 type units. 17 units are scheduled to come online by 2020, with a total new capacity of 20,000 MWe.

7.2 CHARACTERISTICS OF THE RUSSIAN UNITS PLANNED TO BE INSTALLED ON THE PAKS SITE

7.2.1 KEY TECHNICAL PARAMETERS

Table 11 lists the main technical parameters of VVER-1200 units:

Reactor heat output	3,200 MW_e
Net deliverable output (depends on the secondary circuit technologies used)	1113 MW_e
Operating time	60 years
Planned output utilization factor	>90%
Time lost per year due to scheduled major maintenance	20 days
Self-consumption	7.1%
Type of usable fuel	UO_2
Fuel cycle, time spent by a cartridge in the reactor	54 months (3 x 18 months)
Campaign length	18 months
Fuel requirement	40.58 t UO_2 / 18 months
Fuels required (fuel + cartridge)	56.4 t / 18 months
Number of fresh cassettes at the time of replacement (equilibrium)	76
Average enriching of fresh cartridges	4.95% (^{235}U)
Average burning out in a fuel	47.5 Mwday / kgU
Controllability	50 % to 100 %, yearly max. 250 units
Number of loops and main circulating pumps (MCP)	4, 4 FKSZ/MAP
Pressure in the primary circuit	162 bar
Reactor inlet / outlet temperature	298.2 / 328.9 °C
Steam generator	4 units, horizontal
Steam generator outlet pressure	62.7 bar
Total coolant flow rate in the primary circuit	86,000 m^3/h

Table 11*: Main technical parameters of the VVER-1200 type unit [13], [30], [31]*

7.2.2 SAFETY OBJECTIVES AND DESIGN SOLUTIONS

Safety objective	Design solutions or risk countermeasures applied to achieve the objective
Management of incidents related to the design extension condition	– Double-walled containment structure – Cooling system – Containment cooling system – Hydrogen recombination systems – Core catcher
Prevention of high-pressure processes leading to early breakdown of the containment structure	– Pressure reducing valves – Cooling system
The treatment of produced hydrogen	– Recombination systems
Stabilization and cooling of core melt	– Core catcher
Containment pressure reduction	– Large surface coolers (0 to 24 hours) – Mobile equipment (between 24–72 hours)

Table 12*: Design solutions or countermeasure procedures applied to achieve the objective*

The nuclear systems of the unit are placed in a double-walled containment structure. The inner wall seals the containment structure hermetically, while the outer wall protects the hermetic space from outside impacts (e.g. if an aircraft hits the facilities). The lower part of the containment structure works as a core catcher for core melt.

The security systems that have a 100% protection capacity each are arranged in four independent channels. Each safety channel is equipped with its own diesel generator of 7.5 MW output.

In the case of a breakdown, the systems that provide the cooling of the reactor and the primary circle are augmented by 4 high-pressure hydro-accumulators, which keep the active zone under water without operator intervention in the initial period of breakdowns that involve significant loss of heat transfer agents in the primary circuit, until the active zone malfunction cooling systems (ZÜHR/ZMCS) kick in.

7.3 FUEL

The new nuclear power plant units to be built at the Paks site use enriched uranium-dioxide.

The fuel will be transported to the site in containers that conform to the relevant legislation, normally by train.

The first charge will be delivered to the site approximately 1-1.5 years before the start of commercial operation. Fresh fuel needed for the replacement of spent fuel will be delivered in conformity with the fuel cycle and the time of replacement, on schedule, every 18 months during the planned operating life of 60 years. As a strategic supply, fresh fuel equal to two replacements is stored on the site.

After the spent fuel cartridges have been removed from the reactor, they are placed in a **spent fuel pool**, where the **residual heat** can be removed until the heat subsides to the level where the fuel cartridge is suitable for temporary storing. The fuel cartridge can spend maximum 10 years in the spent fuel pool.

After being stored in the fuel pond, the spent fuels will be stored temporarily. At present, this can be done by either of the following two options:

- the spent fuels are transported to the territory of the Russian Federation for temporary technological storage or technological storage and reprocessing. The spent fuels, or in the case of reprocessing the nuclear waste will be stored on the territory of the Russian Federation for a length of time prescribed in the agreement (contract) mentioned in Article 7 paragraph 1 for the supply of nuclear fuel (20 years), and subsequently they will be returned to Hungary.
- temporary storage of the spent fuels in Hungary.

In view of the planned operational time of the new units and the periods specified in the intergovernmental agreement, we assume **temporary storage in Hungary**, at the site of the units or in their immediate vicinity. Temporary storage is used until the fuels can be directly and finally disposed of or the high activity waste resulting from the reprocessing of the fuels is can be safely put to final storage in Hungary.

Following temporary storage we expect direct and **final disposal of spent fuels in Hungary**, in view of the following:

- according to the Atomic Energy Act, one of the conditions for the final disposal abroad of waste generated in Hungary – namely that a radioactive waste storage facility has been licensed for the radioactive waste to be delivered and has been in operation before the delivery – is not met
- owing to the length of the planned operating life, the long-term feasibility of other options is questionable and involves significant risks

7.4 PRIMARY CIRCUIT

Based on the energy generation process, the planned new nuclear power plant units can be divided into two main parts: the primary and the secondary circuit.

The primary circuit passes the heat generated in the active zone of the reactor (reactor core) to the steam generator, the steam generated in the steam generator drives the turbine of the secondary circuit and generates power in the generator connected to the turbine.

7.5 SECONDARY CIRCUIT

The role of the secondary circuit is to transform the heat generated in the reactor into kinetic and then electric energy. The feedwater flowing in the secondary circuit is boiled up by the 300 to 320ºC water of the primary circuit flowing through the heat exchange pipes of the steam generator.

The steam leaving the steam generator enters the turbine, where its kinetic energy starts driving the rotor of the turbine. The high and low pressure blocks as well as the rotor of the generator share the same turbine shaft. In the high pressure turbine block, the temperature of steam decreases whereas its moisture content increases significantly. For this reason, before the steam gets into the low pressure block, it passes through an entrainment separator and superheater chamber, where water drops harmful for the turbine blades are removed from it.

Steam that has already done its job (dead steam) enters the condenser, where cooling water flows in thousands of thin pipes. On the surfaces of these cooling pipes the steam condenses at a temperature of about 25ºC, after which it is being redirected into the steam generator by the injection pumps through a multi-stage preheater used to increase efficiency.

The efficiency of the steam cycle is ~37%.

7.6 COOLING SYSTEMS

In addition to electric power generation, there is also heat produced in the primary and secondary circuits of nuclear power plants that cannot be used for electric power production, and which is carried off by the cooling systems.

The cooling systems of the planned new nuclear power plant units consist of three main parts:

The role of the ***condenser cooling system*** is to remove the condensation heat of the steam cycle from the *condensers* installed in the *secondary circuit* of the nuclear power plant by circulating mechanically filtered Danube water through the surface condensers.

The ***technological cooling system***, on the other hand, removes excess heat generated in the *auxiliary systems of the secondary circuit*. In new nuclear power plant units, the technological cooling system removes the waste heat of the turbine-generator group, of the injection pump and of the high capacity electric motors via a closed, intermediary cooling circuit. The technological cooling system branches off from the condenser's cooling system inside the turbine building, and the warmed up technological cooling water is drained off together with the condenser's cooling water back into the Danube.

The role of the ***emergency cooling system*** is to supply cooling water to the equipment of the *primary circuit* of the new nuclear power plant that require constant cooling during normal operation of the primary circuit. In addition, the emergency cooling system is also responsible for cooling the units during emergencies, by removing both primary circuit heat and residual heat from the reactor, as well as from the fuel handling sites and the fuel pond. The emergency cooling system has two alternative operation models. One uses forced air cooled cells that pass on excess heat to the air, whereas the other uses fresh water to remove the heat, and in this case the final heat absorber is the Danube river. Basically, the emergency cooling system operates in the fresh water cooling mode, but if, for any reason (such as extreme meteorological circumstances, extreme water levels, or damage to the water extraction facilities preventing their functioning), it is impossible to resort to this solution in order to meet the needs of emergency cooling, the unit automatically switches to the cooling cell mode. The planned new nuclear power plant units will be designed with the site's characteristics in mind, therefore their emergency cooling systems will operate in the fresh-water cooling mode most of the time.

7.6.1 WATER INTAKE FROM THE DANUBE

Depending on the type of cooling used for the emergency cooling system, the volumes of water extracted from the Danube are 64.15 m^3/s and 66.01 m^3/s, respectively, for one unit, totaling 128.3 m^3/s and 132.02 m^3/s, respectively, for two units. For the purpose of evaluating the impacts of water extraction from and discharge into the Danube, always the higher values have been taken into account.

If the emergency cooling system uses *fresh-water technology*, the total volume of raw water taken from the Danube (for condenser cooling, for technological cooling, for emergency cooling and for makeup-water pre-treament) is shown in the following table.

Description	Unit	1 x 1 200 MW_e	2 x 1 200 MW_e
Cooling water for the condenser*	m^3/s	61.5	123
Cooling water for technological uses (secondary circuit)*	m^3/s	2.6	5.2
Safety (primary circuit) coolant*	m^3/s	1.9	3.8
Raw water for preparing makeup water (desalinated water)	m^3/s	0.01	0.02
Total water intake from the Danube**	m^3/s	66.01	132.02
Annual (8760 h), maximum cooling water demand**	billion m^3 per year	2.08	4.16

Table 13*: Volumes of water taken from the Danube for the emergency cooling system in fresh-water cooling mode*

7.6.2 COOLING WATER FOR THE CONDENSER

The cooling water system of the condenser, just like in the case of the four existing units of the nuclear power plant, removes the excess heat with the help of water taken from the Danube, by circulating it through the condenser. The water of the Danube is extracted with the help of a water extraction pump, and is fed through the appropriate filters and pipes to the condensers located in the turbine building.

Based on the examined varieties of condenser cooling systems for the new nuclear power plant units, taking into account technical, economical, environmental and environmental protection considerations, the solution of choice was to take the cooling water from the river bay, and to discharge warm water by crossing the existing cold-water channel and expanding the existing warm water channel.

The volume flow rate of the cooling water needed for the condenser at an approach temperature of Δt = 8°C within the condenser, and for about 2,075 MW_{th} of heat to be removed, is expected to be 61.5 m^3/s for one unit and 123 m^3/s for two units during normal operation.

Unit output	Unit	1 x 1 200 MW_e	2 x 1 200 MW_e
Volume flow rate of cooling water [31]	m^3/s	61.5	123
Volume flow rate of cooling water	m^3/h	221,400	442,800
Warming of coolant inside the condenser [31]	°C	8	8
Annual (8760 h), maximum cooling water demand	billion m^3 per year	1.94	3.88

Table 14: Volumes of condenser cooling water

7.6.3 TECHNOLOGICAL (SECONDARY CIRCUIT) COOLING WATER SYSTEM

Cooling needs apart from that of the condenser of the secondary circuit of the nuclear power plant are met by the technological cooling system. Water required for this purpose is carried by the condenser's cooling system up to the turbine building, where it branches off and is carried along with the help of a properly sized pump increasing its pressure, down to all the users of the technological cooling system. Water warmed up in the technological cooling system returns into the warm water branch of the condenser's cooling system. The technological cooling water and the condenser's cooling waters are discharged together into the Danube. The cooling agent of the technological cooling system is the water of the Danube river, which is first filtered for use in the condenser, and then further cleaned through fine mechanical filters in order to ensure the safe operation of heat exchangers. Inside the closed intermediary cooling system of the turbine building desalinated water cools the heat exchangers of the technological cooling system.

The technological cooling water system is redundant (2x100%), which means that all major parts of the system consist of 2 parallel units, cross connected to each other.

The cooling water requirement of the technological cooling system for one unit during normal operation is expected to be 9,360 m^3/h, and for two units 18,720 m^3/h during normal operation. Transitional operation phases (such as start/stop) do not require significantly different amounts than normal. Calculations for technological water needs have been made with ≈86.6MW_{th} of heat/unit to be removed in mind, with a temperature increase of 8°C, which is identical with that of the condenser cooling system.

Unit output	Unit	1 x 1 200 MW_e	2 x 1 200 MW_e
Volume flow rate of emergency cooling water during normal operation	m^3/s	2.6	5.2
Volume flow rate of emergency cooling water during normal operation	m^3/h	9,360	18,720
Warming of cooling water inside the technological cooling system	°C	8	8
Annual, maximum technological cooling water demand	million m^3/year	82	164

Table 15: Technological cooling water volumes[32]

7.6.4 EMERGENCY COOLING WATER SYSTEM

The auxiliary systems of the primary circuit are cooled by emergency cooling systems built for each unit separately. One unit requires four identical independent supply systems. During normal operation, one redundant system is used, whereas during transitional periods of operation two redundant systems are involved.

This system is independent from both the condenser cooling of the secondary circuit, and from its technological cooling system. Joint engineering structures are only envisaged for their supply and drainage.

The water demand of the emergency cooling system for one unit during normal operation is expected at 6,840 m^3/h, and for two units during normal operation at 13,680 m^3/h. The same for transitional operating conditions (such as start/stop) for one unit is 13,680 m^3/h. Since for operational reasons the two units are not expected to be in a transitional state at the same time, the combined water demand of the two units is not likely to exceed a volume flow rate of 20,520 m^3/h. Calculations for safety water needs have been made with a temperature increase of 8°C, identical with that of the condenser cooling system.

Unit output	Unit	1 x 1 200 MW_e	2 x 1 200 MW_e
Volume flow rate of emergency cooling water during normal operation	m^3/s	1.9	3.8
Volume flow rate of emergency cooling water during normal operation	m^3/h	6,840	13,680
Volume flow rate of cooling water	m^3/h	13,680	20,520
Warming of coolant inside the emergency cooling system	°C	8	

Table 16*: Emergency cooling water volumes*

Cooling with forced air cooling cells

One possible method of operating the emergency cooling system is to use forced air cooled cells that pass on excess heat to the air, the final heat absorber being the surrounding atmosphere. In this case, the emergency cooling system does not extract excess heat by circulating the Danube's water and thus does not discharge any warm water back into the river. This is a quasi closed system, in which the coolant circulates between the emergency cooling cells and the heat exchangers of the emergency cooling system. After the system is filled up at start, it is only necessary to replace the amount evaporated, separated or lost due to sludge removal. This lost amount of water is replaced by the dedicated makeup water preparation system of the plant. The annual demand for replacement cooling water is minimal, since the emergency cooling towers are expected to work about a month a year at most, therefore their demand for Danube water is neglectable compared to other water extraction volumes for cooling.

Unit output	Unit	1 x 1 200 MW_e	2 x 1 200 MW_e
Volume of makeup cooling water	m^3/s	0.04	0.08
Maximum annual demand for replacement cooling water (for emergency cooling, taken from the Danube)	million m^3/year	≈0.1	≈0.2

Table 17*: Volumes of replacement cooling water for emergency cooling, with emergency cooling towers*

Cooling towers using forced air cooling cells for removing the heat of the emergency cooling system are 4 times redundant (4x100% build up) for each unit. (The amount of reserves is to be finalized on the basis of safety analyses conducted at the site). During normal operation, one emergency cooling tower is used and all the others are reserves. On the other hand, at times of start-ups, stops and cooling sessions following stops, two emergency cooling towers are in operation.

These 4 emergency cooling cells for each unit are located next to the containment building. The floor area of the emergency cooling cells is 17x35 m, their full height is about 15 m, the cells themselves being 13 m tall, whereas the chimneys above them are about 2 m high. The emergency cooling pumps are located next to the cooling cells, and their role is to circulate the cooling water between the safety systems and the cooling cell. Emergency cooling towers are twin-cell structures, i.e. all cooling cells have two water distribution systems and two fans.

Water warmed up inside the safety systems of the primary circuit is fed to the safety cells and, with the help of nozzles, is distributed evenly on the wet cooling inlays. The film of water forming on the surface of the cooling inlay is cooled down as a result of a counterflow of atmospheric air. In order to minimize entrainment during this flow across the cooling inlay, a separator is used above the cooling inlays and the nozzles. The chilled cooling water returns from the cooling inlay to the cooling water pool, and from there the circulating pumps carry it back to the safety systems of the primary circuit. Evaporated and separated water is replaced by the makeup water system, which also adds the chemicals needed for the safe operation of the system.

Fresh-water cooling

The second option for operating the emergency cooling system is to use the water of the Danube to remove excess heat from the system, which then is discharged to the river through the warm water channel. In this case the emergency cooling system can be considered an open system, in which the volume flow rate refers to the water of the Danube extracted from the river and circulated through the heat exchangers of the emergency cooling system. The annual maximum demand for cooling water in this case is calculated for 8760 hours of operation, since there might be years when the system's cooling is exclusively provided for by the fresh-water cooling system.

Unit output	Unit	1 x 1 200 MW_e	2 x 1 200 MW_e
Volume flow rate of the emergency cooling water during normal operation (circulated cooling water or Danube water)	m^3/s	1.9	3.8
Annual, maximum demand for emergency cooling water (taken from the Danube)	million m^3/year	59.9	119.8

Table 18*: Emergency cooling water volumes used for fresh-water cooling*

The method of choice for cooling can be finalized after the technological and safety analyses conducted at the site, and if required, the cooling of safety systems can also be solved by building a spray pool or by cooling water supplied from a water intake structure independent from that of the condenser's cooling system.

The emergency cooling system must comply with the requirement set forth by both IAEA and the Nuclear Safety Regulations stating that the removal of residual heat from the reactor must be solved even if the normal procedures of heat absorption are dysfunctional, and even if such condition is caused by external impacts (earthquakes, extreme meteorological conditions, extreme cold, wind, snowstorm, aircraft impacts, fires etc.). [32]

7.6.5 WATER ENGINEERING STRUCTURES OF COOLING WATER SYSTEMS

Existing extended cold-water line

The cold water channel is used jointly by the units of Paks Nuclear Power Plant and Paks II. Nuclear Power Plant. In order to allow the warm-water channel drain warm water from the 1300 units in 2030, when the existing 4 units will operate simultaneously with the planned 2 new units, the warm-water channel must be extended.

Water intake structure

Based on the performed feasibility analyses, the best place for the new river-bay intake plant to serve the new nuclear power plant units is located about 150 meters north of the existing water intake plant, on the bank of the existing cold-water channel of the Paks Nuclear Power Plant. The water intake plant consists of either 3 x 33% or 4 x 25% condenser coolant pumps and filtering systems (6 to 8 parallel systems for the two units). The water intake plant will include a mechanically cleaned rack, a travelling water band screen and appropriate shuttering panels.

When the safety coolant system is operated with freshwater cooling, water is taken from the Danube by 4 safety coolant pumps per unit, housed in the water intake plant. Depending on design allowing for the site features, the water intake plant of the safety coolant system is expected to operate in a significant part of the running time.

Cooling water pipes

The coolant of the condenser cooling water system (including the coolant of the technological cooling water system) will be carried in underground pipes along a 300 to 400 m long route, above the water intake plant and the turbine building. The volume of coolant passing through the cooling water system will be carried by 3 pipes of 3.2 to 4 m in diameter.

The coolant in the emergency cooling water system runs parallel with the condenser cooling water system to the turbine building, and then follows a separate route to the building that houses the emergency cooling system. The volume of coolant passing through the emergency cooling water system is carried in 4 pipes of 0.5 to 0.8 m in diameter.

Turbine condensers and cooling system heat exchangers

The coolant flowing through the condenser cooling water system absorbs the heat that must be absorbed during the condensation of the steam entering the condenser. The heat absorbed in the turbine condenser warms the cooling water that passes through the condenser coolant pipes. The condenser is sized for an 8 °C temperature differential in the coolant.

In the case of the technological and the emergency cooling water systems, the coolant passing through the heat exchangers absorbs the cooling heat from the intermediate closed cooling water system connecting to the technological and the emergency cooling water systems. The absorbed heat warms the cooling (Danube) water passing through the heat exchanger pipes. Similarly to the condenser cooling water system, in the technological and the emergency cooling water systems the temperature of the cooling water is expected to increase by 8°C.

Closed warm-water channels

The warmed-up coolant runs from the turbine building to the cold-water channel, then along the bridge built above the cold-water channel, passes through the reinforced concrete channel built after the bridge to the water-level control spillway along a route of about 500 meters. The warmed-up coolant includes the warmed-up technological cooling water that flows into it in the turbine building as well as the emergency cooling water that pours into it outside the engine room (when emergency cooling is in a freshwater cooling operating mode). The volume of coolant passing through the cooling water system will be carried by 2 reinforced concrete channels of 5 x 3 m in diameter.

Aqueduct

The warned-up coolant will be carried to the water-level control spillway by an appropriate new aqueduct built above the existing cold-water channel. The aqueduct will be built of prefabricated reinforced concrete blocks, with piers located in the bed of the existing cold-water channel. The width of the bridge is between 25 and 30 m, the largest span between two supports does not exceed 50 m.

Water level control spillway

The function of the level-control spillway is to ensure the condenser coolant pressure required for the reliable operation of the condenser cooling water system and to provide an option for back mixing warm water into the cold water channel.

New free flow, trapezoid cross-section channel

From the level-control spillway to the existing warm-water channel a new, trapezoid cross-section, free-flow warm-water channel section needs to be made of reinforced concrete, including a new fork piece to feed the warm water coming from the new units to the existing warm-water channel. In the new free-flow channel, warm water is moved by gravitation towards the existing warm-water channel along a route of about 500 m. The planned bottom width of the new free-flow channel is 16 m, with a channel width of 80 m (and a freeboard width of 50 m), the 1:2 slope, and an average water height of about 2.5 to 3 m.

Existing extended warm-water channel

After the new fork piece, the warmed-up coolant is transferred to the return structure through an appropriately extended section of the warm-water channel. The warmed-up coolant is returned to the Danube through the appropriately extended warm-water channel by gravity.

During the implementation of the Paks Nuclear Power Plant, the existing warm-water channel was made suitable for supplying the warm water requirements of the Paks Nuclear Power Plant as well as 2 x 1000 MW additional units planned at that time. Based on that concept, the warm-water channel was sized for 220 m^3/s. Suitability of the warm-water channel for the planned 2 x 1200 MW units was reviewed in consideration of the expected water levels of the Danube and of the fact that the existing water-level control spillway of he Paks Nuclear Power Plant limits the maximum water levels that can be maintained in the warm-water channel.

In order to allow the warm-water channel to drain warm water from the 6 units in 2030, when the existing 4 units will operate simultaneously with the planned 2 new units, the warm-water channel must be extended. As in 2025 the volume of water required for the new units would significantly increase water level in the warm-water channel and would render the performance of warm-water channel extension more difficult, it is advisable to complete the channel extension that will become necessary in 2030 already in 2025.

Existing energy dissipation device with a second discharge point

Warm water can be returned to the Danube with the help of the new energy dissipation device, developed according to the volume of warm water required for the operation the existing 4 units and the planned 2 new units.

The implementation of a second discharge point offers more benefits than the extension of the existing energy dissipation structure. If a structure is made at the second discharge point on the area enclosed by the cold-water channel and the warm-water channel, and an energy recovery hydroelectric plant is installed in it, it is possible to improve the mixing of the warm water discharged into the Danube, and a considerable amount of electric power can be regained while minimizing the affected Natura 2000 areas.

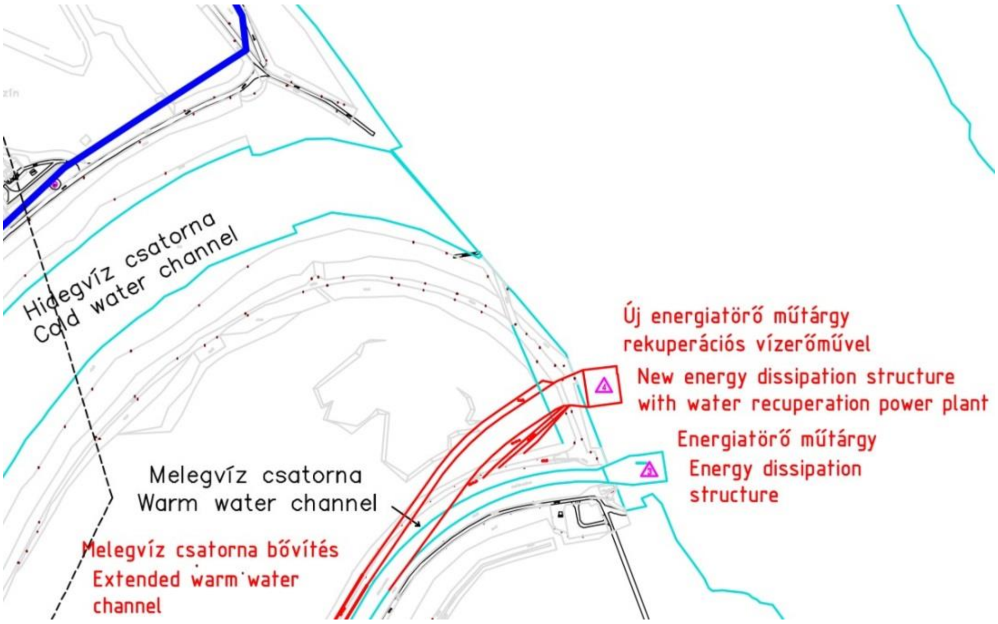


Figure 32: Site plan of the existing energy dissipation device and a second, new discharge point with a recovering hydroelectric plant

7.6.5.1 Recovery power plant

By damming the warm-water conduit coming from the nuclear power plant, a gradient can be ensured at the Danube mouth of the warm-water channel, which is suitable for the operation of water turbines of approximately 7 to 8 MW total nominal output. Based on the Danube flow regime and unit operation, nearly 35 GWh energy may be so generated annually.

The upstream water level of the recovery power plant is dammed by a barrage dam at the end of the warm water channel, with water turbines and direct service facilities. They include the barring structures setting the course of the water along with the components required for the operation of these structures, and the lifting equipment and auxiliary facilities needed for servicing and maintenance. The electric and control engineering equipment, the switchboards and the transformers are located in a separate electrical building next to the hydroelectric plant. The cables providing connection to the power plant and the transmission lines delivering the generated electricity are connected to this facility. The equipment providing auxiliary power, a compressor and an oil station are also located here.

The recovery power plant has an overflow facility that can provide an outlet for the maximum volume of cooling water coming from the nuclear power plant without any untoward effect and can channel it back safely to the Danube when the water turbines fail to operate or are maintained.

The hydroelectric plant is an autonomous facility is surrounded by its own perimeter fence and does not require the continuous presence of an operator. A physical dam and an alarm system secure the property.

7.7 AUXILIARY SYSTEMS AND AUXILIARY FACILITIES

7.7.1 DESALINATED WATER

A new water pre-treatment facility is planned in connection with the extension of the units planned to be built with a capacity of 3 x 100 percent. 3 parallel units are constructed for the most important elements of the system, with suitable cross connections.

The technology of the pre-treatment process of makeup water consists of the following component processes: clarifying, multimedia filtration, desalinizing with membranes and post-desalinizing with deionization, if necessary. The desalinizing process with membranes consists of three subdivisions: ultra filtration, reverse osmosis and electro-deionization. The essence of the pre-treatment of makeup water is desalinizing with membranes and an important characteristic of this process is, that compared to the traditional process of calcareous softening and deionization desalinizing, it uses at least one order of magnitude fewer chemicals and in this way the quantity of the chemicals emitted together with the produced waste water can be significantly decreased. The pre-treatment equipment provides the necessary supplementary cooling water for the cooling towers of the safety of cooling water system. The water quality required for the supplementary cooling water can be obtained from the intermediate process of the pre-treatment of makeup water, after the desalinizing process with membranes. Consequently, the preliminary stage of the pre-treatment of makeup water has a higher capacity (depending on the storage of supplementary cooling water and the requirements for the quality of water in the cooling towers) and the volume of water that goes through the fine desalinizing is not more than the salt-free water demands of the primary and secondary circles.

Depending on the two possible ways of operations of the emergency cooling water system, the makeup water pre-treatment equipment also has two possible modes of operations. Since the cooling tower operating mode of the emergency cooling water system is available only for a short time (a few days in a year, probably not more than a month) we have supplied the data for the water balance of the pre-treatment equipment of makeup water for the characteristic mode of operation, when the emergency cooling water system is cooled by fresh water and there is no requirement for supplementary cooling water.

Based on the above, the raw water demand of the pre-treatment equipment of makeup water for one unit is expected to be 36 m^3/h and for normal operation; of two units it is expected to be 72 m^3/h. The planned annual raw water demand of the two units is not expected to exceed 640,000 m^3.

Description	Unit of measure	1x1200 MW	2x1200 MW
Raw water (from the Danube)	m^3/s	0.01	0.02
Raw water (from the Danube)	m^3/h	36	72
Waste water	m^3/h	12	24
Generated desalinated water	m^3/h	24	48

Table 19*: Water balance of the makeup water pre-treatment plant during normal operation*

The function of the desalinated water storage and distribution system is to store and deliver desalinated water to the desalinated water consumers in the primary circle, the turbine building and the auxiliary facilities. The makeup water pre-treatment plant and the desalinated water storage facilities must jointly satisfy the simultaneous maximum desalinated water requirements. The expected desalinated water requirement of the new nuclear power plant units is 24 m^3/h in the case of one unit during normal operation, and for two units during normal operation 18,720m^3/h. The higher desalinated water requirements that arise during interim operational states are met by desalinated water from the desalinated water storage. As interim operational states last only a few days a year, the desalinated water requirement for normal operation is predominant. The combined annual desalinated water requirement of the two planned units is not expected to exceed 420 thousand m^3.

The waste water of the joint makeup-water pre-treatment facility of the new nuclear power plant units is 12 m^3/h during normal operation in the case of one unit, and 24 m^3/h during normal operation for two units. The annual volume of the waste water generated by the makeup-water pre-treatment plant is not expected to exceed 220 thousand m^3.

The waste water generated in the makeup-water pre-treatment plant during the individual technological partial processes is collected and stored in the interim waste water collection store. The waste waters generated in the various processes are mixed and checked before discharge for compliance with the relevant emission limits. If needed, they are chemically neutralized. Waste water is discharged to the technical waste water system of the power plant. [32]

7.7.2 TECHNOLOGICAL WASTE WATER

7.7.2.1 Radioactive waste water management system in the primary circuit

The primary circuit waste water management system collects, treats and stores the radioactive waste water produced in normal operation. This system also receives the potentially radioactive waste waters of the turbine building systems (e.g. elutriation of the steam generator on the supply water side).

One of the key tasks of liquid radioactive waste handling is the selective collection of different types of waste waters on the basis of the basic physical and chemical properties of waste waters. By separating active and inactive waste waters the selective collection of waste water can significantly reduce the amount of different categories of waste waiting for final disposal. Most of the radioactive waters are returned to the proper technological process of the primary circuit after the required treatment operations. The radioactive waste waters which cannot be fed back into the technological process go through a cleaning technology line and in the end the separated active contaminants are condensed and stored as required. After treatment and disposal, the treated and tested radioactive waste water with radionuclide concentration is discharged into the warm water channel from the primary circuit waste water system through a controlled ejector pipe after a control tank.

The expected average maximum annual and daily discharge of treated waste water from the radioactive waste water system is shown in the following table.

Description	Unit of measure	1x1200 MW	2x1200 MW
Normal operation	m^3/h	5	10
Annual waste water volume	thousand m^3per year	44	88

Table 20*: Volume of primary circuit liquid radioactive waste [32]*

7.7.2.2 Turbine building waste water management system

The waste water treatment system of the turbine building collects and processes the waste water of the turbine building and the auxiliary equipment. This system only treats non radioactive waste waters.

The turbine building waste water management system can be divided into three subsystems:

- closed condensate collection system;
- leachate collection system;
- industrial waste water system.

In normal operation the waste water of the turbine building's closed condensate collection system returns to the supply water system and does not become waste water. The waste water of the leachate collection system and the industrial waste water system is discharged as waste water after proper treatment, neutralization or oil removal. The volume of waste water is shown in the following table.

Description	Unit of measure	1x1200 MW	2x1200 MW
Normal operation	m^3/h	20	40
Annual waste water volume	thousand m^3per year	175	350

Table 21: Volume of liquid waste from the turbine building

The combined annual waste water volume generated in the turbine building and in the auxiliary facilities of the two planned units is not expected to exceed 350 thousand m^3.

After proper inspection and making sure that discharge limits are met, the waste waters collected by the waste water collection systems are discharged into the warm water channel by the turbine building's waste water system. [32]

7.7.3 WASTE WATER FROM EMERGENCY COOLING TOWERS

If the emergency cooling water system is operated in the cooling tower mode, the cooling system must be elutriated during heat transfer, because of the evaporation taking place in the cooling towers and the contamination getting in with the air, in order to limit the concentration of contaminants in the cooling water. The waste water of the elutriation process required when the emergency cooling tower is used is passed into the Danube through the warm water outlet channels together with the warm condenser cooling water. Its quantity is smaller by orders of magnitude than the quantity of the condenser cooling water.

If the emergency cooling system is operated in cooling tower mode, the waste water comes from the elutriation of the cooling tower. Practically, the elutriated water is produced when the water which is partly desalinated in the makeup water preparation equipment is thickened by evaporation in the cooling tower. The following table shows the quantities of waste water coming from the cooling towers broken down by hour and year with the assumptions made for operation.

Description	Unit of measure	1x1200 MW	2x1 200 MW
Waste water from the elutriation of the waste water in emergency cooling towers	m^3/h	36	72
Annual maximum average waste water quantity (assuming max. 1 month operating time)	thousand m^3per year	26	52

Table 22: Maximum volume of waste water from the emergency cooling towers after elutriation

For the two new units, the combined annual quantity of the waste water stemming from the cooling tower operation of the emergency cooling system is not expected to exceed 52 thousand m^3.

After proper inspection for meeting the discharge limits, the waste waters generated are discharged into the warm water channel by the turbine building's waste water system.

7.7.4 DRINKING WATER – COMMUNAL WASTE WATER

Source: Decision support analysis of the various aspects of drinking water supply to the new NPP units of Paks, and of sewage handling, MVM ERBE Zrt. [6-10]

Studies suggest that the best source of water for the new power plant would be the Csámpa waterworks and its auxiliary systems, and the best communal sewage treatment system would be the water treatment facility and its auxiliary equipment operating on the premises of the Paks Nuclear Power Plant, both for technical and business reasons.

The maximum quantity of drinking water will be needed when the fist unit begins operation and the construction of the second unit is under way at the same time, with a maximum quantity of 646 m^3/day, with 95% of this, or 614 ^{3} per day becoming sewage water.

Csámpai vízműtelep – Csámpa Waterworks

Figure 33*: Location of the Csámpa Waterworks[33]*

7.7.5 RAINWATER

Rainwater drained from the yards and roofs of the new nuclear power plant units and the non-contaminated surface waters collected from other areas are directly fed into the warm water channel.

Clean and potentially oil-contaminated rain waters are collected separately in the operating area. In order to catch rainwaters potentially contaminated with oil, oil traps of the required size will be installed in the overground car parks. Transformer foundations will be built with adequately sized shafts to store the accumulated rain water and oil traps will be installed to manage oil leaks. The rainwater collected from the area around the oil tank will also be passed through the oil trap. Rainwater free from oil is drained together with the clean rain water.

7.7.6 FIRE WATER

The new nuclear power plant units will have a common fire water network, which will receive water from the raw water system of the new units. A maximum of 380 m^3/h raw water will be fed into the fire water basin through a pipe. The fire water supply system will be built in accordance with the fire protection plan to be prepared later.

7.7.7 RACKING AND STORAGE OF CHEMICALS

The planned new nuclear power plant has its own unloading and storage system for chemicals. A chemical unloading and storage system receives, extracts, stores and treats all the chemicals used by the power plant in a separate room in the water preparation building. A supply of chemicals sufficient for at least 30 days needs to be stored – using the normal operating mode of the power plant as a basis. In order to ensure that the chemicals do not contaminate the environment, proper damage prevention basins will be installed. There will be chemical collection basins and floor pits around the chemical storage tanks in the chemical storage building to ensure that potentially leaking chemicals could be passed to the chemical waste water treatment system. There will be proper chemical forwarding pumps installed at the chemical storage tanks. There will be an appropriate pneumatic system for moving non-liquid chemicals. The pre-packed quantities of the stored chemicals will be moved by trucks or hoisting machines.

Description	Stored quantity
Hydrazine and ammonia storage	
Ammonium hydroxide	1 m^3
Hydrazine	3 t
Hydrogen storage	13 m^3
Chemical storeroom	
Nitric acid	4 m^3
Sulphuric acid	7 m^3
Water treatment plant	
Hydrochloride acid	53 m^3
Sodium hydroxide	40 m^3
Boric acid storage	2 x 3 t

Table 23*: Storing chemicals during operation*

7.7.8 DIESEL GENERATORS

Emergency power is supplied to the safety systems by 4 diesel generators per power plant unit, each having an output of ~7,5 MWe, with the fuel heat input being 18,75 MW_{th} per generator. Each one of the diesel generators is capable of supplying the required amount of electric power in the case of an emergency shutdown. For a safe shutdown, 168 hours of uninterrupted diesel generator operation must be ensured for each power plant unit. Consequently, the total storage capacity required for the operation of one generator (assuming a fuel heat input of 42 MJ/kg; specific weight of 0.83 kg/l and a degree of efficiency of 40%) is ~325 m3. In order to ensure the level of redundancy necessary for safe fuel supply, each diesel generator device will be equipped with a separate fuel tank capable of holding the amount of diesel fuel required for 168 hours of uninterrupted operation. As a result, storage capacity for holding 8 × 325 m3 (a total of 2600 m3) of diesel fuel will be available in the buildings where the diesel generators are installed.

Under normal operating conditions, any planned operation of the diesel generators can take place for test purposes only, meaning an average test run period of 8 hours per generator per month, with each generator tested separately; the maximum duration of test operation is 8×8×12, that is, 768 hours.

7.7.9 SECONDARY BOILER

In order to supply the amount of steam required for the acceleration of the start-up of the units during the implementation phase and the operating period, 2 auxiliary electric steam boilers, each with an output of 15 MW, will be installed. Power will be supplied to the boilers via the 10 kV electrical network, and the combined steam supply capacity of the boilers will be 46 t/h at 12 bar and 192°C. [34]

7.7.10 BUILDING SERVICES

The purpose of the nuclear power plant's HVAC (Heating, Ventilation and Air Conditioning) systems is to prevent or reduce the spread of radioactive substances within the facility, and to provide the air conditioning key for maintaining the standard conditions necessary for the personnel and/ or equipment.

7.7.11 COMPRESSED AIR SUPPLY SYSTEM

The compressed air required by the primary and secondary circuits is supplied by the compressor substations and air dryer equipment. Generally, compressed air is supplied to the primary and secondary circuits by two compressed air supply stations per unit.

7.7.12 DISTRICT HEATING SYSTEM

The purpose of the district heating system currently in use at the Paks Power Plant is to:

- supply warm water to the primary circuit of the heat exchangers of the heat distribution centres located at residential districts, thus providing heating for these districts;
- supply the City of Paks with warm utility water and to feed warm water into the heating system of the power plant.

The peak heat requirement of district heating is estimated at 30 MW_{th} so the current system is oversized and has some redundant capacity. The district heating system was built in a network structure including an outgoing and a return main pipeline (nominal outgoing/return temperature: 130 / 70°C, or in the event of prolonged cold weather: 150 / 70°C), complete with heat exchangers and pumps, as well as valves required for their disconnection.

The district heating system consists of the following three main components:

- Heat distribution centers (heat exchangers);
- Circulation system;
- Replacement-water system.

Within the context of the implementation of the new power plant units, the design of the district heating system to be established will be equivalent to the existing system, that is, from the branches of the newly installed turbines the steam would be conveyed to a common distribution pipe, and heat exchangers would be installed after the manifold depending on heat requirements, subject to an output of approximately 30 MW. The entire system including heat exchangers, circulation and manifold would be installed in a separate building section (separate building). [35]

7.8 CONTROL ENGINEERING

The purpose of the control engineering system is to ensure a safe and reliable control of the energy production processes at the power plant, and to reduce the likelihood of failures, breakdowns and accidents to the minimum acceptable level. The control engineering system ensures comprehensive monitoring and automatic control of the technological and energy production processes, generates a warning message when detecting anomalies, and seeks to eliminate such anomalies by applying the appropriate redundant solutions.

The continuous monitoring of processes and equipment that are required for the operation of the power plant but represent a load / exposure for the natural environment and the human population is ensured through the use of monitoring equipment and systems that are controlled independently of the technological processes.

7.9 ELECTRICAL SYSTEMS

As far as environmental load is concerned, the power plant electricity supply system of the new units consists of 2 three-phase interplant transformers and 1 three-phase reserve mains/starting transformer per unit. [36]

Main transformer

Effective power: min. 1200/3 MW (about 1500/3 MVA)
Quantity: 3 single phase units
Oil quantity: about 90 tons/ single-phase transformer; about 270 tons / 3 singe-phase transformers
Maximum noise load: about 75 dB / transformer

Normal internal use transformer

Effective power: about 70 MW (about 90 MVA)
Quantity: min. 2
Oil quantity: about 33 tons/ transformer; about 66 tons / 2 units
Maximum noise load: about 70 dB / transformer

Reserve mains / start-up transformer

It is recommended to consider the use of at least one transformer for each unit with a power equivalent to that of a normal internal use transformer.
Effective power: about 70 MW (about 90 MVA)
Quantity: 1
Oil quantity: about 33 tons
Maximum noise load: about 70 dB

The estimated total oil quantity of the main, interplant and reserve transformers listed above is: ~370 tons/ unit

There will be damage prevention basins under the transformers to prevent any possible oil contamination.

7.10 CIVIL ENGINEERING

7.10.1 FOUNDATION LAYERS OF THE PLANNED UNITS

At a depth of 10 m the geological formation is generally made up of fine-grained, low-cohesion, crumbly sediments. The fine-grain sediments are generally compressible layers with varying consistency, low plasticity and load bearing capacity. Underneath these layers the flood plain formation is moderately compact, suitable for foundations with proper load bearing capacity but because of its grain distribution it is sensitive to erosion and dynamic effects (e.g. an earthquake) and is susceptible to liquefaction under water. Muddy clay lenses may block the path of rainwater into the ground, and form so called pendular water lenses. The level of hanging water lentils is always higher than the level of ground water at an average ground water level.

Paks II. The general ± 0,00 level of the future Paks II Nuclear Power Plant was recorded at 97 mBf.

Taking the assumed initial basic data into account, the estimated foundation depths are as follows:

- Reactor building complex (nuclear island), turbine building, diesel generators and other buildings that are part of the safety system. Estimated foundation depth – due to the space required by the technology and the significant dynamic loads of the turbo machine group – is about 14-20 m. Plate foundation supported by reinforced concrete piles are planned for this sites.
- Other building that are not part of the safety system Deepened shallow foundation or plate foundation built on partial soil replacement is planned for other separate buildings that do not contain technological equipment resulting in significant dynamic use. The estimated foundation depth is 2-6 m.

7.10.2 INSTALLATION SITE PLAN OF THE PAKS II NUCLEAR POWER PLANT

On the installation site plan prepared for the environmental impact assessment study, the buildings and edifices were arranged on the basis of technological considerations, taking the technological units with the maximum spatial requirement into account. Due to functional, building physics, structural, seismic design and fire protection considerations the layout and the sizes may be subject to change.

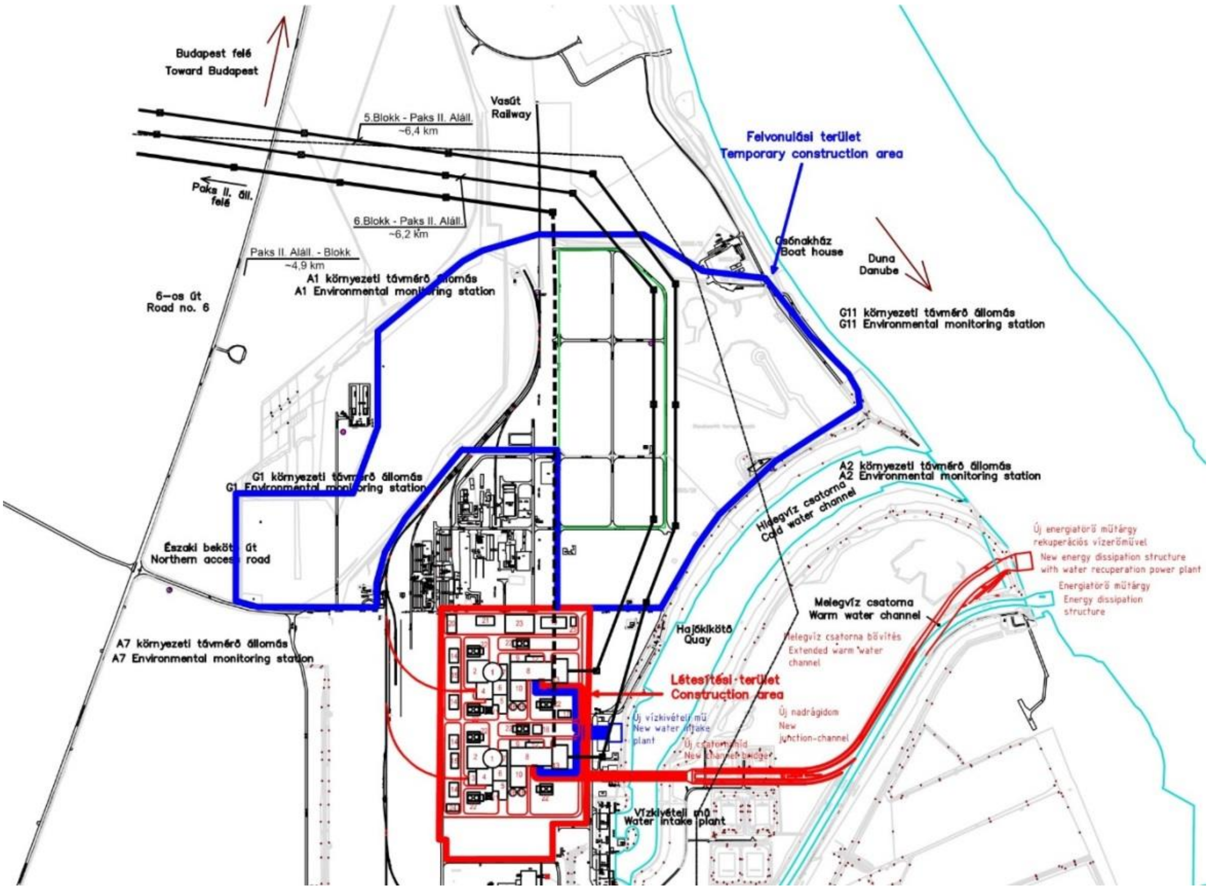
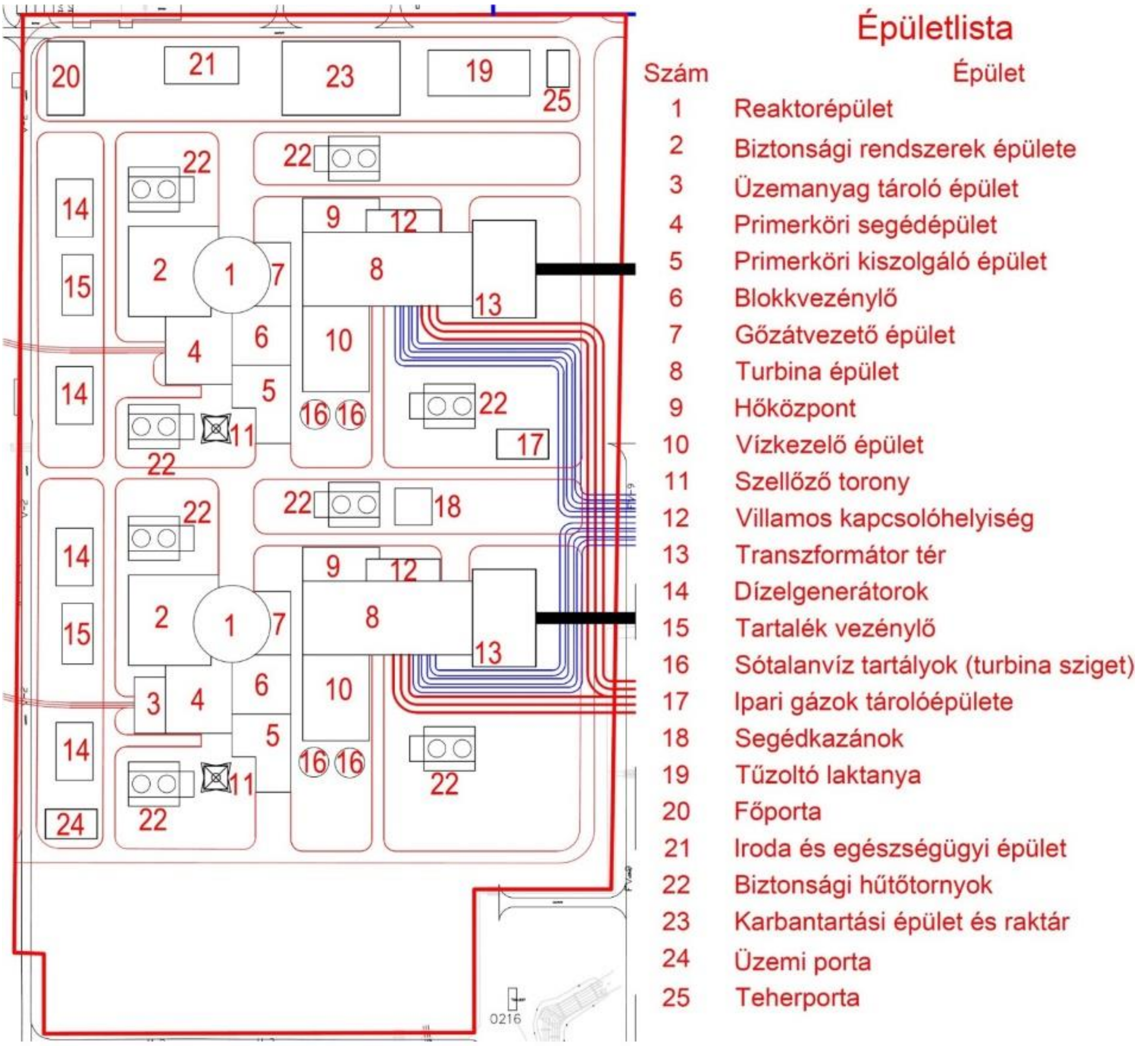


Figure 34: Installation site plan of Paks II – General map

7.10.3 CHARACTERISTIC FEATURES OF PAKS II BUILDINGS AND EDIFICES



Épületlista – List of buildings
Szám – Number
Épület – Building
1. Reaktorépület – Reactor building
2. Biztonsági rendszerek épülete – Building for safety systems
3. Üzemanyag tároló épület – Fuel storage
4. Primerköri segédépület – Primary circuit auxiliary building
5. Primerköri kiszolgáló épület – Primary circuit service building
6. Blokkvezénylő – Unit control room
7. Gőzátvezető épület – Steam transfer building
8. Turbina épület – Turbine building
9. Hőközpont – Heat centre
10. Vízkezelő épület – Water treatment building
11. Szellőző torony –Ventilation tower
12. Villamos kapcsolóhelyiség – Electrical switch room
13. Transzformátor tér –Transformer area
14. Dieselgenerátorok – Diesel generators
15. Tartalék vezénylő – Reserve control room
16. Sótalanvíz tartályok (turbina sziget) – Desalinating tanks (turbine island)
17. Ipari gázok tárolóépülete – Storage for industrial gases
18. Segédkazánok – Secondary boilers
19. Tűzoltó laktanya – Fire service building
20. Főporta – Main entrance
21. Iroda és egészségügyi épület – Office and healthcare building
22. Biztonsági hűtőtornyok – Emergency cooling towers
23. Karbantartási épület és raktár – Maintenance building and store
24. Üzemi porta – Staff entrance
25. Teherporta – Freight entrance

Figure 35: Location of the Paks II buildings and structures on the installation site plan

Description of the Paks II buildings and edifices are detailed to the extent required for determining the basic data of the environmental impact assessment study and are based largely on the data provided by the suppliers. Where there were no data, the structures of the existing nuclear power plant were used as a starting point. All the buildings and edifices on the construction site must be adequately sized for fire protection and seismic design.

7.10.4 VISUALIZATION OF PAKS II

Views of the building complexes of Paks II and the 400 kV line are shown from a bird's eye view and at eye-level from the following perspectives:

- View 1: Viewed from south-west, from the area between the Paks Nuclear Power Plant and Paks II
- View 2: Viewed from a north-western direction, from the corner of the temporary constraction area

VIEW 1:

Figure 36: The planned units and the 400 kV line from a bird's eye view – south-west

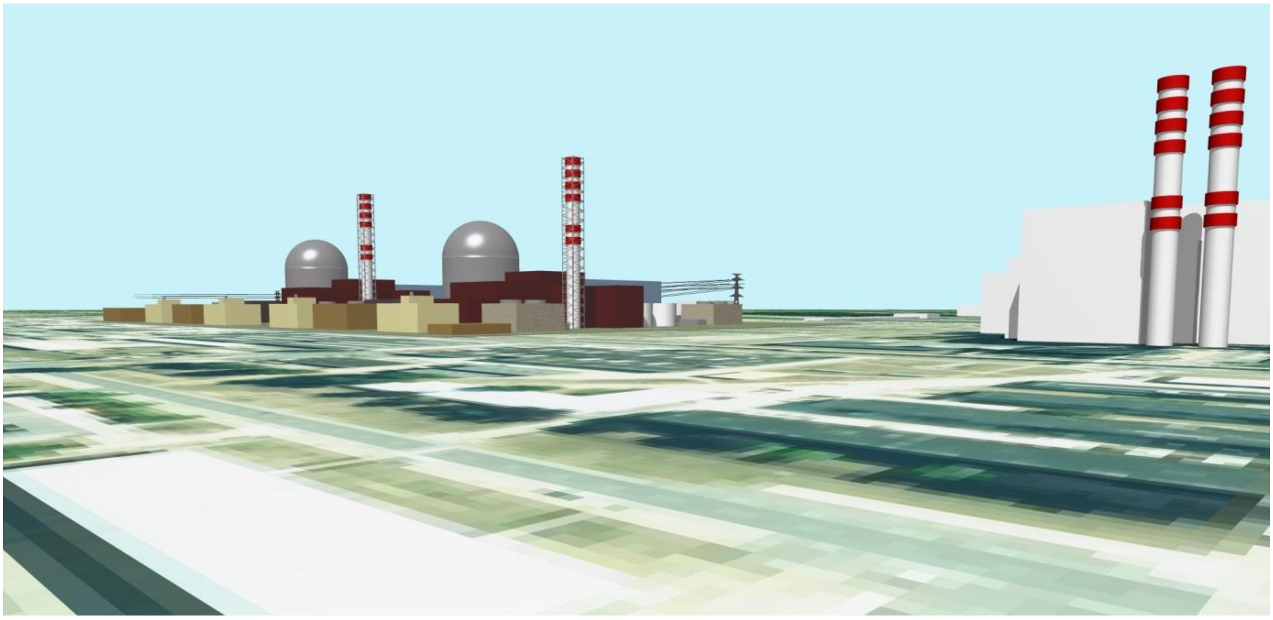


Figure 37: Visual design of the planned units and the 400 kV line at eye-level – south-west

VIEW 2:

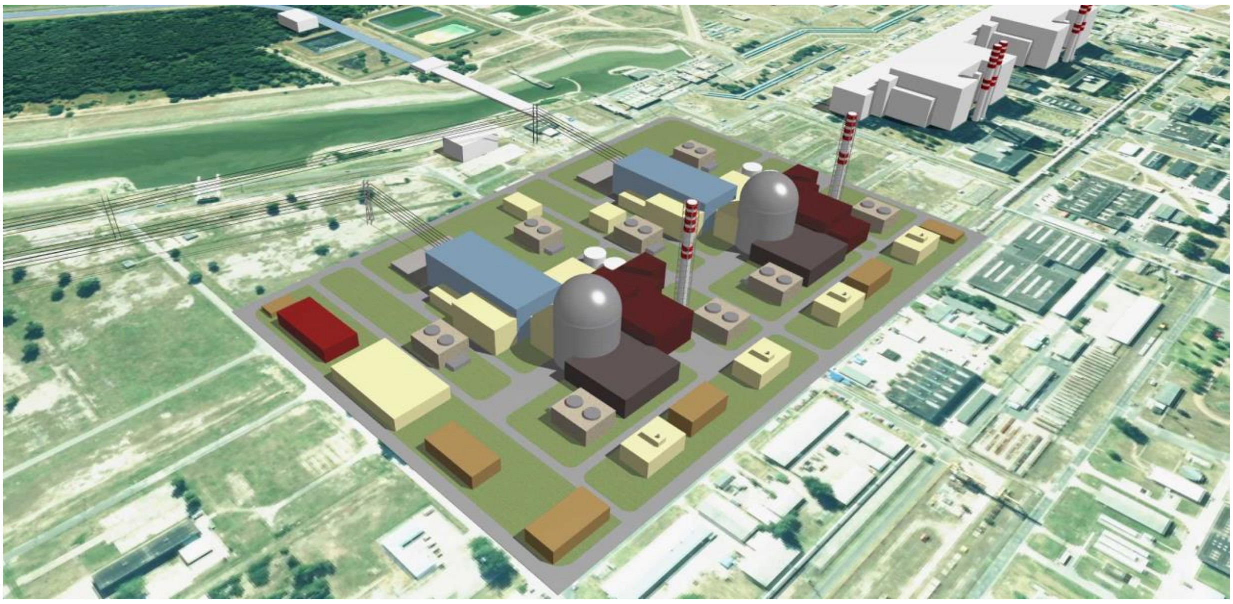


Figure 38: The planned units and the 400 kV line from a bird's eye view – north-west

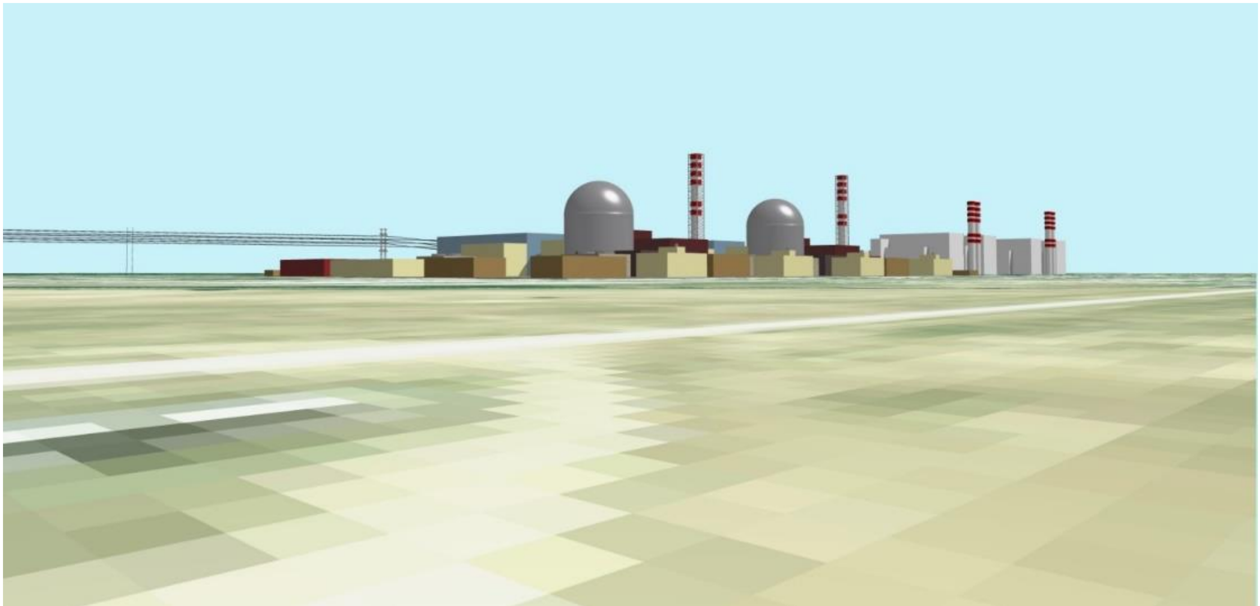


Figure 39: The planned units and the 400 kV line at eye-level – north-west

7.11 ACCEPTANCE CRITERIA FOR THE INDIVIDUAL MODES OF OPERATION

7.11.1 NORMAL OPERATION

Operating condition	Description	Frequency (probability) f [1/year])	Exposure of the population to additional radiation	
			Criterion	VVER-1200 projection
TA1/DBC1	Normal operation	1	20 μSv/year	< 2 μSv/year

Table 24: Acceptance Criteria – normal operation [30]

7.11.2 DESIGN BASIS CONDITIONS

Operating condition	Description	Frequency (probability) f [1/year])	Exposure of the population to additional radiation	
			Criterion	VVER-1200 projection
TA2/DBC2	Expected operational events	$f \geq 10^{-2}$	100 μSv/year	< 60 μSv/year
TA3/DBC3	Low-frequency design basis condition failures	$10^{-2} > f \geq 10^{-4}$	1 mSv/event	< 1 μSv/event
TA4/DBC4	Very low probability design basis failures	$10^{-4} > f \geq 10^{-6}$	5 mSv/event	< 3.4 mSv/event

According to the NSR, the dose the population is exposed to may not exceed the dose limit (90 μSv), which is less than the criterion set out in the table (100 μSv), but exceeds the forecast value (60 μSv).

Table 25: Acceptance Criteria – Design Basis Condition [30]

7.11.3 EFFECTIVE INTERNATIONAL AND HUNGARIAN REQUIREMENTS FOR DESIGN EXTENSION CONDITIONS

EFFECTIVE INTERNATIONAL AND HUNGARIAN REQUIREMENTS (AS PER NSR VALID ON OCTOBER 20, 2014)		
Volume 2 - GENERIC NUCLEAR ISLAND REQUIREMENTS **Chapter 1 - SAFETY REQUIREMENTS**	***Appendix 3 to Government Decree No. 118/2011. (VII. 11.)*** ***Nuclear Safety Regulations*** **Volume 3: Nuclear power plant design requirements:**	**Decree No. 16/2000. (VI. 8.) of the Minister of Health on the execution of the individual provisions of Act CXVI of 1996 on nuclear energy**
2.5.1 Off-site release Targets for Severe Accidents **2.5.2** Off-site release Targets for Complex Sequences **Appendix B 1.** Criteria for Limited Impact for DEC	**3.2.4.0700** For a new nuclear power plant unit, the limited environmental impact criterion is met if the following items are verified for events resulting in a DEC1 operational state and for events resulting in a DEC2 operational state, also taking into account the provisions of Section 3.2.2.4100. in the latter case:	**Intervention levels applicable to emergency exposure to radiation** *Intervention level:* The value of the avoidable equivalent dose or effective dose which require consideration of the intervention measures when reached. The avoidable dose or derivative value is exclusively applicable to the radiation route or routes subject to the particular measure.
No Emergency Protection Action beyond 800 m from the reactor during releases from the containment structure *Emergency Protection Action:* Actions involving public evacuation, based on projected doses up to 7 days, which may be implemented during the emergency phase of an accident, e. g. during the period in which significant releases may occur. This period is generally shorter than 7 days.	*a)* beyond a distance of 800 m from the nuclear reactor, there is no need to take early emergency measures, i.e. the population does not need to be urgently evacuated	**Stay-indoors:** 10 mSv effective dose within a period not exceeding 2 days **Rescue:** 50 mSv effective dose within a period not exceeding 1 week **Iodine profilaxis:** 100 mGy bound swallowed thyroid dose
no Delayed Action at any time beyond about 3 km from the reactor *Delayed Action:* Actions involving public temporary relocation, based on projected doses up to 30 days	*b)* beyond a distance of 3 km from the nuclear reactor, there is no need to take any provisional measures, i.e. the population does not need to be temporarily evacuated;	**Temporary evacuation:** 30 mSv/month effective dose (termination 10 mSv/month effective dose)

EFFECTIVE INTERNATIONAL AND HUNGARIAN REQUIREMENTS (AS PER NSR VALID ON OCTOBER 20, 2014)		
Volume 2 - GENERIC NUCLEAR ISLAND REQUIREMENTS **Chapter 1 - SAFETY REQUIREMENTS**	***Appendix 3 to Government Decree No. 118/2011. (VII. 11.)*** ***Nuclear Safety Regulations*** **Volume 3: Nuclear power plant design requirements:**	**Decree No. 16/2000. (VI. 8.) of the Minister of Health on the execution of the individual provisions of Act CXVI of 1996 on nuclear energy**
caused by ground shine and aerosol re-suspension, which may be implemented after the practical end of the releases phase of an accident.		
no Long Term Action at any distance beyond 800 m from the reactor *Long Term Action:* Actions involving public permanent resettlement, based on projected doses up to 50 years caused by ground shine and aerosol re-suspension. Doses due to ingestion are not considered in this definition.	*c)* beyond a distance of 800 m from the nuclear reactor, there is no need to take early emergency measures, i.e. the population does not need to be urgently evacuated	**Final evacuation:** >1 Sv/ life effective dose
limited economic impact: restrictions on the consumption of foodstuff and corps shall be limited in terms of timescale and ground area	*d)* only limited economic impacts are possible outside the area of the power plant.	
Appendix B 2. Release Targets for Design Basis Category 3 and 4 Conditions (1) no action beyond 800 m (2) limited economic impact	**3.2.4.0100.** For processes starting from initial events resulting in a DBC2 to 4 operating state, it shall be verified that the exposure of the reference group of the population does not exceed: *a)* in the case of a new nuclear power plant unit: *aa)* the dose limit applicable in the case of a process that starts from an initial event resulting in a DBC2 operating state (90 μSv/year) *aa)* the 1 mSv/event value applicable in the case of a process that starts from an initial event resulting in a DBC3 operating state, and *aa)* the 5 mSv/event applicable in the case of a process that starts from an initial event resulting in a DBC4 mode of operation.	***Appendix 2 to Decree No. 16/2000. (VI. 8.) of the Minister of Health*** ***I Action levels of dose limits and radon concentrations applicable to employees*** 4.2 The total exposure of the members of the population to external and internal radiation from artificial sources, other than exposures related to medical diagnostic and therapeutic intervention purposes, patient care and voluntary participation in medical research, may not exceed the **1 mSv effective dose rate** per annum. **Under special conditions and for any individual year, OTH may permit a higher dose rate,** provided that for 5 consecutive years following that year, the average individual exposure to radiation does not exceed the 1 mSv effective dose per annum. Irrespectively of the above limit on the effective dose, the annual equivalent dose rate for eye lenses is 15 mSv. The annual equivalent dosage rate for skin – averaged out for any 1 cm2 – and limbs is 50 mSv.

Table 26*: Effective international and Hungarian requirements for Design Extension Conditions*

7.11.4 DESIGN BASIS EVENTS

For each individual operational state of the VVER-1200 units, the events resulting in the highest environmental emission within the particular operating state can be determined. The events qualifying as design-basis breakdown events can be finally reviewed on the basis of the detailed technical specifications.

7.12 CHARACTERISTICS OF IMPLEMENTING PAKS II

7.12.1 INSTALLATION AREAS OF PAKS II. AND ASSOCIATED FACILITIES

In the course of implementing the new nuclear power plants, the construction of the technological part of the power plant and the associated facilities required for operation will affect the following areas:

Paks II Nuclear power plant

- Service area for the construction of the power plant: *Temporary construction site*
- Construction area of the new nuclear power plant units: *Operating area*

Associated facilities

Freshwater intake from the Danube: *cold-water channel, water intake structure*

Draining warmed-up coolant: *area enclosed by the cold- and warm-water channels ("island"), and the area of the energy recovery hydroplant*

Unit lines and transmission lines

Route of the 400kV unit line and 120kV transmission line to the new substation

7.12.2 PLANNED STAGES IN THE IMPLEMENTATION OF PAKS II

The process of implementing the new nuclear power plant units consists of the following main steps, which can be started in possession of the required and effective implementation and construction permits:

- Activities preceding construction
  - Preparation of the temporary construction area, landscaping
  - Demolition of the buildings, structures and pavings at the construction site
  - Replacement / dismantling of the line facilities on the construction site
  - Removal / transfer of plants from the construction site
  - Removal / selective disposal of the topsoil
  - Infrastructure building
  - Building offices and sanitary units for the constructors
- Building and installation activities
  - Excavation of the construction pit
  - Building the cutoff wall and / or the sheet-pile wall
  - Foundation work
  - Dewatering the construction pit up to the level piling and foundation reach above groundwater
  - Building the reactor complex (nuclear island) and the connected turbine building
  - Construction of separate buildings not containing technological equipment
  - Construction of the water intake structure
  - Building the associated facilities

  - Extension of the cold- and warm-water channels
  - Building a new warm-water channel branch
  - Building an recovery hydroelectric plant
  - Building cooling cells
  - Building the unit lines and the transmission line
  - Technological fitting and installation
  - Landscaping and earthworks at the premises of the power plant
- Processes preceding operation
  - Commissioning
  - Test runs
  - Individual tests of equipment (safety and non-safety)
  - (Complex) test runs of technological (safety and non-safety) systems
  - Insertion of the first charge / tests
  - Unit test runs
  - Grid connection
  - Test run
  - Warranty measurements

The associated facilities subject to separate licensing (the new electrical substation, the spent fuel interim storage) will be implemented in adjustment to the time schedule of unit implementation.

7.12.3 DRAFT TIME SCHEDULE FOR THE IMPLEMENTATION OF PAKS II

The expected dates during the implementation period are given in the following table, presuming an undisturbed licensing and that 5 years pass between the implementation of the two units:

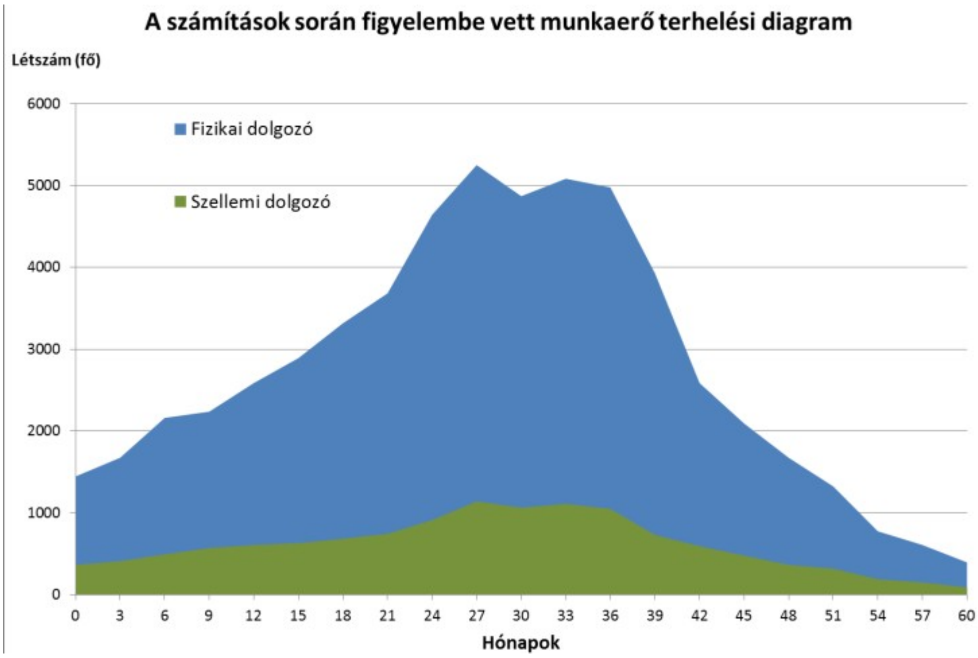
Activity	Paks II	
	Unit 1	Unit 2
Start of environmental licensing	2014	
Demolition on the implementation site	2017-2022	
Preparation of construction and implementation plans for licensing	2018-2019	
Landscaping, earth moving	2018-2019	
Obtaining the permits and licences required for the start of implementation	2018-2020	
Start of implementation	2020	2025
Foundation work	2020-2021	2025-2026
Building and fitting structures	2022-2023	2027-2028
Tests and commissioning	2024	2029
Insertion of the first charge	2024	2029
First grid connection	2024	2029
Test run start date	2025	2030
Start of commercial operation	2025	2030

Table 27: Operating time schedule of the Paks II units

7.12.4 HUMAN RESOURCE REQUIREMENT DURING THE IMPLEMENTATION PERIOD

The time required for the implementation of a unit is about 5 years. The starting date of the implementation of the second unit was taken into consideration with a 5-years interval after the first unit. If one unit is implemented (based on reports from the supplier of the technology) we calculated with maximum 5250 persons in the implementation period.

In respect of the time schedule of employment, we relied on the distribution given by PÖYRY ERŐTERV.



A számítások során figyelembe vett munkaerő terhelési diagram - Site staff workload diagram considered for calculations
Létszám (fő) – Headcount (persons)
Fizikai dolgozó – Blue collar
Szellemi dolgozó – White collar
Hónapok – Months

Figure 40*: Site staff workload diagram considered for calculations [33], [37], [38]*

7.13 CHARACTERISTIC FEATURES OF THE OPERATION OF PAKS II

7.13.1 DRAFT TIME SCHEDULE OF THE OPERATION OF PAKS II

Paks II Unit 1 of Paks II will start commercial operation in 2025 and Unit 2 will start commercial operation in 2030.

The scheduled life of the planned nuclear power plant units is 60 years.

Presumably, an extension procedure will be conducted for the operating time of units 1 and 2 of Paks II, however in this study the related impacts are not discussed.

7.13.2 HUMAN RESOURCES REQUIRED FOR THE OPERATION OF THE NEW NUCLEAR POWER PLANT UNITS

Based on the analysis of ERBE, if one unit is in operation, 600 people may be employed as permanent staff, including 400 employees working in core time and 200 employees working in shifts. Of the 200 shift workers, assuming 5 shifts and a 3-shift daily work schedule, 120 employees/day are required in addition to the core time employees. So we can reckon with 520 employees being on site every day.

Following the commissioning of unit 2, 800 employees will be required for the operation of the two units, of whom 300 employees will be working in shifts and 500 employees will be working in core time during the day. Of the 300 shift workers, assuming 5 shifts and a 3-shift daily work schedule, 180 employees/day are required in addition to the core time employees. So we can reckon with 680 employees being on site every day.

The operator headcount does not include those who perform maintenance duties because considering the current practice a significant part of these tasks will be outsourced.

Based on the data provided by the nuclear power plant supplier, the additional headcount demand for the major repair of each unit expected to be carried out every ten years is approximately 1 000, which includes 200 core time employees during the day and 800 shift workers. Assuming 5 shifts and a 3-shift daily work schedule, 480 employees/day are required in addition to the core time employees. So during the maintenance period we can reckon with 680 employees being on site daily in addition to the operator headcount. [6-10], [6-18], [6-19] [37], [38]

7.13.3 OPERATIONAL PROPERTIES OF THE NEW NUCLEAR POWER PLANT UNITS

7.13.3.1 Controllability, availability and maintenance

The electrical output of the new nuclear power plant units will be controllable between 50 and 100%, and it will be able to operate both in load-follow and island modes. The load change speed of the units is 5% (60 MW) / minute in both the up and down direction. The expected annual availability of the new nuclear power plant units will be >90 %, including also the annual minor repairs and the transfer time of spent fuels. Overhauls are expected to be performed every 10 years, each requiring about 1 month. The expected time requirement of annual maintenance is 20 calendar days (fuel transfer and minor repairs), while the expected time of major stoppages is 30 calendar days (overhaul of secondary and primary circuits).

7.13.3.2 Annual power engineering data of the new nuclear power plant units

Description	Unit of measure	Value/unit
Peak capacity usage hours	h/year	8,147
Installed electrical output (gross)	MW	1200
Self-consumption	MW	87
Electric power generated per unit	GWh p.a.	9,776
Electricity delivered per unit	GWh p.a.	9,068

Table 28*: Annual power data*

7.13.4 ANNUAL MATERIALS AND ENERGY BALANCE OF THE NEW NUCLEAR POWER PLANT UNITS

The annual materials and energy balance was determined by taking into account the annual operating time (8 147 hours) relative to the technical availability and full load for 2 x 1200 MW units. Depending on the main equipment selected, the values in the table may be subject to change.

Description	**Unit of measure**	**Value**
Annual gross electric power generation	GWh p.a.	19,552
Self-consumption of electricity	GWh p.a.	1,418
Annual net electric power generation	GWh p.a.	18,136
Fuel requirement	t/18 months	64.6
Fuels required (fuel + cartridge)	t/18 months	96
Strategic fuel charge	t	225.6
Oil consumption		
Bulk oil in steam turbines	m^3	~240
Bulk oil in transformers	t	about 804
Oil for main transformers	t	about 540
Oil for normal internal use transformers	t	about 132
Oil for reserve internal use transformers	t	about 66
Lubricant and hydraulic oils	t/year	20
Diesel generators	m^3/168 hours	2,600
Generator hydrogen cooling		8 m^3
Lubricant grease	kg/year	about 280
Water requirement		
Technological water requirement		
Condenser cooling water (including technological cooling water)	million m^3/year	≈3 900
Desalinated water	thousand m^3	640
Communal water requirement	m^3 per year	25,276
during maximum requirement (first unit is operative, second units is in the progress of construction)	m^3 per year	235,790
Consumption of chemicals		
Hydrochloric acid (33% HCl)	m^3/year	640
Sodium hydroxide (100% NaOH)	m^3/year	480
Ammonium hydroxide	m^3	15
Hydrazine	t	32
Nitric acid	m^3	51
Sulphuric acid	m^3	80
Boric acid	t	62
Other chemicals of the water pre-treatment plant (chlorine removal chemical, antifouling agent)	t/year	25
Technological waste water		
Waste water from the water pre-treatment plant	thousand m^3per year	200
Volume of primary circuit liquid radioactive waste	thousand m^3per year	88
Turbine building and auxiliary facilities, liquid waste water	thousand m^3 per year	350
Communal waste water	m^3 per year	24,012
during maximum generation (first unit is operative, second units is in the progress of construction)	m^3 per year	224,110
Wastes		
Radioactive wastes		
Low-activity radioactive waste	m^3 per year	140
Formation-activity radioactive waste	m^3 per year	22
High-activity radioactive waste	m^3 per year	1.0
Large-size, unmanageable radioactive waste (generated in the course of maintenance/improvement)	m^3 per year	10
Conventional, non-radioactive wastes		
Non-hazardous waste	t/year	800
Hazardous waste	t/year	100

Table 29: Characteristic features of the operation of Paks II

7.14 DECOMMISSIONING THE NEW NUCLEAR POWER PLANT UNITS

7.14.1 DECOMMISSIONING STRATEGY FOLLOWED DURING THE DISMANTLING OF THE NEW NUCLEAR POWER PLANT UNITS

In this EIAS the immediate dismantling option is considered for the decommissioning of Paks II taking into account the international trends and the following considerations:

- current legal regulations guarantee that the resources needed for dismantling will be available at the end of the operating period
- final placement can be ensured for the radioactive waste produced during dismantling within the available time span
- there is no reason to worry that the knowledge required for dismantling will be lost.

The process of dismantling a nuclear facility, thus that of a nuclear power plant is a long and complex activity. The currently valid scope of the actual dismantling tasks, their design and detailed elaboration are always specific of the site or facility and significantly depend on the strategy chosen for the dismantling of the facility. The dismantling strategy used after the real shutdown of the units will be determined later on the basis of detailed analyses with a far broader horizon. Optimization of the shutdown strategy to be selected in the future will have to be performed within the framework of the development of the national program in compliance with Directive 2011/70/Euratom of the European Council. [62]

The licensing of decommissioning and dismantling - at least in 60 years but no later than in about 2080 - will have to be carried out for the actual status, taking into account the legislative environment. [39]

7.14.2 FINANCING AND COSTS OF DISMANTLING ACTIVITIES

According to Article 62 (1) of Act CXVI of 1996 on Atomic Energy the costs of dismantling nuclear facilities are to be financed from a separate state fund, the Central Fund for Nuclear Energy (CFNE).

The body managing the Central Fund for Nuclear Energy is the ministry directed by the appointed minister.

In the course of the implementation of the new units preparations should be made for the transformation of the CNFF, which would allow among others the financing of the dismantling of the new units.

The costs of dismantling can only be estimated according to the present level of knowledge. Based on supplier forecasts the prognosis could be highlighted that suggests that dismantling of the new units will presumably be simpler and less waste will be produced on dismantling than it is predictable for the dismantling of energy reactors used now.

8 NETWORK CONNECTION TO THE HUNGARIAN POWER SYSTEM

This section presents the power engineering tasks and network development needs identified by current assessments and necessary for the implementation of the Paks II Power Plant. Their joint environmental impact is insignificant compared to the entire environmental impact of the power plant to be established. Note that subject to later studies and decisions, the location and building of the station, the route of the transmission lines and the placement of the poles may change.

8.1 COMPATIBILITY OF THE NEW UNITS WITH THE HUNGARIAN POWER SYSTEM

The currently operating units of the Paks Nuclear Power Plant will be connected to the Hungarian power system through the 400 kV switching equipment of the 400 / 120 kV substation owned by MAVIR Zrt as Transmission System Operator.

In a decision-supporting feasibility study PÖYRY ERŐTERV Zrt. conducted a preliminary analysis of several versions of the electricity network developments needed for the Lévai Project, the station sites and the required transformation of the transmission lines. Preliminary network calculations have been performed to see what conditions are required for the transmission of the generated amount of power with units of net 1200 MW capacity under regular operating conditions and in case of a system disturbance.

The results show that the new power plant units can be integrated into the power grid only if new network connections are built.

- The connection of the new units to the power grid requires the establishment of a new 400 / 120 kV substation (Paks II substation).
- The findings of the studies on double outage states and the reserve supply for the new Nuclear Power Plant require the installation of a third 400 / 120 kV transformer in the region.
- The installation of a Paks-Albertirsa dual-system transmission line is a basic and indispensible condition for the expansion.

In order to ensure appropriate stability for the electric power system, the capacity needs of the largest feed-in volume with the highest unit capacity installed in the system must be provided within a short time for the purposes of the network in the case of any unplanned outage of such feed-in. In Hungary it is the responsibility of MAVIR Zrt as the system operator. The unit capacity of the new power plant units will likely be around 1200 MW, making them the largest in the Hungarian power system. Before the first unit of the Paks II Nuclear Power Station is commissioned, a tertiary reserve capacity equivalent to that of the new unit should be ensured. This need will have to be met by sourcing power through the import power transmission route and/or by creating a new tertiary reserve capacity in a fast start-up domestic power plant.

Based on the studies it was established that by implementing the above developments and expansions, the power generated by the new units can be safely connected to and used in the Hungarian power grid.

8.2 INSTALLATION SITE OF THE NEW 400 / 120 KV PAKS II SUBSTATION

By taking into account the installation criteria of typical MAVIR stations, the special goals and requirements for the MAVIR transmission network station, and the special criteria of the Paks II Nuclear Power Station for connection to the grid, several possible locations have been identified for the Paks II substation. The substation site optimal from the points of view of feasibility and safety is located along the transmission line routes going north-west in the area between the roads going from Paks to Nagydorog and Kölesd, where the Kölesd road crosses the 400 kV power line, 6 km from the planned site of the new units, near the 2 km section of road 6233, on the north side of the road, next to the existing transmission line corridor.

Based on received data, we considered this site as the starting point for our investigation, but it should be noted that the designation of the final location for the Paks II substation is the competence of MAVIR Zrt as the future owner of the substation, and to our knowledge the final decision has not yet been made.

In accordance with current practice in Hungary, the Paks II substation will be a typical MAVIR 400 / 120 station.

The Paks II substation and the transmission lines (except for the unit lines) connecting to the Hungarian electricity grid will be owned by MAVIR Zrt and will be part of the public grid.

8.3 400 kV LINE IN THE UNIT AND THE 120 kV POWER TRANSMISSION LINE

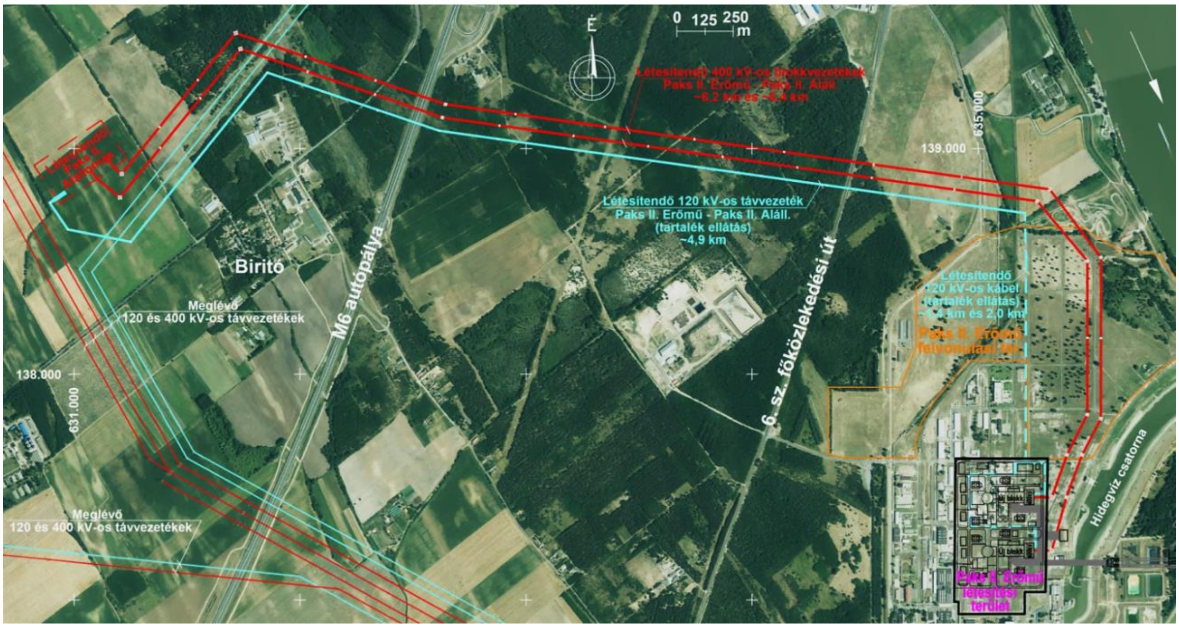
In Hungary all 400 kV transmission lines are overhead lines.

Based on the specifics of the development area and on technical, economic and environmental criteria, the power lines directly linked to the power plant can be installed as follows:

- the 400 kV unit lines will be overhead type;
- the section of the 120 kV line within the site of the power plant providing reserve supply will be an underground cable and outside it an overhead power line.

8.3.1 400 kV UNIT LINES

The power generated in the units of the Paks II Nuclear Power Station will be transmitted through 400 kV unit cables (production cables) to the future Paks II substation. The route of the unit line is shown in Figure *41* and its legend in Figure *42*



Létesítendő 400 kV-os blokktávvezetékek – 400 kV unit lines to be built
Létesítendő 120 kV-os távvezeték – 120 kV transmission line to be built
Paks II Atomerőmű – Paks II Nuclear Power Plant
Paks II alállomás – Paks II substation
M6 autópálya – Motorway Main Road No. 6
Létesítendő 120 kV-os kábel (tartalék ellátás) – 120 kV cable (reserve supply) to be built
Paks II Atomerőmű felvonulási tér – Paks II Nuclear Power Plant temporary construction area
Meglévő 120 és 400 kV-os távvezetékek – Existing 120 and 400 kV transmission lines
Hidegvíz csatorna – Cold-water channel

Figure 41: Route of the unit cables between the Paks II Nuclear Power Station and the Paks II substation (Site 2).

Jelmagyarázat – Legend
Létesítendő 400 kV-os blokkvezeték nyomvonala – Route of the 400 kV unit line to be built
Létesítendő 120 kV-os vezeték (tartalék ellátás) nyomvonala – Route of the 120 kV unit line (reserve supply) to be built
Létesítendő 120 kV-os kábel (tartalék ellátás) nyomvonala – Route of the 120 kV unit cable (reserve supply) to be built
Meglévő 400 kV-os távvezeték nyomvonala – Route of the existing 400 kV transmission line
Meglévő 120 kV-os távvezeték nyomvonala – Route of the existing 120 kV transmission line
Paks II Erőmű létesítési terület határa – Boundary of the Paks II construction area
Paks II erőmű felvonulási terület határa – Boundary of the Paks II temporary construction area
Paks II Alállomás határa – Boundary of the Paks II substation

Figure 42: Legend for the route drawing of the unit line on drawing No. V-01195 ERBE

The power generated in the two new nuclear power plant units will be transmitted to the Paks II substation by a transmission line installed on separate lines of towers for each unit. The use of separate overhead lines along this relatively short route increases operational safety.

Route lengths of the 400 kV unit cables between the Paks II Power Plant and the Paks II substation: ~6.4 km and ~6.2 km A total of 40 poles will be made of the FENYŐ type. The width of the safety zone will be 34.4 m in each direction from the axis of the route, making a total width of 68.8 m (for each unit line), in case of two parallel unit lines, the total width of the safety zone is 128.8 m.

Subject to later studies and decision, the technical solution for the unit cables and their pole type may change with a view to increased safety.

Landscape

The transmission line concerned will be going along a nearly flat area. The route will mainly cut across agricultural land and woods outside the power plant site.

The type of poles planned to be used for the transmission lines connecting to Paks II has been used in the past in Hungary for a network; some examples are shown in the following photos.

Figure 43: The Martonvásár-Győr 400 kV overhead transmission line with PINE poles

Figure 44: The Pécs-National Border 400 kV overhead transmission line with PINE poles, line corridor

We wish to use, as appropriate and as circumstances permit, all the methods that worked well for previous overhead transmission lines to facilitate compatibility of the new transmission lines with the environment and reduce any disturbance caused to the environment (e.g. parallel routes; painting the poles green; installing bird nests on the poles and devices that enhance the visibility of the lines for birds).

Impact of the operation of the transmission line

Electrical and magnetic field strengths

An electromagnetic field is generated near high-voltage transmission lines. The limits of electrical filed intensity and magnetic induction to be considered for physiological effects have been specified by the International Radiation Protection Association (IRPA) working under the UN World Health Organization (WHO). The Hungarian requirements (MSZ 151-1-2000/15.6.3.) are in line with the recommendations of the international association adopted worldwide.

Time that can be spent under the transmission line	**Electrical field strength E (kV/m)**	**Magnetic induction B (μT)**
a few hours per day	10	1000
unlimited	5	100

Table 30: Permissible values of electrical field intensity and magnetic induction

Typical values of electrical field intensity and magnetic induction in the vicinity of existing transmission line:

	Values measured at a height of 1.8 m above ground under 120 to 750 kV lines in Hungary	
	electrical field strength [kV/m]	**magnetic induction [μT]**
under the overhead power lines	2-17*	10-37
at the edge of the safety zone	0.2-1.1	1-9

* note
A value higher than 10 kV/m is measured only under the conductor of a 750 kV transmission line.

Table 31: Measured values of electrical field intensity and magnetic induction

By selecting the necessary height of the transmission line above the ground when planning installation it can be ensured that the value of electrical and magnetic field intensity measured under the most adverse conditions will be under the limit specified in the WHO recommendation. We wish to repeat here that the route of the transmission line concerned will avoid inhabited areas.

According to previous research findings, the electrical and magnetic field strengths in the vicinity of overhead transmission lines does not have any demonstrable harmful effects on health.

Corona discharge (ionizing effect, radiofrequency effects, radiation loss)

One of the most noticeable phenomena for the environment that occurs on overhead power lines is corona discharge (in short: corona). This can be observed especially in rainy, foggy weather if the inhomogeneous electrical field generated on the surface of the power conductor cable exceeds the value of 30 kV/cm. In this case, the air around the conductor becomes ionized and a discharge occurs, which can be seen in darkness, accompanied by crackling noise.

Corona may have the following direct environmental effects:

- crackling, fizzing noise due to the ionizing effect of high local field strength;
- high-frequency electromagnetic waves are generated, which may disturb radio and TV reception in the vicinity of the power lines;
- a loss occurs in the power line due to the corona.

Ionizing effects

Due to coronal discharge, especially on overhead power lines above 400 kV, mainly ozone (O_3) and nitrogen oxide (NO_x) are formed, but the values are below the measurable limit and are insignificant compared to any other source.

8.3.2 120 kV TRANSMISSION LINE

The task of the 120 kV transmission line will be to supply the Paks II Nuclear power plant with power from the future Paks II substation. Paks II. Electric substation:

The route length of the 120 kV unit cables between the Paks II Power Plant and the Paks II substation is ~6.4 km, its cable sections being ~1.4 km and ~2.0 km. A total of 19 poles will be made of the SZIGETVÁR type. The width of the safety zone will be 15.6 m in each direction from the axis of the route, making a total width of 31.2 m.

Subject to later studies and decision, it may be necessary to install the 120 kV fall-back power lines on separate tower lines for each unit in order to increase the safety of the units. In addition, the type and the number of the towers may also change.

8.3.3 COMMON SAFETY ZONE

If the two 400 kV unit lines and the 120 kV transmission line providing fall-back power run parallel, the total width of the safety zone will increase to 170 m.

8.3.4 CONSTRUCTION OF THE TRANSMISSION LINE

The main phases of construction are as follows:

- preparatory work, routing
- groundwork
- assembling the towers and the insulation chains
- tower erection
- wire stringing and adjustment

The construction of a transmission line requires a 3 to 5 m wide strip of land. When arable soil is used for construction work, a pedological expert opinion is prepared for recultivation, on the basis of which the temporary alternative use of the arable soil is licensed by the competent land registry.

The overall dimensions of the towers above the ground depend on whether a supporting or a strain tower is installed but also on the cross-section and the number of conductors fitted on the towers.

The space required for onsite assembly and erection of the towers should also be considered when calculating the space needed for construction, which, depending on the type of tower and the installation site, is as follows:

- for 400 kV towers: about 60x40 m
- for 120 kV towers: about 40x40 m

These strips of land are temporarily withdrawn from cultivation in the case of arable soil.

The three transmission lines of Paks II can be built at the same time or staggered. In the case of staggered construction, the 400 kV and the 120 kV transmission lines for unit 1 must be built first, followed by the 400 kV line for unit 2.

Time required for construction work:

- Landscaping, earth moving: 2 working days/km
- Groundwork: 2 weeks/km
- Tower assembly and erection: 1 week/km
- Wire work: 1-3 weeks/km

The work processes outlined above partly overlap, so the estimated implementation time is about 8-10 months. In the case of staggered construction, the time required for implementation may be significantly longer. During this time the environment is not disturbed at the same time along the entire length of the power lines. Equipment is used on the work area only for the time that is absolutely necessary, going from one tower site to the next. Construction will involve both machine and manual (human) work in line with the installation technology.

The following photo shows the mounting of poles during a previous installation of a transmission line.

Figure 45*: Martonvásár-Győr 400 kV overhead transmission line, assembly*

9 POTENTIAL IMPACT FACTORS OF PAKS II, IMPACT BEARERS AND IMPACT MATRICES

9.1 POTENTIAL IMPACT FACTORS

The first step of the environmental impact assessment is to determine the potential impact factors related to creating the conditions of nuclear energy production, and to the operation of the plant, resulting from the technological parameters detailed above. The impact factors related to the planned nuclear units are grouped thematically around (1) location, (2) time and (3) characteristic types of impacts.

Constructing and operating the new nuclear units may affect the following ***locations***:

Paks II Nuclear Power Plant

- *Operation site of the new nuclear units*
- *The building yard*

Paks II Nuclear Power Plant – Connected Facilities

- *Cold water canal*
- *Warm water canal*
- *Area enclosed by the cold and warm water canals ("island")*
- *Site of the power recovery water plant*

Unit line and transmission line

- *Route of the 400 kV unit line and 120 kV transmission line to the new substation*

Transport Routes

- *Roads affected by transportation to and from the plant*

The potential ***temporal*** impact factors of the new nuclear units and their facilities (preparations/construction/installation, operation, and decommissioning) are grouped chronologically with respect to the various sites affected.

Preparations, construction and installation: Approximately 5 years of construction work, in addition to preparation activities, in 2 quasi consecutive cycles for 2 units, adding up to about 10 years altogether.

Operation: The assumed operation time of the planned new nuclear power plant unit is 60 years, which, in view of the procedure of prolonging the operation time of the 4 current units, can be divided into several periods

- Joint operation of units 1to 4 of the Paks Nuclear Power Plant and unit 1 of Paks II between 2025 and 2030
- Joint operation of units 1 to 4 of the Paks Nuclear Power Plant and units 1 to 2 of Paks II between 2030 and 2032
- Joint operation of units 1 to 2 of Paks II after the closure of units 1 to 4 of the Paks Nuclear Power Plant between 2037 and 2085
- Independent operation of unit 2 of Paks II after the expiry and closure of unit 1 of Paks II between 2085-2090
- End of operation of Paks II, unit 2 in 2090

Decommissioning: At the determined expiry time, first unit 1 and then unit 2 of Paks II is closed (based on article 31, appendix 1 of Government Decree No. 314/2005, this activity also requires an environmental impact study).

The **typical impact factors** for each of the above mentioned periods are also examined in this study. Considering the character of the facility, emissions and wastes are divided into two groups: common, non-radioactive types and radioactive types.

- **Use of the environmental elements**
- **Emission of pollutants**
  - *Common, non-radioactive pollutants*
  - *Radioactive pollutants*
- **Wastes**
  - *Generation and management of common, non-radioactive wastes*
  - *Generation and management of radioactive wastes*
- **Spent fuels**
  - *Handling and storage of fuels removed from the reactor zone*

9.2 IMPACT BEARERS

The second step of the environmental impact study is to appraise and define the impact processes triggered by the impact factors related to the implementation and operation of Paks II, including the events related to its construction, service and decommissioning. Based on these processes, it is possible to define **the scope of environmental elements and systems where** the processes triggered by the impact factors (use and straining of environmental resources) **may lead to direct** and **indirect effects.**

During the construction, operation and decommissioning of the new nuclear units, the following elements and systems of the environment are to be taken into account as impact bearers:

Surface waters – Danube
Geological formation, underground water (operation site, Danube valley)
Air
Inhabited environment (noise, radioactive pollutants, wastes)

Biosphere, ecosystem
Artificial environment, engineering objects
Population (common and radioactive pollutants)

9.3 POTENTIAL IMPACT MATRICES

The assumed impacts of potential impact factors on the affected parties are summed up in the matrices below.

The impact factors as well as the impact bearers during the construction, operation and decommissioning, as well as for abnormal service conditions (service breakdowns, emergencies and design basis conditions) during all three phases have been identified.

Impact factors	***Impact bearers***								
	Environmental elements/systems								
	Surface water	*Geological formation, underground water*		*Air*	*Inhabited environment*	*Biosphere, ecosystem*	*Cultural heritage*	*Population*	*Built environment*
	Danube	*Site*	*Danube valley*						
Installation									
Demolition of buildings	-	U	-	S	S	S	-	U,S	U,S
Site occupation	U	U	-	S	U	S	-		U
Transportation	-	-	-	S	U,S	S	S	S	U,S
Construction of the facility	U	U	-	S	U,S	S	-	S	U,S
Installation of technology	U	U	-	S	U,S	S	-	S	U,S
Related activities	U	U	-	S	U,S	S	-	S	U,S
Service breakdowns, emergencies	S	S	-	S	S	S	S	S	S
Operation									
Technology	S	U	S	S	U,S	S	-	S	U,S
Related activities	-	-	-	S	U,S	S	-	S	U,S
Transportation	-	-	-	S	U,S	S	S	S	U,S
Service breakdowns, emergencies	S	S	-	S	S	S	S	S	S
Decommissioning									
Disassembling technology	-	S	-	S	U,S	S	-	S	S
Demolition of buildings	-	S	-	S	U,S	S	-	S	S
Transportation	-	S	-	S	U,S	S	-	S	S
Related activities	S	S	-	S	U,S	S	-	S	S
Landscaping	-	S	-	S	U	S	-	S	U
Service breakdowns, emergencies	S	S	-	S	S	S	S	S	S

Legend:
U – Use of the environment
S – Straining of environmental resources

Table 32: Summary impact matrix – identifying the types of impact factors, as well as impact bearers

Impact factors	***Impact bearers***								
	Environmental elements/systems								
	Surface water	*Geological formation, underground water*		*Air*	*Inhabited environment*	*Biosphere, ecosystem*	*Cultural heritage*	*Population*	*Built environment*
	Danube	*Site*	*Danube valley*						
Installation									
Demolition of buildings	-	U	-	C	C	C	-	C, U	C, U
Site occupation	U	U	-	C	U	C	-		U
Transportation	-	-	-	C	U, C	C	C	C	U, C
Construction of the facility	U	U	-	C	U, C	C	-	C	U, C
Installation of technology	U	U	-	C	U, C	C	-	C	U, C
Related activities	U	U	-	C	U, C	C	-	C	U, C
Service breakdowns, emergencies (E)	C	C	-	C	C	C	C	C	C
Operation									
Technology	E+D	U	C	E+D	U, E+D	E+D	-	E+D	U, E+D
Related activities	-	-	-	C	U, C	C	-	E+D	U, C
Transportation	-	-	-	C	U, E+D	E+D	C	E+D	U, E+D
Service breakdowns, emergencies (E) Design-basis conditions (D)	E+D	E+D	-	E+D	E+D	E+D	C	E+D	E+D
Decommissioning									
Disassembling technology	-	E+D	-	E+D	U, E+D	E+D	-	E+D	E+D
Demolition of buildings	-	E+D	-	E+D	U, E+D	E+D	-	E+D	E+D
Transportation	-	E+D	-	E+D	U, E+D	E+D	-	E+D	E+D
Related activities	C	E+D	-	C	U, E+D	E+D	-	E+D	E+D
Landscaping	-	C	-	E+D	U	E+D	-	E+D	-
Service breakdowns, emergencies (E) Design-basis conditions (D)	C	E+D	-	E+D	E+D	E+D	E+D	E+D	E+D

Legend:

C – Common environmental impacts
R – Radiological impacts

Table 33: Summary impact matrix, identifying common and radiological impacts

10 SOCIAL-ECONOMIC IMPACTS OF PAKS DEVELOPMENT

10.1 ECONOMIC IMPACTS AND CONDITIONS

The planned development at Paks will have significant impacts also onto the economy of the entire country, the region and Paks city.

On national level we should highlight the improving economic performance (GDP) as it will grow as a result of the project, because parallel with the preparatory works for the planned project domestic undertakings will begin preparations as they want to be involved into the project implementation, and all this have and will have effects onto education, development of the human resources and technical assets of the relevant undertakings and their innovation.

As specified in Paragraph 2 of Article 4 of Act II of 2014, on the promulgation of the Treaty between the Hungarian Government and the Government of the Russian Federation on the cooperation in peaceful utilisation of nuclear energy „The Parties shall do their best efforts to reach the 40% minimum localisation level if this is reasonably feasible in order that the cooperation envisaged in the present Treaty can be implemented and frameworks specified by the relevant laws so allow" thus the Hungarian Government regards the planned project significant not only from aspects of energy policy, but will manage the project as a top priority also from aspects of industrial policy. Thus out of the total project CAPEX (planned as 12,5 billion EUR) 5 billion EUR would most probably implemented involving domestic undertakings, and this figure represents nearly 5% of the domestic annual GDP, so this is quite a significant item even on national economic level.

From energy policy aspects and as the Government expects, the „mix" that can ensure the electric energy generation for the country will remain well-balanced also after the date when 1-4. Paks units will be de-commissioned, and the country's dependence of import energy carriers (nuclear fuel can be acquired from several sources of supply and a sizeable stock can be also stored) and dependence of direct electric energy import will reduce versus the "no-development" scenario, and the price of electric energy generated by Paks development will remain competitive on long term, providing a competitive advantage for the energy-intensive domestic undertakings, enabling even the increase in their production volume.

It is an extremely critical criteria from industry policy aspects that undertakings involved into the project (as mentioned above) will be more competitive also after the project as a result of developments in their human resources and physical assets and this improvement will have multiplicator impacts onto the performance of the national economy, employment rate, expanding consumption of the population, in addition to the direct impacts onto Paks development, and as a result also onto the state's income from tax and royalty. There is another national economic aspect, namely that Paks development will enrich the treasury with a high-value and up-to-date asset, and as added value the development will also help sustaining a world-famous and state-of-the-art professional culture.

There is another goal on national economy level related to the planned new units of the Nuclear Power Plant: domestic suppliers should have a chance for participating in the works in as high as possible number. The maximum share that can be realistically achieved is around 30-40 %. Results of presently ongoing international Nuclear Power Plant projects can clearly demonstrate that sub.-contractors (suppliers) can be intensively involved from the national economy of the ordering party into the preparatory, construction, technology assembly, manufacturing and then operation and maintenance works and processes only if they are consciously prepared and developed in a planned manner and organised into a system that can supplement, complement and strengthen each other. The degree of usefulness of the power plant project on national economy level will be greatly enhanced if the preparation is well-planned, properly designed and sub-contractors are systematically prepared and trained, as thus significant extra cost potentially arising during the project can be avoided.

The implementation of new units is a project that can for years or even for one full decade offer significant orders for several domestic companies, contractors and provide employment for several thousand employees either on the site, or in various planning, technical engineering and research institutes, pre-assembly and manufacturing factories and plants during the preparatory works. If we want to cover 30-40% of the total project CAPEX with domestic suppliers and contractors it will require well-planned preparations and well-organised cooperation among the companies and institutions. Hungary's manufacturing capacity in the energy sector and the capacity of various construction and building companies have significantly declined during the past two decades. Total re-vitalisation is not realistic, and the goal could rather be to prepare and collaborate with primarily small and medium size companies that are potentially capable of such cooperation.

As part of the preparatory project the potentially eligible companies and contractors that can be involved into the planned project were surveyed. Two approaches were applied. Firstly companies regarded as high-priority were analysed on national level, and secondly companies located in the environment of Paks Nuclear Power Plant, primarily as potential candidates for the sub-contractors chain were surveyed. As a result of the national survey nearly 150 potentially relevant companies were recorded in the database, broken down to suppliers, service providers by professions (nuclear, civil engineering, control technology, electricity, architecture, chemistry, other) and to activities (R+D, planning, manufacturing, transportation, building, assembly, commissioning, expert jobs, other). Assets, capacities, references, quality assurance parameters of the companies, and import share of components for manufacturing were all recorded.

It is a natural expectation that companies operating in the wider environment of Paks Nuclear Power Plant can be involved into the implementation as participants with fair chance, thus enhancing the regional entrepreneurial potential and providing chances for employing local manpower. The region contains 90 settlements in the area carefully delineated using specific criteria and covering both banks of Duna and 3 counties. The study addressed companies operating in the field of building industry, manufacturing, assembly and transportation, and their headcount is minimum 10 employees, and are interested in and willing to participate in the project implementation through some kind of contractual structure. As part of the surveying process, the potentially cooperating companies were classified into various categories based on competences (employees and assets/equipments), references, capital power, balance data, certificates or accreditations and readiness for further training. The regional companies can be candidates in the project not only directly, but also indirectly in auxiliary works (e.g. infrastructure construction). As a result of the survey nearly 240 regional companies were registered in the database.

10.2 SOCIAL RELATIONSHIPS, SET OF CONDITIONS

MVM Paks Nuclear Power Plant Zrt. has been present almost for four decades in the region defined by a Paks – Szekszárd - Kalocsa centres. As a result of well-planned and structured process the Pant has built up a regional set of connections that covers a cooperation based on mutual respect, understanding and benefits. This robust supporting and symbiotic relationship provided a solid basis for the decision-makers for adopting decision with utmost significance like extension of the operation time and implementation of new units. Decisions adopted by the Parliament and the Government aiming at the construction of the new Nuclear Power Plant units extremely require to improve the economic and social relationship with the region around the power plant, and to enrich and energize its content. Strengthening the regional acceptance and cooperation readiness, improving confidence of local governments, municipalities, companies and citizens is one of the key pre-conditions for the expansion program, and this should be addressed already during the preparatory phase of the main project.

MVM Paks Nuclear Power Plant Zrt. is evidently the no. 1. company and employer of the region and it has explicitly assumed the responsibility for the status of the environment, the quality of life of the local population, development and future of the region. The power plant and the related development project can be successful if the plant itself can function in a virulent economic and social environment, and efficiencies can mutually strengthen each other. The process of implementation of the new units is an outstanding issue for people living around the Paks Nuclear Power Plant and they are looking forward to democratic processes offering them the chance for offering opinion. The level of support from the region is quite reassuring at the moment and relations are dynamic, improving through serious expectations are also formed. Local government, municipalities and population of the settlements as well as the stakeholder companies expect initiative steps to verify long term cooperation as early as during the preparatory phase of the main project.

It is imperative that the recipient region must be involved and made interested, and this will primarily connected to manpower supply and its logistical system, in addition to undertaking development. The preparatory project addressed these issues in full details. First of all we had to prepare the list of professions that are required for the construction, assembly commissioning and then operation of the Nuclear Power Plant and that is consistent with the National Training Registry system and the domestic high-level training guidelines. This document was prepared in cooperation with eminent energy experts and university departments with experiences from major projects. Manpower needs of potential bidders can form the basis for all subsequent surveys. Conclusion of the inter-governmental treaty between Hungary and Russia could simplify the situation, and from then we had to use only the preliminary data supplied by Atomstroyexport as the sole data base.

A large-scale survey was prepared covering 90 settlements in Tolna, Baranya and Bács-Kiskun counties in order that the presently available skilled manpower and that can potentially be made available for future demands in the wider region can be registered. As there was no state and public administration registry system available the database had to be prepared using results of a large-scale field work based on sampling work. All this can provide a solid basis for a study on availability of regional manpower labour and its preparation for the main project. Based on the survey of available manpower broken down to professions these data available in the region can be easily compared with the regional manpower potential. It is assumed that only 20% of the manpower available in the studied region can be involved into the construction and assembly works of the planned new units of the Nuclear Power Plant, so we can state the only 25-30 % of the required manpower can be supplied from the region. Naturally there are significant differences in various professions. Based on results of comparative analysis we can state that major shortage problems would primarily emerge in the following professions: carpenter, scaffolding workers, reinforced concrete workers, qualified welder, fitter and ironer, electricity system and control technology assembly technicians.

The special secondary-level training, vocational training and adult education institutions and companies in the region were also surveyed, including their education and training capacities and conditions, infrastructure, practice background, development plans and flexibility. These schools and training institutions can supply the manpower that is presently not available on the labour market and cannot be predicted as they can launch targeted and tailor-made new training courses, increase the headcount in the existing courses and improve training conditions. Departments, faculties and chairs in the domestic technical high-level education system were also surveyed including some high-priority institutions with similar profile in the neighbouring countries. A decision-preparatory document was also prepared analysing re-start of the College of Energy Technology in Paks as an off-site faculty.

A system was also prepared for students presently learning in various secondary schools for encouraging and incentivising them to continue their studies in technical universities and colleges, broken down to discipline levels and supplemented with energy-related practices and on-the-spot professional practical training. There is a system of cooperation agreements signed with various secondary schools in the region around Paks Nuclear Power Plant and they contain a specific supplementary training for physics from class 11 with enhanced level high-school graduation certificate. Students studying in various universities in the country are more inclined to return into the region if the project can offer them employment and challenging professional carrier opportunities. A special fellowship and mentoring system was also elaborated both for medium and high levels because young experts can be retained and effects of international brain drain can be prevented in the electricity sector only through these solutions.

Human resource research documents can provide data regarding the manpower needs arising during the project broken down to headcount figures and years and the relevant service needs attached thereto. Enforced employment of regional manpower (which should be in fact an issue of top priority) demands for accommodation and other services can be significantly reduced but then traffic and commuting demands would increase. Kalocsa region would also receive a high-priority treatment including promotion to ferry services on Duna. Environmentally-friendly traffic solutions should be also preferred just like large-size parking plots that can be later utilised for other purposes. Available accommodation places should be surveyed including the relevant development and expansion options in line with the recommendations of the International Atomic Energy Agency. In addition to securing accommodation facilities in accordance with the transition and 21st century requirements actions will be required for securing final settlement opportunities for the would-be operating crew and the family members. Acceptance attitude of various settlements should be also analysed. Issues like food supply, catering services, medical or healthcare and social services for more than 1 000 people will also need attention and solution, as well as public security issues, sport and leisure time and recreational activities and programs. Expansion options for nurseries, kindergartens and education facilities should be carefully analysed well in advance, and securing employment options in time for women (family members) is also a key issue.

On regional level the a planned development will primarily be significant during the implementation phase: infrastructure will develop, regional companies engaged in providing accommodation and related services for people working on the project will earn extra income, and following the development and the de-commissioning of units 1-4. mainly on long term a solvent employment and contractor group will remain in the region as they will be responsible for the operation and maintenance of the new units, thus compensating the negative economic and social impacts potentially arising from the shutdown of the old units.

Though Paks city has developed definite decentralisation ideas, it will have a high-priority role already during the preparatory phase, thus it is reasonable for the city to maintain continuous cooperation with the project. Surveying the required infrastructure developments and launching the related planning and preparatory actions as well as identification of the required resources is going on. Development options for Paks Industrial Park and opportunities for enlarging its territory are also key issues. It is very important that plants and other facilities (including offices as well) that will be involved into the preparation of construction and assembly and later the operation of the power plant settle down in or near the city. Szekszárd is a major city and should be treated accordingly during the project preparation and implementation phases. Villages located in the region of the power plant that assume specific roles in order to support and make the project successful (e.g. accepting the container city for accommodation, providing the required land and public utility connections, smooth licensing procedure, manpower mobilisation, cooperation in training, communication support, residential area plotting, providing sport and recreation programs and facilities) will be included into the partner settlement network. Members of this network will not be entitled for any financial benefit but will receive various opportunities. All this requires detailed preparatory work form these settlements in order that the final result can be based on realistic local resources.

MVM Paks Nuclear Power Plant Zrt. has been operating a social support system for nearly a decade in the form of a foundation with the purpose to help regional, urban and rural development, undertaking development and establishment of new workplaces. With the help of this foundation various developments of more than HUF 30 billion value have been implemented in the beneficiary region through direct and indirect support (down-payment for bidding), also including several hundred new workplaces.

An organisation has to be established which is able to efficiently represent the realistic demands and interests of the regional population with the help of a registered legal entity status, independent program, operation system and budget in order that a successful dialogue can be established and maintained between the Nuclear Power Plant and the population in the region. Accordingly, the Social Control, Information and Settlement Development society (TEIT) was established in 1992 with the representatives of local governments and municipalities of 13 settlements. The Society performs control activity, and maintains a close cooperation with the power plant in forwarding information. Its goal is not to oppose the power plant, but rather protecting the interest of the population, maintaining sincere dialogue and cooperation and to improve mutual confidence. TEIT publishes periodicals and established a social committee for control.

There are living various communication opportunities between MVM Paks Nuclear Power Plant Zrt. and the regional population looking back to several decades history. This wide-range communication and commenting opportunity provides a solid base and building for confidence-building, steady cooperation and consensus-creation. In the spirit of open-door policy the power plant operates a visitor centre next to the power plant and at Kalocsa, and these are the most important places for meetings between the population and the nuclear industry, and they can offer daily opportunities for personally capturing information for every Hungarian citizen including people living in the region. The power plant maintains close cooperation with representatives of the local, regional and national press and media, supplying them with regular or ad hoc (if so required) information documents. MVM Paks Nuclear Power Plant Zrt. issues its own newsletter providing exact information on events in the power plant, the plans and development ideas. The newsletter is widely circulated and delivered to every post-box of houses in settlements within a 12 km radius (TEIT). people living in Paks, Kalocsa, Gerjen and Uszód can obtain information round the clock through the monitors displayed in the city/village centres showing the timely local broadcasting conditions in an easy-to-understand and comparative approach.

11 THE CURRENT AND LIKELY WEATHER OF THE 30KM ENVIRONS OF PAKS

11.1 CLIMATE PROFILE OF THE ENVIRONS OF PAKS IN A 30KM RADIUS

Average annual **mean temperature** is 10.7°C at the Paks station, which exceeds the nationwide average. Looking at the average annual progression of temperature one can see that July is the hottest month in the region, and January the coldest. Based on the temperature analysis one can see that average temperature is showing an increasing trend at annual level; and the analysis of the daily occurrence of summer, hot and sweltering days also allows observing ever more frequent extremities within single years.

Regarding annual total precipitation, 1961 was the driest year (285.9 mm) in Paks since 1951, while the wettest one was 2010 (990.9 mm), which also broke the absolute maximum record to date. Upon studying ten-year averages one may state that the last ten years were the wettest all in all during the period. In terms of annual total precipitation, a somewhat increasing trend is typical in the vicinity of Paks, and upon examination of extreme values, century old records were relegated to history in multiple cases during this 30 year period. Regarding the yearly progression of precipitation one may state that June is the wettest month in the vicinity of Paks, followed by the other two summer months and May, in other words, most precipitation falls during the summer period. After that period, a secondary maximum can be observed in November. March is the driest month, but precipitation is usually also small in January-February.

December is the month with the least **sunshine** in the vicinity of Paks due to extended cloud cover and short daylight hours; average daily sunshine duration comes to just 53 hours then. The months of May to September are the richest in sunshine; values above an average of 250 hours occurred in this period, and the month of July was the sunniest among them in terms of the past 30 years' average, followed by August, then June. Sunshine duration in the summer half of the year is close to two and a half times that in the winter half.

Annual **mean sea level pressure** in the vicinity of Paks is 1017.5hPa, its progression during the year is similar to the nationwide progression, with the highest values usually occurring in January, and the lowest ones in April. Average air pressure for the summer half of the year is lower than it is in the case of the winter half.

In the vicinity of Paks, actual **evaporation** is the lowest in the period from November to February, and the greatest in the period between May and August. Potential evaporation is lowest during winter, when it is almost the same as actual evaporation; however from spring to autumn it far exceeds the latter, since an appropriate quantity of evaporable water is not available. The vicinity of Paks qualifies as an arid area from the perspective of precipitation supply.

The **temperature of the soil surface** follows the sun's progress directly, and thus the warming up and cooling down of the soil's top layer changes in parallel with air temperature day by day and year by year. As depth increases, however, the effect of the sun weakens more and more, both daily and seasonal fluctuations decrease, and temperature becomes constant at a certain depth.

Wind conditions: Northwesterly and north-northwesterly are the most common convections by annual comparison, with the southern direction appearing as the secondary maximum. In the summer half of the year, north-northwest dominates, followed by the northwest direction, then north, with the southern direction relegated to fourth place. In the winter half of the year, the prevailing wind direction is northwest, but the southerly direction takes second place here, with north-northwest being third. Annual average wind speed is characterised by a decreasing trend during the 1997-2010 period. The strongest gust of 24.8 m/s in the period was registered on 19 November 2004. The direction of maximum wind gusts is northwest in most cases, followed by the southerly, then the north-northwest directions. Looking at speed, wind gusts between 2-4 m/s occur most of the time, but those between 1-2 m/s and 4-6 m/s are also common. Wind speeds exceeding 12 m/s only occur at in lower proportion during the year, and those exceeding 17 m/s only seldom.

Based on data from the 7 years under consideration, the north-northwest wind direction prevailed at the **Paks instrument tower's** 20 metre height level, and north occurred most times beside that. The south and south-southwest directions were also relatively common. The north-northwest direction was also most common at 50 metres height, with the order being similar to that at the 20 metre level, the signs of the northwestern wind direction increasing, however, are already starting to show. The north-northwest wind also prevailed here, followed by the southwestern and north wind, so southerly winds were less pronounced than at the lower levels. While the prevalence of the 2-4m/s range is hardly greater at 20 metres than that of the range below it, its dominance is already unequivocal at 50 metres, and at 120 metres the speed that occurred in the greatest proportion was already between 4 and 6m/s. During the length of time under consideration, maximum average speed was 12m/s at 20 metres, almost 18m/s at 50 metres, and values above 20m/s also occurred at 120 metres.No wind gusts exceeding 25m/s occurred at 20 metres, there were, however, gusts greater than 30m/s at 120 metres.

11.2 CLIMATE CHANGE DURING THE 21ST CENTURY IN THE VICINITY OF PAKS BASED ON CLIMATE MODEL RESULTS

After year 2010, "last year was extremely wet" is something that was often said, and our experiences from the next statement are perhaps even fresher: "The summer of 2012 was extremely hot." The **variability** of individual years is a natural part of climate, and it exists even without any external constraint whatsoever, therefore such instances cannot be attributed to climate change. When examining the climate, it is values, trends and changes taken as averages of long years that are considered.

The most important uncertainty of climatic modelling is **uncertainty derived from the models**. Models resolve the equations that govern the processes of the climate system with the help of numerical methods. In the course of this numeric solution, state parameters (i.e. temperature, wind speed, etc.) are regarded in the points of a three-dimensional spatial grid, and certain interactions are described in simplified form with the help of what are referred to as parameterizations. The models developed at the various institutes differ in many respects: they may apply different approaches and parameterizations to describe the same physical process, furthermore they might use grids of differing resolutions. All of these differences also have their effect on model results.

Anthropogenic activity (i.e. of human origin) has been proven to have an effect on climate processes, therefore it also needs to be taken into consideration in climate models. It is not possible to define how man's activity will develop in the future in an exact manner: we do not know the degree by which humankind's headcount will increase, what energy and economic policies various countries are going to adopt, what the level of technological development will be, i.e. we cannot tell the amount of pollutant emission in the future either. Multiple kinds of emission scenarios were created to this end (Nakicenovic and Swart, 2000), which quantify the impact of human activity in the form of carbon dioxide emission. There are scenarios that describe a pessimistic future (in other words ones that assume additional significant emissions), but optimistic and average scenarios also exist, and all of them have vastly differing degrees of atmospheric greenhouse gas incidence by 2100. Uncertainties resulting from this are called **scenario uncertainties.**

Models are first tested in respect of the climate of the past, and developed on the basis of the results. After that, simulations regarding the future are conducted with them, using extra greenhouse gases caused by human activity as an input parameter. Since the different models characterise the climate in different ways, results from multiple models are always considered when examining climate change (which is known as the ensemble method), because this way the uncertainties of climate simulation outcomes can be quantified.

Uncertainty in the scenarios is manifested from the second half of the 21st century. When examining climate change, it is important to use multiple, meaning at least two models in order to quantify uncertainty, since all of the models describe the climate of the future as being equally possible.

11.2.1 THE AVAILABLE MODELS

Results from the global models are less applicable to the Carpathian Basin, also as a consequence, among other things, of their poor resolution. That is why global information needs to be refined with the help of regional climatic models in order to determine the ratio of uncertainties. A number of regional climate models were run with 25 and 50km horizontal grid resolution in the framework of the European Union's ENSEMBLES Project (van der Linden and Mitchell, 2009), applying the ***average scenario*** (***A1B***) from among the scenarios.

Two regional climate models have been adopted at the Hungarian Meteorological Service (OMSZ) during recent years for studying climate change:

- ***ALADIN-Climate,*** *a regional climate model developed by Météo France in Toulouse in the scope of international cooperation, moreover*
- ***REMO,*** *the regional climate model developed by the Max Planck Institute in Hamburg.*

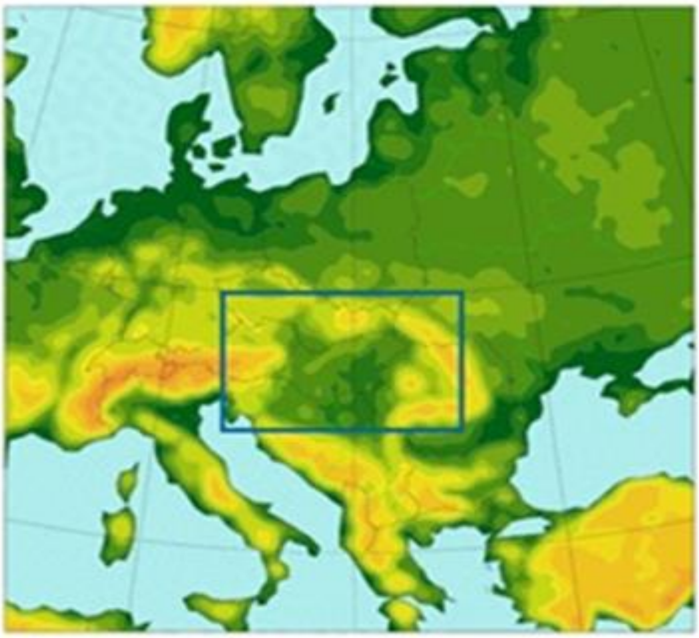


Figure 46: The 25 (entire panel) and 10km (blue rectangle) resolution domains of the ALADIN-Climate model

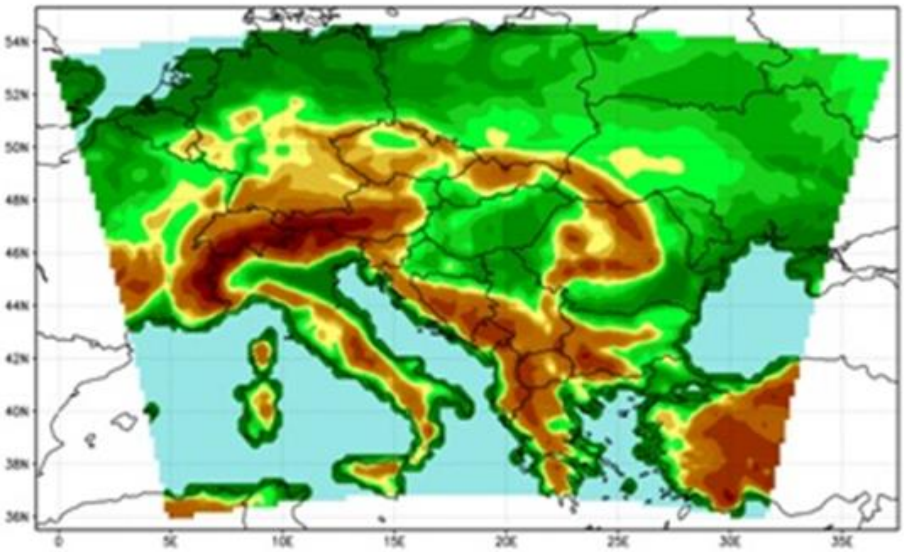


Figure 47: The REMO model's domain covered with 25km resolution

Simulations were first run concerning the past with these models in order to test them across a more extended past period known by virtue of measurements, and to help their improvement with conclusions thus discerned.

	ALADIN-Climate 4.5		REMO 5.0	
Period	1961-2000	1961–2100	1961-2000	1951–2100
Resolution	25 and 10km	10km	25km	25km
Fringe criterion	Reanalyses	GCM	Reanalyses	GCM

GCM: Global Climate Model

Table 34: The characteristics of experiments conducted using the ALADIN-Climate and REMO regional climate models

The two regional climate models applied at OMSZ (ALADIN-Climate and REMO) are used to scale down the results of global models to a range with a finer resolution. Input data for this, known as fringe criteria, were provided by the general global circulation model (ARPEGE-Climat) in the case of ALADIN-Climate, and the global Atmosphere and Ocean Global Circulation Model (ECHAM5/MPI-OM) in that of REMO.

The summary of these simulations are provided in the following table.

Model	Resolution	Fringe criterion	Scenario	Period
ALADIN-Climate 5.2	50km	ERA-Interim	-	1989-2008
	10 and 50km	ARPEGE	RCP8.5	1951–2100
REMO 2009	10km	ERA-Interim	-	1989-2008
	10km	ECHAM	RCP8.5	1951–2100

Table 35: The experiment planned with the ALADIN-Climate and REMO models

The updating of fine resolution simulations is still in its initial stage.

11.2.2 Processing of available model results in respect of average conditions for the 30km vicinity of Paks

The selected area comprises 7 × 7 points from the 10km, and 4 × 3 points from the 25km resolution model.

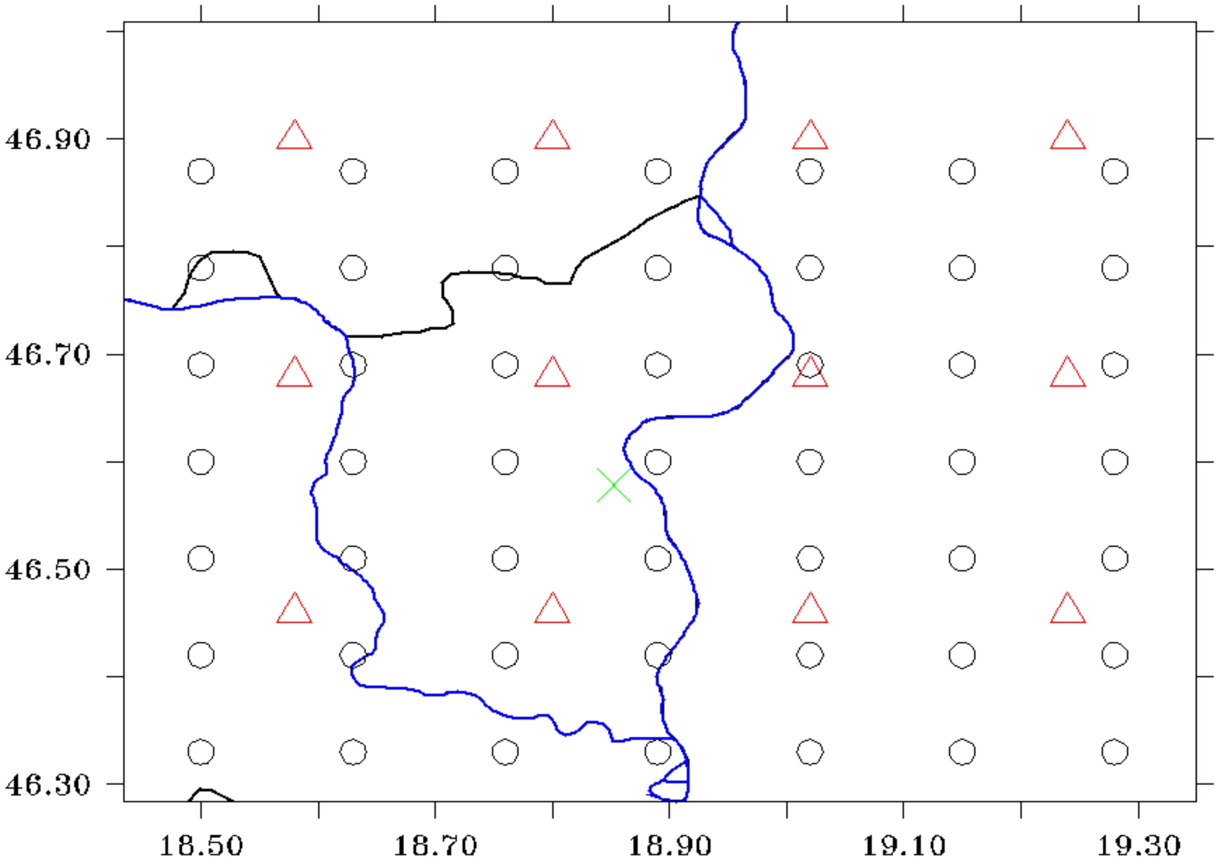
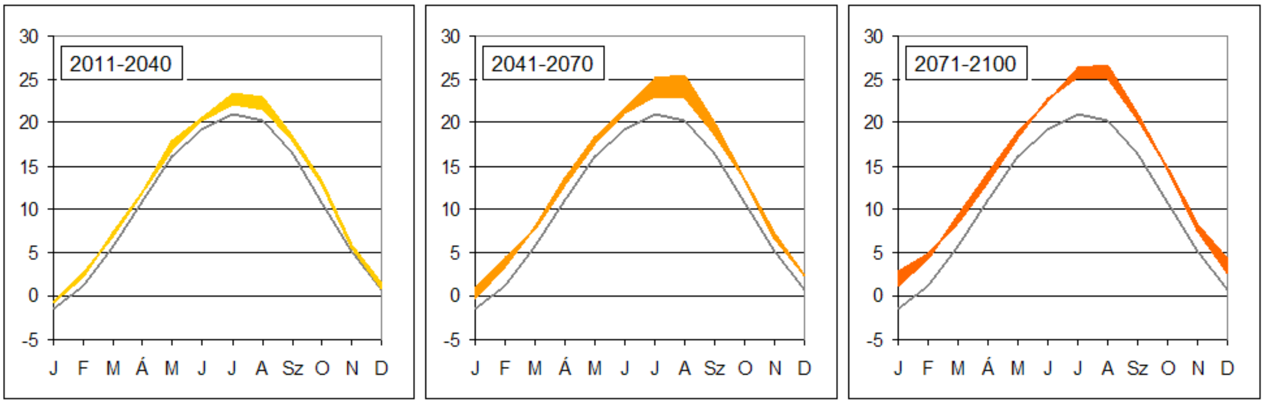


Figure 48: The ALADIN-Climate (black) and REMO (red) models' grid points situated in the surroundings of the Paks Nuclear Power Plant (green)

The selected future periods were 2011-2040, 2041-2070 and 2071-2100, since climate can only be interpreted on a longer timescale of at least 30 years according to the World Meteorological Organization's recommendation. The models describe actual processes in an approximative way, therefore results are laden with lesser and greater errors by necessity. In the interest of eliminating systematic errors, future results are not interpreted on their own, rather in relation to the models' own reference period of 1961-1990—meaning that changes are specified (even though the models' defects will not necessarily be constant over time).

In addition to processes that form the natural climate, model simulations also take the effects of human activity into consideration. As we are not in a position to be aware of how that will develop over the entire 21st century, different hypotheses—referred to as scenarios—are determined, which present the different development opportunities of anthropogenic activity in the future. The human impact is quantified in the form of carbon dioxide concentration for the models, i.e. the various scenarios describe different progressions of atmospheric carbon dioxide concentration (all showing strictly monotonous growth). There are optimistic, pessimistic and more subtly differentiated versions among the scenarios; the model experiments conducted at OMSZ relied on the ***average scenario (A1B)***. During implementation, measured carbon dioxide concentration levels are incorporated in the model simulations' section lasting until 2000, and the said hypothetical scenario is taken as the basis beyond that. Most specialists who deal with climate modelling usually take the period between 1961-1990 as the basis, because this is how the model can show significant, major change signals concerning the 21st century.

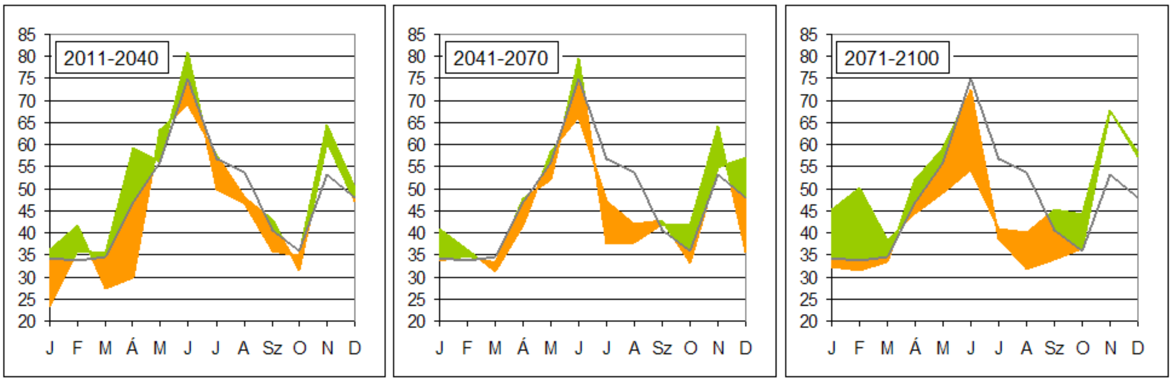
Gradual warming can be expected for the surroundings of Paks during the 21st century according to both models, at annual, seasonal and monthly level alike. What this means is that the farther the 30-year period considered, the stronger the monthly, seasonal and annual average temperature increase will be. There will still be natural variability among the years, so months and seasons colder than the average may also occur in the future.



Remark:
When illustrating information applicable to the future, change the models indicated for the respective period were added to measurements concerning 1961-1990, then the area between the two annual progressions received on the basis of the two models' results were shaded.

Figure 49: The annual progression of monthly average temperatures (°C) according to observations in 1961-1990 (gray line), and annual progression anticipated on the basis of the two models (°C; the uncertainty interval they limit are in coloured bands) in the vicinity of Paks

In the case of precipitation, and unlike temperatures, one cannot talk about unequivocal and linear changes over the 21st century, either concerning the three future periods, the seasons or the two models. The models agree about the slight change of annual precipitation, but considering seasonal distributions is also important, and great differences can be seen in this regard. According to the models, decrease during summer and increase during autumn is unequivocal, but the models are uncertain as to direction of change in spring and winter. Change is clear-cut according to the models: for every season, therefore also at annual level, in respect of all three future periods in the vicinity of Paks. The greatest changes will appear as we near the end of the century, furthermore they always mostly occur in summer and autumn, when atmospheric humidity is lowest anyway.



Remark:
When illustrating information applicable to the future, measurements concerning 1961-1990 were increased by the extent of (strong) relative change the models indicated for the respective period, then the area between the two annual progressions received on the basis of the two models' results were shaded (green for increase and yellow in the case of decrease).

Figure 50: The annual progression of monthly total precipitation (mm) according to observations in 1961-1990 (gray line), and annual progression anticipated on the basis of the two models (mm; the uncertainty interval they limit are in coloured bands) in the vicinity of Paks

The models do not forecast major or even unequivocal changes regarding wind speed magnitude, particularly not at annual level.

12 Expected impacts of the proposed development and the environmental conditions on the Danube water temperature, flood exposure, cooling water extraction and river morphology changes

The Danube model studies conducted as part of the Environmental Impact Study of Paks II aim to determine how the Paks Power Plant site affected in case the conditions deemed to be the most extreme and most unfavourable occur, to investigate the morphodynamic changes developing as a result of the various hydrological events and to assess the typical parameters of the heat plume in the Danube of the warmed up cooling water returned into the Danube.

The Danube models studied and analysed the following aspects in details:

- One dimensional (1D) modelling of the impacts arising from extreme natural and artificial conditions
    - on the exposure of the site to floods
    - on the safety of cooling water extraction
- Two dimensional (2D) modelling of extreme low and high water events
- River morphology changes, morphodynamics
    - One dimensional (1D) model assessment of suspended sediment and bed loads
    - Two dimensional (2D) model assessment of morphodynamic processes in the Danube channel
- The impact of the warmed up cooling water returned in the Danube - Three dimensional (3D) modelling of the heat plume
- Mixing study of the waste water treatment plant operation in failure events

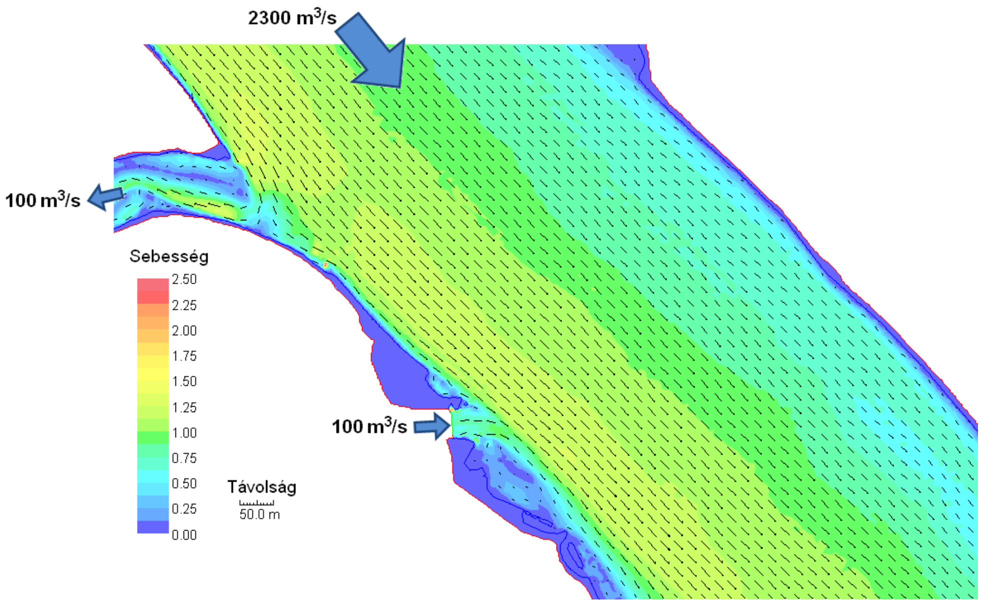
12.1 THE IMPACT OF THE ERECTION OF PAKS II ON THE DANUBE

During the construction of Paks II only the extension of the mouth profile of the cold water canal, and the foundation body installed as the foundation of the recuperation structure designed approximately 200 m upstream of the current existing hot water outflow will have a minimum impact influencing the flow conditions on the immediate Danube right bank.

In order to substantiate the evaluation set forth below the following subchapter presents the impacts exerted on the changes of the flow velocity distribution, illustrating the findings of the 2D hydrodynamic model simulation.

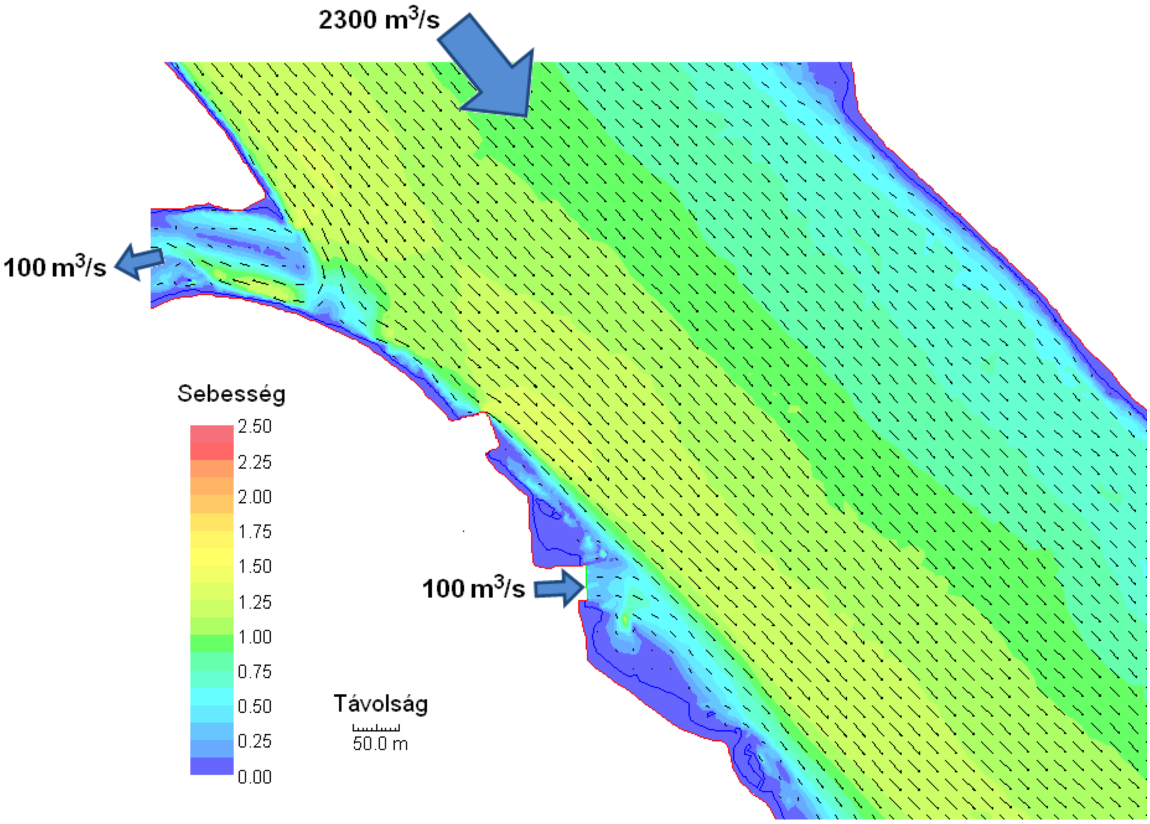
12.1.1 THE IMPACT OF THE ERECTION OF PAKS II ON THE FLOW SPACE AND RIVER MORPHOLOGY CHANGES IN THE DANUBE

Using the 2D flow model calibrated to the current conditions the depth integrated flow area was determined for the multiple year Danube discharge rate applicable in the water space in the neighbourhood of the site (2 300 m³/s) – for the case of the Paks Power Plant and the conditions during the construction works. Based on the comparison of the two velocity fields it can be established that the construction of Paks II hardly causes any change in the Danube flow conditions (velocity distribution, water levels). Due to the aforementioned reasons negligible changes should be reckoned with in terms of river morphology changes and the mixing of the hot water discharged when the proposed development is implemented.



Sebesség – velocity, Távolság - distance

Figure 51: Calculated depth integrated velocity area in the surrounding of the cold water and hot water canal mouths in the event of 2 300 m³/s multiple year average Danube discharge rate and 100 m³/s cooling water extraction intensity– Paks Power Plant stand alone operation



Sebesség – velocity, Távolság - distance

Figure 52: Calculated depth integrated velocity area in the surrounding of the cold water and hot water canal mouths in the event of 2 300 m³/s multiple year average Danube discharge rate and 100 m³/s cooling water extraction intensity– Paks Power Plant – Paks II under contruction

12.1.2 DISCHARGE OF TREATED MUNICIPAL WASTE WATER DURING CONSTRUCTION

The maximum volume of drinking water supply requirements is encountered during the period when the operation of the first unit is already commenced and the second unit is being constructed at the same time. This amount is maximum 646 m³/day, and the related maximum amount of wastewater is 95 % of this volume, i.e. 614 m³/day.

Total capacity of the municipal wastewater treatment plant currently operating at the power plant site is 1 870 m³/day, of which the wastewater treatment plant marked No II – reconstructed in 2012 – operates with a capacity of 1 200 m³/day, the other is taken into account as stand-by at the time being. Since the average amount of municipal wastewater streams currently generated within the Paks Power Plant site is approximately 300 m³/day (Paks Power Plant operation), therefore a free treatment capacity of ~1570 m³/day is safely available.

Taking the proposed development into account the design discharge rate of municipal wastewater can be assumed for the purposes of safety 1000 m³/day (300 + 614 m³/day), which can be covered alone by the 1 200 m³/day capacity facility marked No II – reconstructed in 2012 – of the waste water treatment plant.

The limit values of the water classification for the receiver are contained in the Ministerial Decree No.10/2010. (VIII. 18.) VM on the limit values applicable to the contamination of surface waters and laying the rules for the application thereof (Annex no 2: Water Quality Limits Applicable for Watercourses).

Classification of the different types of water body according to their respective ecological status is contained for physical and chemical components in the National River Basin Management Plan (VGT) developed pursuant to Ministerial Decree No.31/2004. (XII. 30.) KvVM laying down certain rules for the monitoring and state assessment of surface waters (*"Background material for Chapter 5 of the VGT, Physico-chemical limit values and the classification system related to the good status of surface water bodies"*). This proposes a five component classification system for physical and chemical components of the water (Class I: excellent, Class II: good, Class III: moderate, Class IV: poor, Class V: bad).

The design wastewater discharge rate – both during implementation and operation – is less than the capacity of the waste water treatment plant (1870 m³/day). As the wastewater discharge rate is decisive in the implementation phase, therefore the mixing study is carried out with the treatment capacity of the plant, i.e. a discharge rate of 1000 m³/day using a 2D transport model for the cases listed below.

1.) Mixing test for standard operation of the waste water treatment plant

- *direct receiver 0+050 river km right bank profile of the hot water canal (design state: 3 blocks operation, 75 m³/s canal water discharge),*
- *indirect receiver: Danube 1526+250 river km right bank profile,*
- *treated wastewater discharge: 1000 m³/nap,*
- *concentrations of the treated contaminant components: the limit value according to the water rights operation permit (Decision of the South Transdanubian Environmental Protection, Nature Conservation and Water Management Inspectorate No 917-20/2009-9992).*

1.1) In the event of extreme low Danube water discharge rate (Q = 579 m³/s),

1.2.) In the event of multiple years average Danube water discharge rate (Q = 2300 m³/s).

2.) Mixing test for failure event of the waste water treatment plant

- *direct receiver: Danube 1526+810 river km right bank profile,*
- *untreated wastewater discharge: 1000 m³/nap,*
- *concentrations of the untreated contaminant components: concentrations of the raw wastewater arriving to the waste water treatment plant.*

2.1) In the event of extreme low Danube water discharge rate (Q = 579 m³/s),

2.2.) In the event of multiple years average Danube water discharge rate (Q = 2300 m³/s).

During the mixing tests the load bearing capacity of the receiving water body must be taken into account for which classification information is provided by the geographic extension of the water quality grade leaps as an impact area.

12.1.2.1 Summary of the wastewater discharge on the Danube water body

As a result of the mixing study it can be concluded that <u>under the standard operation of the waste water treatment plant</u> the increments in concentrations is one order of magnitude less than the limit values for physical and chemical components pursuant to Ministerial Decree No.10/2010. (VIII. 18.) VM on the limit values applicable to the contamination of surface waters and laying the rules for the application thereof (Annex No 2: Water quality parameters for watercourses) (i.e. compared to Grade II, "good" status of the VGT WFD), and therefore practically it does not cause any impairment of grade levels in the water space and water body of the Danube, even in the case of extremely low (recurrent in every 20 000 years once, Q = 579 m³/s) Danube discharge rates. For metals the impact is even less. The standard impact area is restricted to an approximately 20 metres long and approximately 4 metres wide cross section downstream of the discharge of the treated wastewater into the hot water canal. The impact on the Danube water body is negligible. The hot water canal is paved, therefore no impact on underground water should be taken into account. The impact of the wastewater discharge directly through the Danube water body on the underground water quality is negligible.

In the case of a failure event (direct discharge into the Danube by-passing the hot water canal), when untreated wastewater exposure of the Danube at 1525+810 river km on the right bank is considered, the extent of impairment of the physical and chemical water quality components on the Danube is such that it may entail a grade level water quality status (low level of water quality impairment), the impact area of which is ~200 m downstream and ~10 m crosswise staying in the Danube right bank strip at extreme low Danube water stages. In the range of the average Danube discharge rate the impact area is reduced to less than half: ~80 m downstream and ~4 m in transverse direction. Eventually encountered failure events are periodical and by the resetting of the operating state of the waste water treatment plant the standard operating conditions prevail, that is the impact area is limited to the lower 50 metre section of the hot water canal and to the ~8 m strip close to the right bank of the hot water canal and practically no impact is felt on the Danube.

12.1.2.2 Summary of the impact of wastewater discharge on drinking water bases

The hydrogeological safety zone (zone of protection) with a 50 years calculated migration time of the Foktő-Baráka water base situated the closest to the standard discharge site lies some 3450 metres from it, the northern edge of which touched upon the Danube 1522.8 river km profile. Pursuant to Joint Ministerial Decree No.6/2009. (IV. 14.) KvVM–EüM–FVM on the limit values necessary for the protection of the geological medium and underground water bodies against pollution and the measurement of contamination levels the contamination limit value in the safety zone marked “B” in the safety zones of operating and prospective long term bank filtrated drinking water bases include 25 mg/l nitrate (= 5.65 mg/l nitrate-N) concentration, and 0.5 mg/l ammonium (= 0.39 ammonium-N) concentration. According to the calculations the concentration increment developing in the Danube water body due to the wastewater discharge from the standard operation during the design construction period is not expected to exert any detectable impact on the water bases concerned.

In the case of failure events, (direct discharge into the Danube by-passing the hot water canal), when untreated wastewater exposure of the Danube at 1525+810 river km on the right bank is considered, the extent of impact can be detected (in the case of the most sensitive component, ammonium the maximum of concentration increment is 0.04 mg/l and 0.02 mg/l in the periods with extremely low and average Danube discharge rates, respectively), but it does not increase the ammonium and nitrate concentrations above the limit values applicable to underground water bodies in the hydrogeological safety zone (zone of protection) with a 50 years calculated migration time of the Foktő-Baráka water base situated 3100 metres downstream of the discharge point. The impact of the contamination plume will disappear within approximately 20 metres as a result of the crosswise levelling of the plume. Eventually encountered failure events are periodical and by the resetting of the operating state of the waste water treatment plant the standard operating conditions prevail, that is the impact area and its impact increasing the concentrations to a slight extent are restored.

12.1.2.3 Water and wastewater quality monitoring

Continuous tracking of the purified wastewater discharge from the waste water treatment plant of the existing power plant and during the implementation of the new site and operating of the facilities to be constructed in order to monitor compliance with the emission limit values of the water quality components set forth in the water rights operation licence and effective laws and regulation will also be important in line with the VGT which was developed according to the Water Framework Directive.

12.2 THE IMPACTS OF THE OPERATION OF PAKS II ON THE DANUBE

12.2.1 DESIGN OPERATION STAGES

Modelling was made in line with the following design operating states of the operation of the existing and proposed new units as follows.

Design standard operation – Paks Power Plant (2014-2025)

The scenario includes maximum 100 m³/s cooling water extraction (through the existing cold water canal), which is returned through the existing hot water canal, Q = 100 m³/s

Design standard operation – Simultaneous operation of Paks Power Plant and Paks II (2030-2032)

This scenario includes cooling water extraction through the Danube mouth cross profile, and the return of water partly via the existing hot water canal through the energy dissipation device, discharged into the Danube on the right bank with a maximum 100 m³/s hot-discharge rate, on partly through the recuperation structure intended to be set up 200 metres upstream of this point, also into the Danube right bank, with maximum 132 m³/s hot water discharge rate, Q = 132+100 = 232 m³/s.

Design standard operation – Paks II stand alone operation (2037-2085)

Cooling water extraction and hot water discharge, Q = 132 m³/s

12.2.2 DESCRIPTION OF THE EXPECTED CHANGES BASED ON THE ANALYSIS OF THE FLOW VELOCITY FIELD IN THE DANUBE

The highest level of extraction and discharge can be expected in the period between 2030 and 2032 with a total flow of 232 m³/s to and from the 4 existing units (maximum 100 m³/s) and to and from the 2 new units (maximum 132 m³/s).

The water extraction plant is implemented in the cold water canal, thus it was no direct impact on the Danube flow space and Danube river bed, only a slight extent of indirect impact, due to the operation of the transfer pumps of the water extraction plant and of the cold water canal section (siltation, dredging) leading to it. This indirect impact is of negligible geographic extent and periodical in nature, just like the impacts caused by the currently operating power plants.

Hot water from the existing four units is discharged into the Danube by the existing hot water canal (1526+250 river km, right bank), through an existing energy dissipation device.

A new hot water canal channel bottom is constructed in order to discharge the hot water from the two new units, and at the Danube mouth of it (Danube 1526+450 river km) a recuperation structure is set up. The proposed construction of the hot water canal mouth has a direct impact on the Danube flow conditions and local morphology changes.

The impacts are manifested in the local changes to the flow conditions:

The new hot water discharge outflow point causes impoundment upstream, directly downstream of the cold water canal mouth, because it will break the nearly parallel shoreline current established in the riparian zone of the Danube. Large scale eddies – one clockwise and another anticlockwise – with nearly vertical axis are formed between the inflow of the cold water canal and of the new hot water inflow, which whirl dynamically causing periodically the eddies to burble in the near shoreline strip of the Danube right bank. A large scale eddy turning clockwise is formed downstream of the hot water discharge site, shifting the hot water plume towards the middle of the Danube. This also has a dynamic behaviour, sometimes eddies burble and are drifted in the environment of the Danube flow at the right bank strip, or spreading towards the Danube centre line.

There is a stagnant flow in the large scale whirlpools which are formed, resulting an eventual settlement of the transported suspended sediment and siltation of the dead space.

In the area where the flow directions are modified a slight extent of impoundment and a small scale shift in the position of the main current line of the Danube can be expected.

The modification effects of the flow referred to above are more explicit in the low water - and medium water periods on the Danube, while in times of Danube high waters the impacts are less prominent and the main Danube current dominates.

12.2.2.1 Assessment of extreme low and high water flow cases on the Danube in 2D modelling

The aforementioned permanent low water and flood water modelling of Danube bed runoff were accomplished with the help of the Delft3D-Flow hydrodynamic model, using its two dimensional (2D) depth integrated module for extreme low and high Danube flow conditions (recurrent in every 20 000 years), at the Danube 1500-1530 river km channel bottom section.

The assessed Danube-section includes the upstream and downstream sections of the existing and proposed power plant sites.

PRESENTATION OF THE RESULTS FROM 2D FLOW MODELLING CASES IN EXTREME HIGH WATER FLOW

Design standard operation – Paks Power Plant

This scenario includes extremely high permanent Danube discharge rates recurrent in every 20 000 years in the amount of $\mathbf{Q_{Danube}=14\ 799\ m^3/s}$ and maximum 100 m^3/s cooling water extraction which is returned through the energy dissipation device.

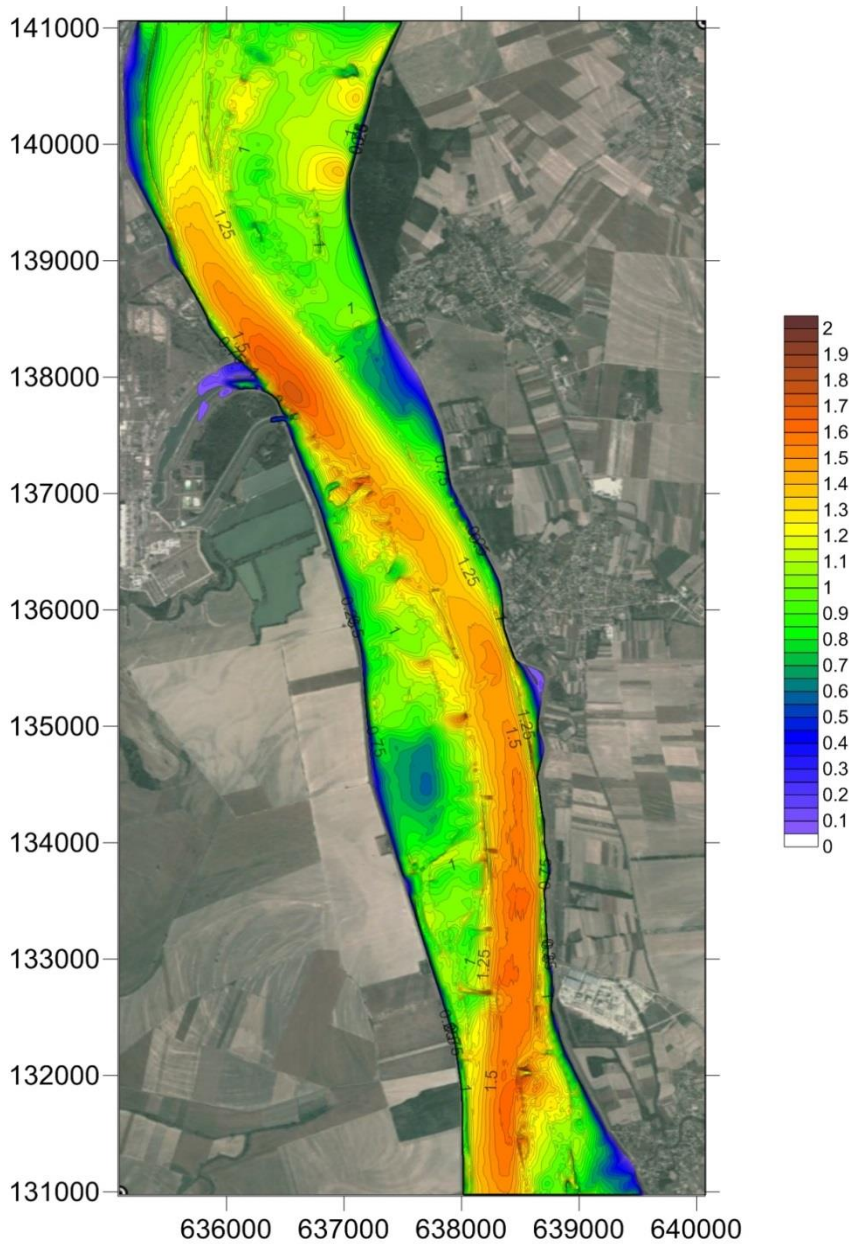


Figure 53: The distribution of absolute velicity values on the Danube 1519-1530 river km section [m/s] – Paks Power Plant, extreme high water ($Q_{20\ 000years}$ = 14 799 m³/s, water extraction 100 m³/s) – Paks Power Plant in stand alone operation – including EOV coordinates

Design standard operation – Simultaneous operation of Paks Power Plant and Paks II

This scenario includes extremely high permanent Danube discharge rates recurrent in every 20 000 years in the amount of **Q_{Danube}=14 799 m³/s** and maximum 232 m³/s cooling water extraction. Water is returned partly via the existing hot water canal through the energy dissipation device, discharged into the Danube on the right bank with a maximum 100 m³/s hot-discharge rate, on partly through the recuperation structure intended to be set up 200 metres upstream of this point, also into the Danube right bank, with maximum 132 m³/s hot water discharge rate.

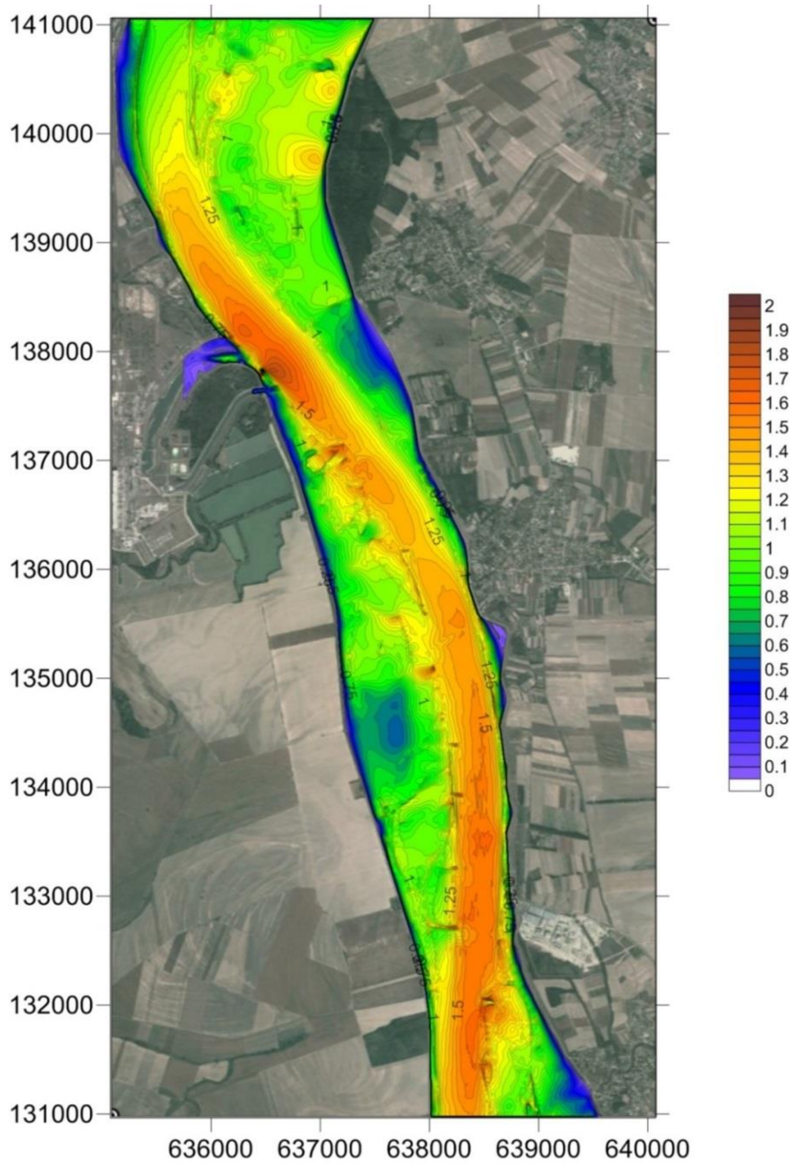


Figure 54: The distribution of absolute velicity values on the Danube 1519-1530 river km section [m/s] – Design standard operation, extreme high water ($Q_{20\,000years}$ = 14 799 m³/s, water extration at 232 m³/s) – Paks Power Plant and Paks II joint operation – including EOV coordinates

Flood events

For the purposes of assessing flood events the upper (discharge rate) boundary condition was the extremely high permanent Danube discharge rates recurrent in every 20 000 years in the amount of Q_{Danube}=14 799 m³/s (in culminating position). The lower boundary condition was provided as a water level (at Danube 1500 river km) 81.55 metres above Baltic sea level during the calculations.

During the model calculations for the sake of safety it was assumed that the current flood control works on the Danube are developed in the future and the travelling flood can be contained within the embankments with the help of protection measures against floods.

Based on the model calculation the water level on the Danube culminates at 96.90 metres above Baltic sea level in the event of an extreme flood event (a flood discharge rate recurrent in every 20 000 years), under the most unfavourable conditions in the surrounding of the existing and proposed site. If the flood control dike on the Danube right bank bursts at this Danube water level, or any of the bank line profile of the cold water canal and hot water canal is damaged, the inundation picture illustrated on the figure may be formed.

You can see that it will not threaten the ground level at 97.00 metres above Baltic sea level of either the existing site, or the site of the proposed development by static inundation, but provided the wave motion becomes more intensive for whatever reason, it may generate an emergency situation and may affect vulnerable objects on the surface or in the public utility ducts. Therefore the vulnerable objects situated close to the surface are recommended to be provided by active protection (parapet wall, etc.), and installed for the proposed development, respectively.

Figure 55: Static inundation image developing when the Danube is at 96.90 metres above Baltic sea level

The case referred to above can be considered a failure event, since development entailing the increase of the right and left bank embankments and crest levels on the section of the Danube concerned is not anticipated in the future even on the long term, since the design flood elevations (1 %, that is recurrent in every 100 year once) remain below the current level of the dike crests.

It can be seen in the one dimensional failure event flood model simulation, that provided no flood control works are heightened, the maximum Danube water level in the neighbourhood of the site will stay below 96.30 metres above Baltic sea level even in the case of an extreme flood with maximum water levels arriving from the direction of Bratislava – staying within the dikes – even when the impacts of a landslide or river wall collapse is taken into account. Therefore, no more than the 96.30 metres above Baltic sea level inundation could be formed eventually (for instance, as a result of the flood control embankment) in the environment of the power plant site.

Figure 56: Static inundation image developing when the Danube is at 96.30 metres above Baltic sea level

RESULTS FROM 2D FLOW MODELLING CASES IN EXTREME LOW WATER FLOW CASES

For the purposes of the assessment of extreme low water events the upper (discharge rate) boundary condition (at Danube 1530 river km) is the design discharge rate in permanent situation with a volume rate of flow of Q=579 m³/s, recurrent once in every 20 000 years).

Design standard operation - Paks Power Plant

Including extreme, permanent Danube low water discharge rates recurrent in every 20 000 years, $\mathbf{Q_{Danube} = 579\ m^3/s}$ and a maximum 100 m³/s cooling water extraction (through the existing cold water canal), with return through the energy dissipation device.

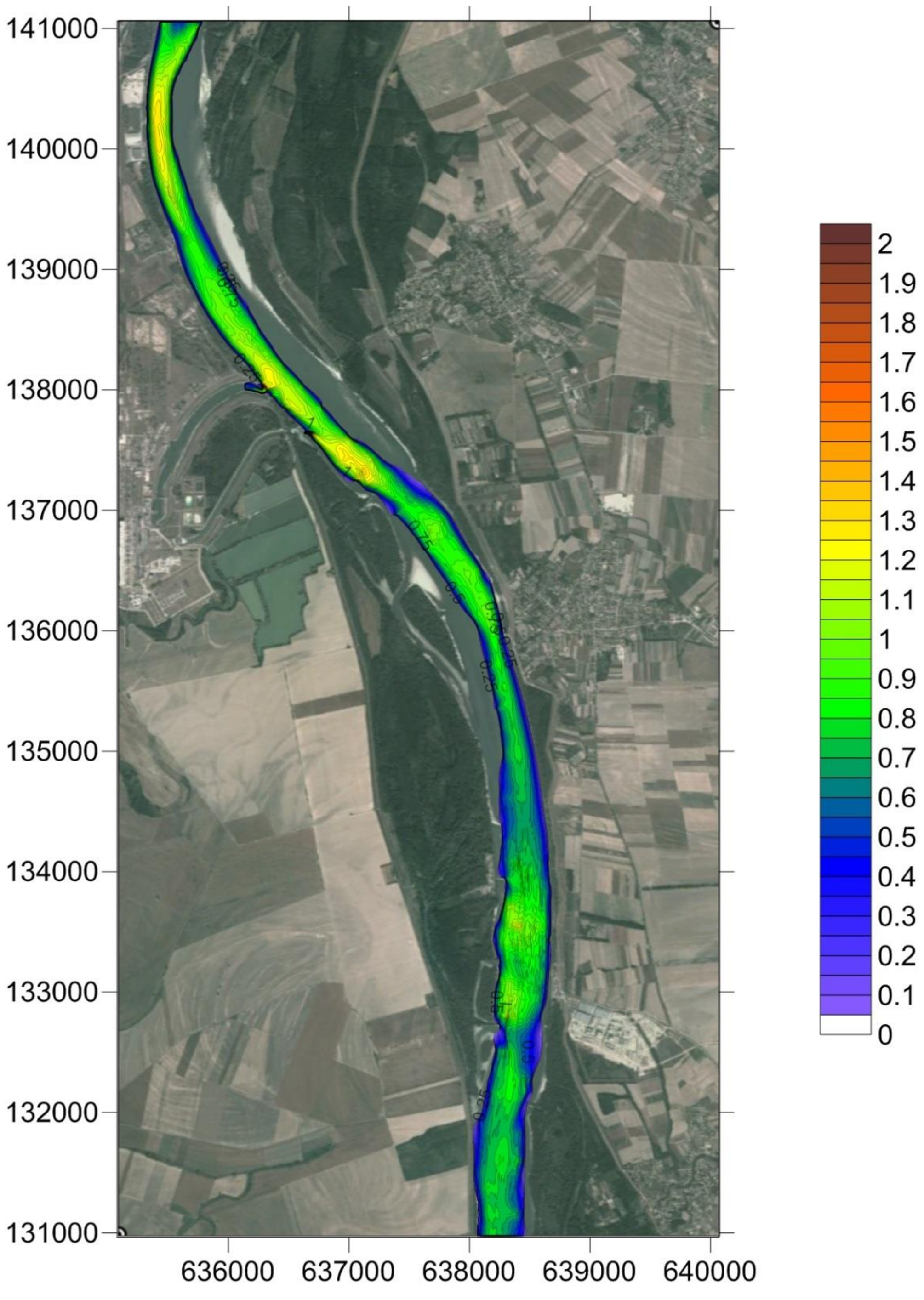


Figure 57: The distribution of absolute velocity values on the Danube 1519-1530 river km section [m/s] – Paks Power Plant in stand alone operation, extreme low water stage ($Q_{20\,000 years}$ = 579 m³/s, water extraction 100 m³/s) – including EOV coordinates

Paks Power Plant and Paks II simultaneously

This scenario includes extremely low permanent Danube discharge rates recurrent in every 20 000 years in the amount of **Q_{Danube}=579 m³/s** and maximum 232 m³/s cooling water extraction (through the Danube mouth cross profile, to be constructed by the extension of the existing cold water canal). Water is returned partly via the existing hot water canal through the energy dissipation device, discharged into the Danube on the right bank with a maximum 100 m³/s hot-discharge rate, on partly through the recuperation structure intended to be set up 200 metres upstream of this point, also into the Danube right bank, with maximum 132 m³/s hot water discharge rate

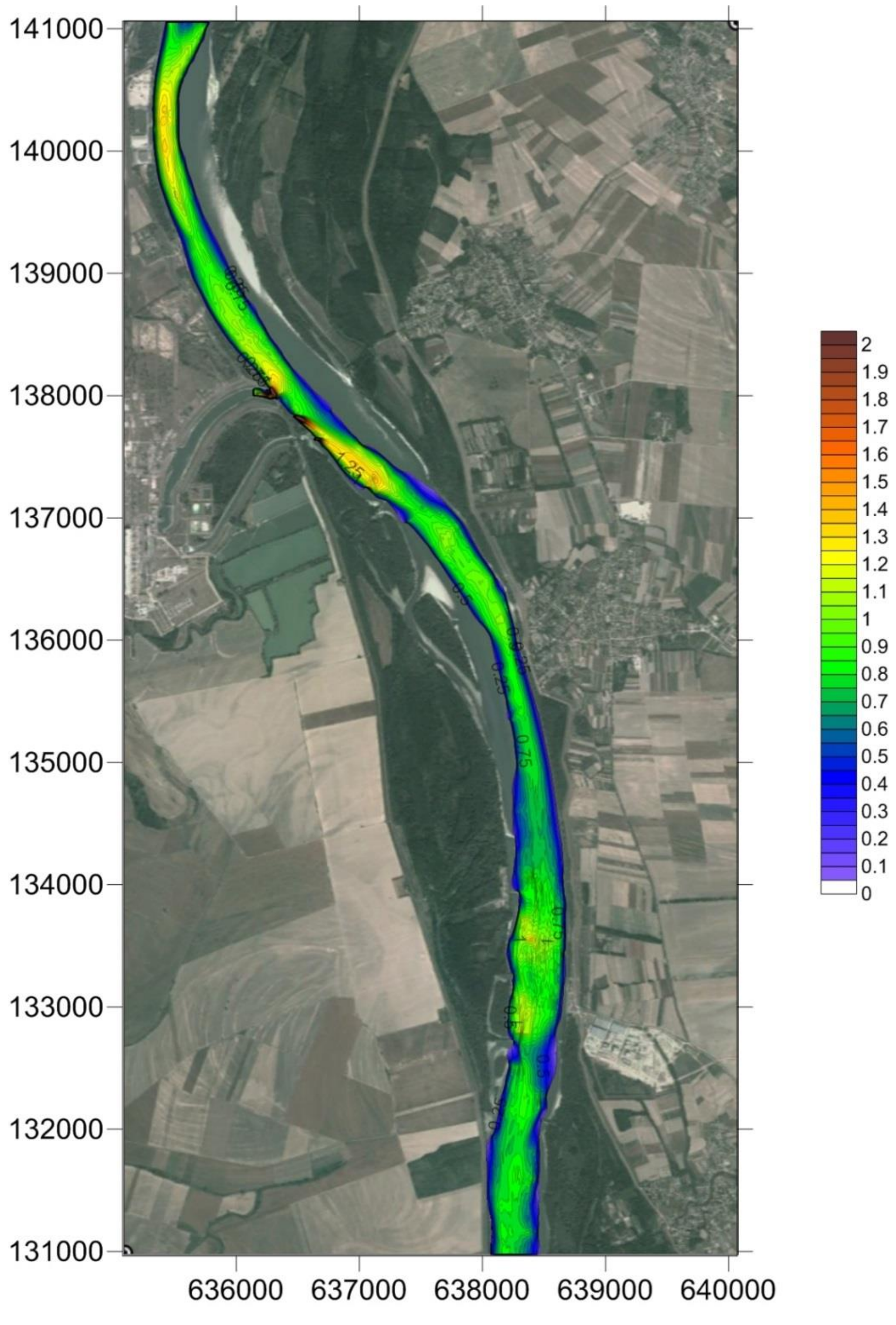


Figure 58: The distribution of absolute velocity values on the Danube 1519-1530 river km section [m/s] – design operating state, extreme low water ($Q_{20\,000 years}$ = 579 m³/s, water extraction 232 m³/s) – Paks Power Plant and Paks II joint operation – including EOV coordinates

12.2.2.2 A comprehensive evaluation of the 2D hydrodynamic impacts of extreme low and high water cases (1500 - 1530 river km of the Danube)

- In the baseline state (current state) the flood waves with 20 000 years recurrence frequency will cause embankment crest surpassing problems on the left bank of the Danube, which has an approximately 0.metre lower crest level. In the light of the crest height of the dam this impact can not be prevented by hastily-made emergency dikes.
- Extreme flood levels will stay in the power plant cross profile way below the ground level of the existing and proposed future site (97 metres above Baltic sea level) even in the case of a prospective increase in the height of the embankments.
- If a dam burst is assumed on the left bank caused by natural causes of due to an emergency decision, its impact is left below 20 cm on the upper edge of the assessed section and in this case the flood wave will pass below the ground level of the existing and proposed future site of the power plant.
- The increase of the proposed cooling water extraction – provided the extension project is implemented – causes a water level drop less than 12 cm in low water stages and less than 3 cm in high water.
- The landslide version impounds water levels upstream of the cold water canal. Downstream of the landslide the water level is reduced due to the accelerated water movement in the strait.
- The water level increasing and decreasing impact of the landslide narrowing the main channel (upstream and downstream of the landslide site, respectively), is low both in high water and low water. The water level increasing impact may reach 5 and 3 centimetres in the low and high water stages, respectively.

12.2.3 ASSESSMENT OF THE EXPECTED MORPHODYNAMIC IMPACTS FROM THE PROPOSED DEVELOPMENT ON THE DANUBE

The trends of river morphology changes in the Paks Danube section at medium water stages were basically determined by the incidents of the past few decades (primarily industrial level dredging, river training of the Danube at low and medium water stages, the decline of the amount of bed loads received). The declining tendency of annual low and medium water levels of the Danube must be taken for granted in the future, therefore it must be separated from the local impacts of the proposed development on river morphology changes.

12.2.3.1 Analysis of the local morphodynamic impacts

The Danube river morphology changes expected in decisive operational states were investigated with the application of the two dimensional 2D morphodynamic model (Delft3D-Flow).

Based on the results of the model simulation it can be determined that the key driver of the morphodynamic changes is the multiple year average discharge rate on the Danube and flood waves of lesser duration (non-permanent processes) perturb it only to a slight extent.

Hydrological periods (pending on the total annual precipitation rates in the Danube catchment area):

- Period with an average runoff in the basin (1 - 5 year) - Danube discharge rate: Q = 2 300 m³/s
- Substantially more humid (wet) hydrological period (1 - 5 year) - Danube discharge rate: Q = 3 000 m³/s

12.2.3.2 Changes in the Danube main current line

Stand alone operation of the Paks Nuclear Power Plant (2014-2025)

The position of the main current line in the neighbourhood of the site which can be determined in the current flow conditions of the Danube can be found near the right bank of the Danube main channel. This position may be modified to a small extent as a function of changes in the Danube discharge rate.

Simultaneous operation of Paks Power Plant and Paks II (2030-2032)

The main current line is shifted towards the middle of the Danube maximum 25 metres compared to the current state of affairs but is still left close to the right bank. The main current lines differ from each other only in an approximately 1000 metres long stretch in the event of multiple years average Danube discharge rate (2 300 m³/s). The impact area in the surroundings of the site is therefore the approximately 150 metres wide strip stretching along the right bank of the Danube in a length of approximately 1 000 metres measured downstream on the Danube.

In the case of stand alone operation of Paks II (2037-2085)

The main current line differs from the course of the present main current line in a length of 500 metres, with a maximum deviation of 25 metres again. The impact area in the surroundings of the site is therefore the approximately 150 metres wide strip stretching along the right bank of the Danube in a length of approximately 500 metres measured downstream on the Danube.

Duna sodorvonalának helyzete morfodinamikai változások nélkül átlagos lefolyású évben az üzembehelyezés évében – the course of the Danube main current line without changes in the morphodinamics in the year of commissioning, in average hydrological year
Jelmagyarázat – legend
Paks I és Paks II – Paks I and Paks II
mederváltozási kontrolpontok –check points for river bad changes

Figure 59: Calculated trends in the main current line of the Danube at a Danube discharge rate of 2 300 m³/s (average hydrological year), in three operational states: Paks Power Plant operation, Paks Power Plant and Paks II joint operation Paks II stand alone operation

In a wet hydrological year the annual average Danube discharge rate is 3 000 m³/s (1.3 times the multiple year annual discharge rate). In this case the longitudinal impact area is also increased to a small extent by some10 % (1 100 m), while the extent by which the main current line is transferred to the Danube centre line is mitigated by approximately 10 % (22 m).

Duna sodorvonalának helyzete morfodinamikai változások nélkül nedves lefolyású évben az üzembehelyezés évében – the course of the Danube main current line without changes in the morphodinamics in the year of commissioning, in wet hydrological year
Jelmagyarázat – legend
Paks I és Paks II – Paks I and Paks II
mederváltozási kontrolpontok –check points for river bad changes

Figure 60: Calculated trends in the main current line of the Danube at a Danube discharge rate of 2 300 m³/s (wet hydrological year), in three operational states: Paks Power Plant operation, Paks Power Plant and Paks II joint operation Paks II stand alone operation

Changes in the flow velocities, including the relocation of the main current line, is the greatest in the initial period of the changed operational state. Over time the river morphology changes mitigate flow anomalies and after the passing of approximately 5 years the channel bottom is adapted to the altered flow conditions (silts up and erodes), the river bottom changes level out and additional river morphology changes are eliminated.

12.2.3.3 Trends in local Danube river morphology changes as a result of the proposed development project

The river morphology changes calculated for the 5 years service period are illustrated on the figures below. On the figure the colouring of river morphology changes was rendered transparent and overlapped with the orthophoto prepared using an aerial photograph taken on 22 July 2013. The discharge rate measured at the time the aerial photograph of the Danube was shot (Dombori watermark post) on 22 July 2013 was approximately ~2000 m³/s, but the calculations were made with the multiple years average discharge rate of 2300 m³/s.

OPERATION OF THE PAKS POWER PLANT (2014-2025)

Danube discharge rate: Q_{Danube} = 2 300 m³/s (average), cooling water extraction: Q = 100 m³/s

It can be seen on the next figure (Figure 61) that the boundary of the river morphology changes forming along the hot water plume runs at the northern edge of the energy dissipation device following the water of the Danube rippled (foaming) by the series of eddies burbling from the diversion dam (a small size spur) protruding into the flow space and drifted across the flow space.

Számított mederváltozás Paks I üzemelésekor átlagos lefolyású évben ötéves üzemidő után –Calculated Danube river morphology changes during operation of Paks I in average hydrological year after five years of operation
Jelmagyarázat – legend
meter – metre

Figure 61: Calculated Danube river morphology changes after 5 years of operation at 2 300 m³/s-os Danube discharge rate (average hydrological year) and 100 m³/s cooling water extraction – Paks Power Plant in stand alone operation (2014-2025)

The river morphology changes calculated for a year with higher than usual precipitation included local erosion to a maximum level of less than 40 cm, and the level of siltation falling short of 80 cm.

DESIGN OPERATION STATE OF JOINT PAKS POWER PLANT AND PAKS II OPERATION (2030-2032)

Danube discharge rate: Q_{Danube} = 2 300 m³/s (average), cooling water extraction: Q = 100 m³/s + 132 m³/s = 232 m³/s

The river morphology changes over the 5 years period calculated for the joint operation of Paks Power Plant and Paks II show an approximately 10 centimetres more intensive deepening in the area of the existing Danube plume of the hot water load compared to the river morphology changes caused by the operation of the Paks Power Plant, and an approximately 40 cm deepening can be expected along 200 m channel bottom section in the wake of the plume between the proposed new hot water discharge site and the existing site. Minimum level of siltation is expected between the plume and the shoreline. Local impacts can be hardly felt in the environment of the Danube 1525+500 river km profile (cross dam, the control work established on the Danube right protruding into the flow space).

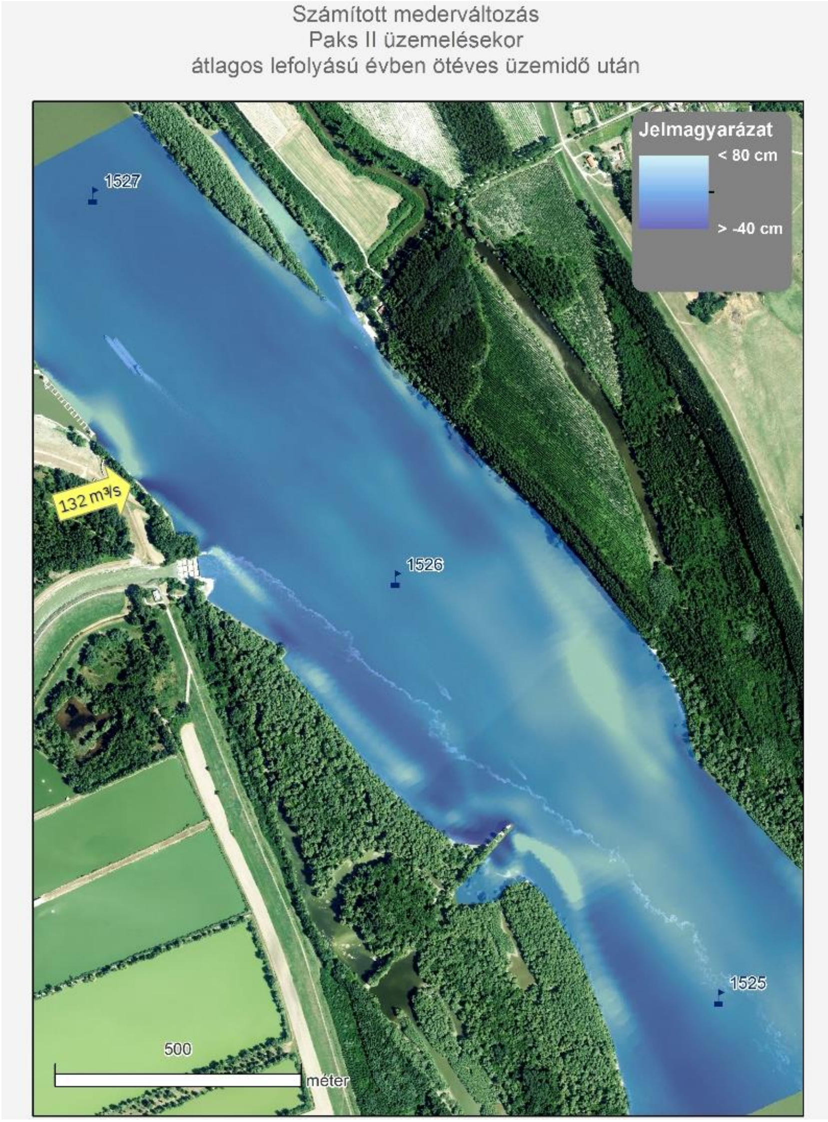
Számított mederváltozás Paks I és Paks II együttes üzemelésekor átlagos lefolyású évben ötéves üzemidő után –Calculated morphology changes during joint operation of Paks I and Paks II in average hydrological year after five years of operation
Jelmagyarázat – legend
meter – metre

Figure 62: Calculated Danube river morphology changes after 5 years of operation at a 2 300 m³/s Danube discharge rate (average hydrological year) and in the case of 100 m³/s cooling water extraction rate (the state between the years 2030-2032) – Paks Power Plant and Paks II jointly (2030-2032)

STAND ALONE OPERATION OF PAKS II IN DESIGN STATE (2037-2085)

Danube discharge rate: Q_{Danube} = 2300 m³/s (average), cooling water extraction: Q = 132 m³/s

The river morphology changes over the 5 years period calculated for the stand alone operation of Paks II show an approximately 5 centimetres more intensive deepening in the area of the existing Danube plume of the hot water load compared to the river morphology changes caused by the operation of the Paks Power Plant alone, and an approximately 10 cm deepening can be expected along 200 m channel bottom section in the wake of the plume between the proposed new hot water discharge site and the existing site, since with the elimination of the lower plume its impounding impact is discontinued. Minimum level of siltation is expected between the plume and the shoreline. Local impacts become negligible downstream of the Danube 1525 river km profile.



Számított mederváltozás Paks II üzemelésekor átlagos lefolyású évben ötéves üzemidő után –Calculated morphology changes during operation of Paks II in average hydrological year after five years of operation
Jelmagyarázat – legend
meter – metre

Figure 63: Calculated Danube river morphology changes after 5 years of operation at a 2 300 m³/s Danube discharge rate (average hydrological year) and in the case of 100 m³/s cooling water extraction rate (the state between the years 2037-2085) – Paks II in stand alone operation (2037-2085)

12.2.3.4 The summarised results of the assessment of local river bottom changes

As a result of the local bottom morphology changes following the five (5) years of operation – approaching the consolidation of the channel bottom – the following can be concluded:

- The key driver the of morphodynamic changes is the multiple year average Danube discharge rate flood waves with shorter duration perturb this trend only in a slight extent.
- During the service years which are substantially more humid than average (3000 m³/s) the extent of river bed changes is a little more intensive compared to the channel bottom level changes over the multiple years average (2300 m³/s) Danube discharge rate.
- Local bottom level increase (siltation) was maximum 80 cm in all cases, while the extent of local channel bottom reduction (deepening, erosion) was in each of the cases maximum 40 cm, with insignificant geographic extension.
- The difference between the river bed changes in the design state of stand alone Paks Power Plant operation (2014-2025), and the stand alone operation of Paks II (2037-2085) is negligible.
- Remarkable differences in river morphology changes can be experienced at the design state of simultaneous operation of both Paks Power Plant and Paks II (2030-2032) compared to the respective stand alone scenarios. This impact is reduced after 2 years because of the gradual exit of the Paks Power Plant units according to the schedule of the lifetime extension project, since water extraction and discharge rates are reduced by 25 m³/s after the quit of each unit and by 2037 the stand alone operation period of Paks II is achieved.

Design operation states of the proposed development (Paks II)	**Determination of the flow impact area and river bottom morphodynamic changes on the Danube compared to the baseline state in the case the proposed development is implemented**	
	Length of the impact area downstream in the main Danube stream [Danube river km], [m]	**Width of the impact area from the Danube right bank along the cross profile [m]**
Paks Power Plant and Paks II joint operation (232 m³/s)	1525+500 - 1527+000 river km (1500 m)	maximum 300 m
Paks II in stand alone service (132 m³/s)	1526+000 - 1527+000 river km (1000 m)	maximum 200 m

Table 36: The determination of the morphodynamic and flow impact areas compared to the current state of affairs

12.2.4 DISCHARGE OF WARMED UP COOLING WATER INTO THE DANUBE

The warmed up technology process water of the proposed new units will be discharged into the Danube on the right bank of the 1526+450 river km Danube profile, on the upstream side of the current inlet point, via a new inlet point approximately 200 metres to the north of the existing hot water canal, crossing the recuperation structure.

The operating schedule of the Paks Power Plant and the proposed new development is summarised in the table below:

Period [years]	Maximum hot water discharge [m³/s]	Number of operating units [pieces]	Design dates [year]	Estimated highest annual water temperature on the Danube [ºC]
2014. (present)	100	Paks Power Plant 4 existing units	2014	25.61 [°C]
2014 – 2025	100	Paks Power Plant 4 existing units		26.10 [°C]
2025 – 2030	166	Paks Power Plant 4 existing units + 1 new unit		
2030 – 2032	232	Paks Power Plant 4 existing units + 2 new units	2032	26.38 [°C]
2032 – 2034	207	Paks Power Plant 3 existing units + 2 new units		
2034 – 2036	182	Paks Power Plant 2 existing units + 2 new units		
2036 – 2037	157	Paks Power Plant 1 existing unit + 2 new units		
2037 – 2085	132	2 new units	2085	28.64 [°C]
2085 – 2090	66	1 new unit		
2090	0	-		

Table 37: The trends in hot water discharge (Q m³/s) in the event the proposed development project is implemented, with the highest expected annual water temperature on the Danube (T_{Danube}, °C) in the design operation dates

When the Danube highest expected background water temperature levels are assumed for the design situations of the heat plume calculations (2014, 2032 and 2085), the outcome of the more pessimistic climate model (DMI-B2 PRODUCE: warming of the Earth between 2000 and 2100 will be 1.8 ºC) was that the duration of the Danube discharge rate below 1500 m³/day is merely about 1 day/year.

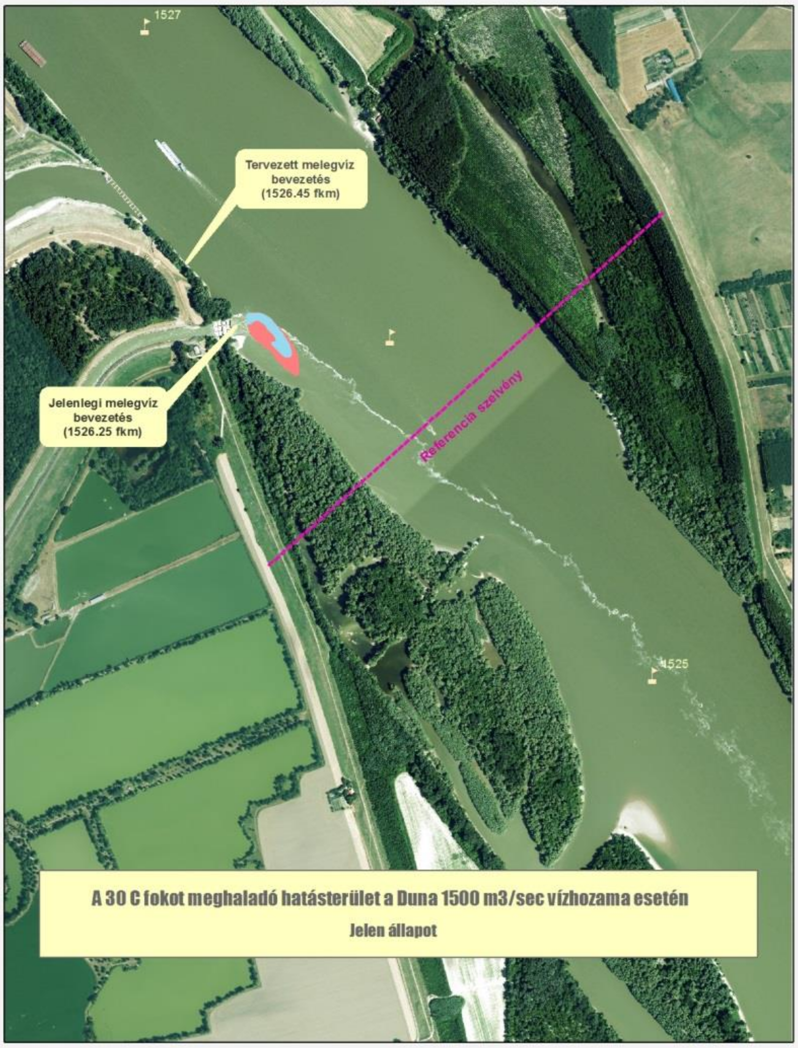
12.2.4.1 The determination of the impact area at 1500 m³/s Danube discharge rate affected by the water temperature of the Danube exceeding 30 °C

The impact areas calculated for the design situations in the years of 2014, 2032 and 2085 calculated for the heat plume with the Danube water space area affected by 30 °C water temperature are presented on the three consecutive figures below.

THE DETERMINATION OF THE IMPACT AREA FOR THE DESIGN STATE IN 2014, AT 1500 M³/S DANUBE DISCHARGE RATE

- the background temperature of the Danube (T_{Danube}) 25.61°C,
- cooling water discharge rate at (q) 100 m³/s, outflow into the Danube at the current site,
- temperature of the warmed up cooling water:
    - (Case 1) $T_{hot\ water}$ =33°C and
    - (Case 2) discharge with a heat gradient of 8°C ($T_{hot\ water} = T_{Danube}$+8°C = 33.61°C).

The area of the water body which is expected to be with a water temperature exceeding 30 ºC of the Danube water temperature distribution with 1 day/year duration calculated for the year of 2014 as decisive is illustrated on the following figure (Figure 64).



Note:
blue: hot water discharge 33 °C, red: heat gradient of 8 °C

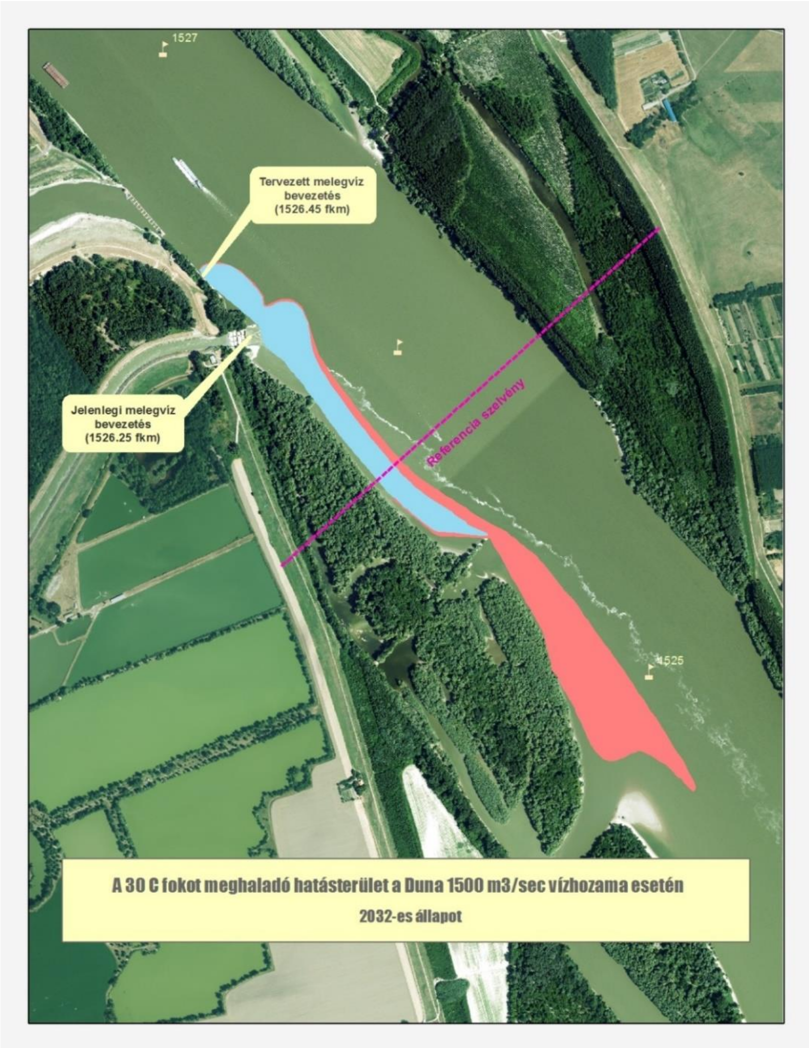
A 30 C fokot meghaladó hatásterület a Duna 1500 m^3/sec vízhozama esetén – jelen állapot – impact area of the heat plume above 30°C in the case of the discharge rate of 1500 m^3/sec of the River Danube – current state
Tervezett melegvíz bevezetés (1526,45 fkm) – designed hot water discharge (1526.45 river km)
Jelenlegi melegvíz bevezetés (1526,25 fkm) – current hot water discharge (1526.25 river km)

Figure 64: The calculated impact area of the heat plume above 30 °C– design state in 2014 ($T_{Danube,max}$=25.61 °C, Q_{Danube}= 1 500 m³/s, hot water discharge rate : 100 m³/s)

THE DETERMINATION OF THE IMPACT AREA FOR THE DESIGN STATE IN 2032, AT 1500 M³/S DANUBE DISCHARGE RATE

- T_{Danube}=26.38°C,
- because of the joint operation of Paks Power Plant and Paks II $q_{current}$=100 m³/s is discharged at the current inlet point and $q_{2032.}$=132 m³/s, flowing into the Danube at the inlet point proposed 200 metres upstream of the current discharge site through the recuperation structure,
- temperature of the warmed up cooling water:
  - (Case 1) $T_{hot\ water}$ =33°C and
  - (Case 2) $T_{hot\ water}$ =34,38°C (8°C heat gradient).

The area of the water body which is expected to be with a water temperature exceeding 30 ºC of the Danube water temperature distribution with 1 day/year duration calculated for the year of 2032 as decisive is illustrated on the following figure.



Note:
blue: hot water discharge 33 °C, red: heat gradient 8 °C

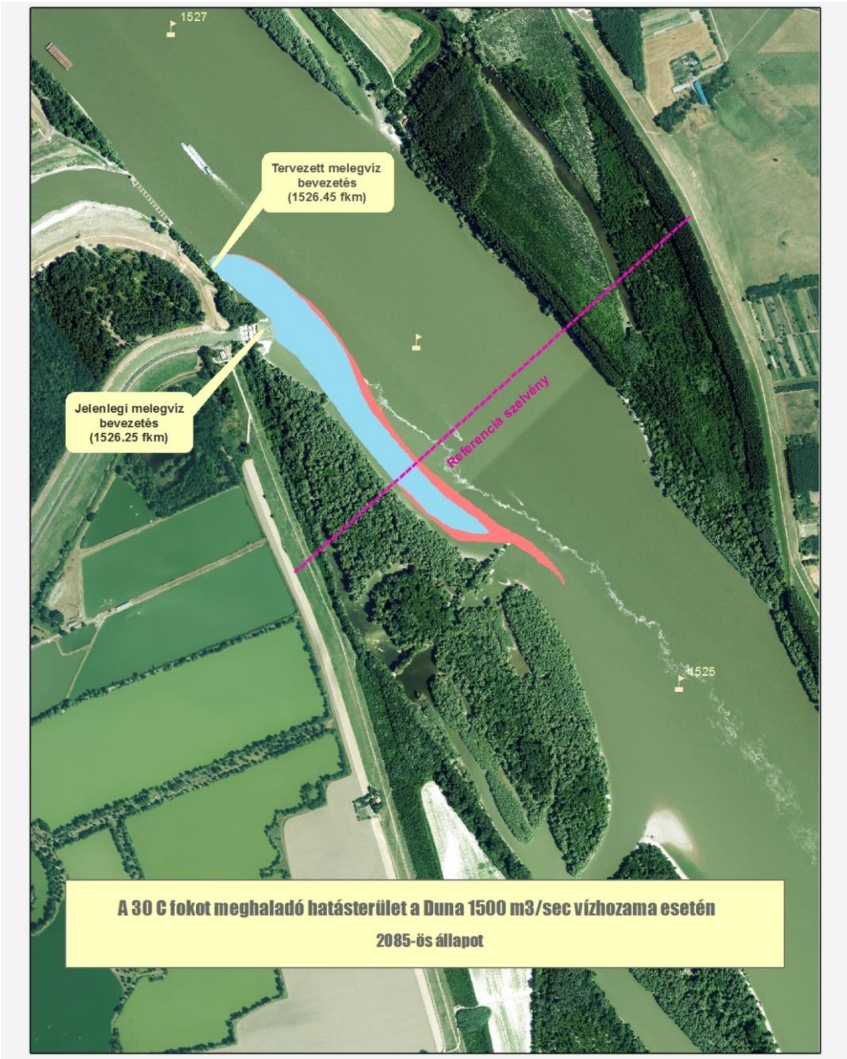
A 30 C fokot meghaladó hatásterület a Duna 1500 m³/sec vízhozama esetén – 2032-es állapot – impact area of the heat plume above 30°C in the case of the discharge rate of 1500 m³/sec of the River Danube – 2032 state
Tervezett melegvíz bevezetés (1526,45 fkm) – designed hot water discharge (1526.45 river km)
Jelenlegi melegvíz bevezetés (1526,25 fkm) – current hot water discharge (1526.25 river km)

Figure 65: The calculated impact area of the heat plume above 30 °C – design state in 2032 (T_{Danube},max=26.38 °C, Q_{Danube}= 1 500 m³/s, hot water discharge rate : 100 ³/s + 132 m³/s) – Paks Power Plant + Paks II in joint operation

THE DETERMINATION OF THE IMPACT AREA FOR THE DESIGN STATE IN 2085, AT 1500 M³/S DANUBE DISCHARGE RATE

- T_{Danube}=28.64°C,
- $q_{2085.}$=132 m³/s, flowing into the Danube at the inlet point proposed upstream of the current discharge site through the recuperation structure,
- temperature of the warmed up cooling water:
  (Case 1) $T_{hot\ water}$ =33°C, and
  (Case 2) $T_{hot\ water}$ =36.64°C (8°C heat gradient).

The area of the water body which is expected to be with a water temperature exceeding 30 ºC of the Danube water temperature distribution with 1 day/year duration calculated for the year of 2085 as decisive is illustrated on the figure below.



Note:
blue: hot water discharge 33 °C, red: heat gradient 8 °C

A 30 C fokot meghaladó hatásterület a Duna 1500 m³/sec vízhozama esetén – 2085-ös állapot – impact area of the heat plume above 30°C in the case of the discharge rate of 1500 m³/sec of the River Danube – 2085 state
Tervezett melegvíz bevezetés (1526,45 fkm) – designed hot water discharge (1526.45 river km)
Jelenlegi melegvíz bevezetés (1526,25 fkm) – current hot water discharge (1526.25 river km)

Figure 66: The calculated impact area of the heat plume above 30 °C – design state of the year 2085 ($T_{Danube,max}$=28.64 °C, Q_{Danube}= 1 500 m³/s, hot water discharge rate : 132 m³/s) – Paks II in stand alone operation

Based on the set of figures above it can be stated that in the current state in the 500 metres Danube reference profile (Danube 1525.75 river km) the water temperature maximum of the Danube water does not reach the 30 °C limit. In the design years of 2032 2085 – at the design Danube discharge rate of 1 500 m³/s – a slight violation of the 30 °C limit is experienced in the reference profile in the case of 33 °C hot water discharge. A higher level of excess temperature can be formed when the discharge is made with 8 °C heat gradient.

12.2.4.1.1 Duration and length of the violation incidents of the 30 °C limit value expected in the +500 m reference profile

JOINT OPERATIONOF THE PAKS NUCLEAR POWER PLANT + PAKS II (2032)

The following summarises the variations of the calculated maximum Danube water temperatures in the design states in the control profile (+500 m) and the duration of the violation of the 30 °C limit value calculated from the pessimistic climate model (DMI-B2 PRODUCE). The duration of the Danube discharge rate below 1500 m³/day is about 1 day/year in the case of the Danube background water temperature (26.38 °C) taken as a basis but for the sake of safety the higher duration levels associated with the 2800 m³/s discharge were taken into account.

The range of limit violation which must be handled by intervention measures	Design state (2014)		Design state (2085.)	
	8 [°C] heat gradient	33 [°C] hot water discharge	8 [°C] heat gradient	33 [°C] hot water discharge
Maximum background Danube water temperature expected [°C]	25.61 [°C]		28.64 [°C]	
Calculated maximum Danube water temperature [°C]	26,11 [°C]	26,36 [°C]	23,81 [°C]	25,23 [°C]
Calculated time of overshoot, duration [nap]	0.2 [nap]	0.1 [day/year]	40 [day/year]	20 [day/year]

Table 38: Length or duration of the violation of the limit value (2032) – Paks Nuclear Power Plant and Paks II in joint operation

Paks II stand alone operation (2085.)

When Paks II is in service, an amount of 132 m³/s cooling water is discharged into the Danube through the recuperation structure. Although the heat load is less than in the 2032 scenario, the required 30 °C limit can only be met downstream of the transverse dam – in the case of a Danube discharge rate below 1500 m³/s with an expected maximum 1 day/year duration – due to the maximum gradual increase of the background temperature over time occurring as a result of the climate change –, since in this case the maximum permissible excess temperature of the plume is merely 30 - 28.64 = 1.36 °C in the 500 m reference profile.

The following summarises the variations of the calculated maximum Danube water temperatures in the design states in the control profile (+500 m) and the duration of the violation of the 30 °C limit value calculated from the pessimistic climate model (DMI-B2 PRODUCE). The duration of the Danube discharge rate below 1500 m³/day is about 1 day/year in the case of the Danube background water temperature (28.64 °C) taken as a basis but for the sake of safety the higher duration levels associated with the 2800 m³/s discharge were taken into account.

The range of limit violation which must be handled by intervention measures	Design state (2014)		Design state (2085.)	
	8 [°C] heat gradient	33 [°C] hot water discharge	8 [°C] heat gradient	33 [°C] hot water discharge
Maximum background Danube water temperature expected [°C]	25.61 [°C]		28.64 [°C]	
Calculated maximum Danube water temperature [°C]	26,11 [°C]	26,36 [°C]	23,81 [°C]	25,23 [°C]
Calculated time of overshoot, duration [nap]	0.2 [nap]	0.1 [day/year]	40 [day/year]	20 [day/year]

Table 39: Length or duration of the violation of the limit value (2085) – Paks II in stand alone operation

Possibilities to avoid limit value violations:

- deloading,
- unit shut down, or
- unit maintenance.

Temperature distribution in the Danube profile at the southern national border (Danube 1433 river km), in case of 1,500 m³/s discharge rate of the Danube

Hot water travels approximately ~93 km from the place of introduction into the Danube (Danube 1526.25 river km), up to the southern national borderline profile (Danube 1433 river km) in the Danube bed during in average 24 hours at Danube medium water discharge rate (2300 m³/s). At lower Danube discharge rates the travel time grows.

It could be seen in the assessment of the joint occurrence of Danube discharge rates and water temperatures with a view to the climatic changes anticipated for the future that the average annual duration of exceeding the design water temperature levels of the Danube taken as a basis is expected to be 1 day/year in the design years.

The largest temperature changes calculated for the southern national border profile of the Danube applicable to the design years of 2014, 2032 and 2085 in the case of 33 °C hot water discharge are summarised in the tables below.

The impact of the 33 °C hot water discharge in the southern national border profile of the Danube

The extent of the largest temperature change in the southern national border profile of the Danube (Danube 1433 river km) $T_{Hot\ water}$ = 33 °C, Q_{Danube}= 1500 m³/s $\Delta T_{Max} = T_{Max} - T_{Hattér}$ [°C]		
design state in 2014	**design state in 2032**	**design state of the year 2085**
T_{Max} = 26.08 [°C]	T_{Max} = 28,13 [°C]	T_{Max} = 28,95 [°C]
$T_{Hattér}$ = 25.61 [°C]	$T_{Hattér}$ = 26.38 [°C]	$T_{Hattér}$ = 28.64 [°C]
ΔT_{Max} = 0.47 [°C]	ΔT_{Max} = 1,75 [°C]	ΔT_{Max} = 0.31 [°C]

Table 40: The extent of the highest temperature change in the southern national border profile of the Danube, $T_{Hot\ water}$ = 33 °C (design state of the years 2014, 2032 and 2085)

The impact of the 8 °C heat gradient hot water discharge in the southern national border profile of the Danube

The extent of the largest temperature change in the southern national border profile of the Danube (Danube 1433 river km) $\Delta T_{heat\ gradient}$ = 8 °C, Q_{Danube}= 1500 m³/s $\Delta T_{Max} = T_{Max} - T_{Hattér}$ [°C]		
design state in 2014	**design state in 2032**	**design state of the year 2085**
T_{Max} = 26,40 [°C]	T_{Max} = 28,24 [°C]	T_{Max} = 29,55 [°C]
$T_{Hattér}$ = 25.61 [°C]	$T_{Hattér}$ = 26.38 [°C]	$T_{Hattér}$ = 28.64 [°C]
ΔT_{Max} = 0.79 [°C]	ΔT_{Max} = 1.86 [°C]	ΔT_{Max} = 0.91 [°C]

Table 41: The extent of the highest temperature change in the southern national border profile of the Danube, $\Delta T_{heat\ gradient}$ = 8 °C (design state of the years 2014, 2032 and 2085)

12.2.5 DISCHARGE OF TREATED MUNICIPAL WASTE WATER DURING THE SERVICE PERIOD

The capacity of the existing waste water treatment plant of the power plant operated on the basis of the water rights operation licence issued by the Inspectorate is 1870 m^3/day, sufficient to receive and treat the maximum municipal wastewater load increments expected in the construction and operation period.

The additional municipal waste water discharge rate in average is 67 m^3/day, peak discharge is at the time of the ten (10) years periodical overhaul is 95 m^3/day.

Since the amount of the municipal wastewater streams generated presently within the area of the Paks Power Plant is in average 300 m^3/day (Paks Power Plant operation), for this reason the municipal waste water discharge rate is not expected to reach 400 m^3/day at the time of simultaneous operation of Paks Power Plant and Paks II, leaving a reserve treatment capacity of ~1 470 m^3/day for free use.

12.2.6 ASSESSMENT OF THE EXTREME NATURAL AND ARTIFICIAL CONDITIONS ON THE FLOOD EXPOSURE OF THE SITE AND SAFETY OF COOLING WATER EXTRACTION

Such cases were modelled as failure events the impact factors of which may develop from natural and artificial conditions of the Danube environment and not as an impact of the proposed development. The following cases were investigated:

- ✓ flood exposure of the site as a consequence of bursting of the Cunovo barrage and extreme partial closure of the Danube channel bottom under critical flow regimes on the Danube, and as a consequence of ice flood accompanied by extreme ice gorges.
- ✓ the trends of cooling water extraction safety in times of extreme low water stated on the Danube, Čunovo barrage system carries out non-operational activities (impoundment by water retention during extreme low water stages on the Danube), furthermore the impact of eventual extreme river wall collapses and river wall slides or packed ice upstream.

12.2.6.1 Assessment of the extreme natural and artificial conditions on the flood exposure of the site

The inundation periods above the safety levels recorded by the Nuclear Power Plant decisive ($T_{overshoot}$) for the Paks Power Plant site relief (Danube 1526.5 river km profile) and the key facilities situated there in the case of exposure to the most unfavourable flood wave – which stays within the flood control works on the Danube section downstream of Bratislava – are presented on the following table.

Key facilities at risk (in the Paks Power Plant site in the environment of the Danube 1526.5 river km profile)	**Design water levels (Danube 1526.5 river km) [metres above Baltic sea level]**	**Duration of overshoot (the least favourable being in the case of the 1965 flood wave) [days]**
Embankment crest level in the surrounding of the power plant, right bank	96,30 metres above Baltic sea level	0.0
Embankment crest level in the surrounding of the power plant, left bank *	95,80* metres above Baltic sea level	16.0
Power plant ground level	97.00 - 97,10 metres above Baltic sea level	0.0
KKÁT unloading hall floor level	92,30 metres above Baltic sea level	68,5
Floor level of the transformer building beside the southern belt canal	93,30 metres above Baltic sea level	59,5
Level of the waste water treatment plant	94.00 metres above Baltic sea level	57.0
Threshold level of the lime mud storage reservoir overspill structure	97.00 metres above Baltic sea level	0.0
Flood control grades** (according to the PA Zrt. embayment watermark post, Danube 1526.5 river km)		
Grade	91,50 metres above Baltic sea level	108.0
Grade	93.00 metres above Baltic sea level	61.0
Grade	94.00 metres above Baltic sea level	56,5
Design flood elevations		
Highest ice free water level (LNV) 2013.06.11.	94.06 metres above Baltic sea level (8790 m³/s)	56.0
DFE $_{2010:}$ Ministerial Decree No 11/2010. (IV. 28.) KvVM on the design level of floods on rivers currently in effect	94,14 metres above Baltic sea level (linear interpolation of the values in the Decree)	55,1

Comments to the table above:
* The source of the elevation dates in the table: Crest levels on the embankments were determined on site with the use of the RTK GPS measuring station.
** Ordering flood control preparedness levels: Flood control preparedness is ordered by the regionally competent environmental protection and water management directorate (KÖVIZIG) concerned by the dangerous situation of the hydrological conditions (flood wave) and defence operations are also organised by managed by them. In the event two or more environmental protection and water management directorates are affected by Grade III flood control preparedness on the same watercourse, the management of defence operations will be escalated to the National Technical Direction Headquarters (OMIT).

Table 42: Expected duration of surpassing some selected flood control protection levels defined for the case when the surroundings of the power plant is inundated by the least favourable (96.30 metres above Baltic sea level) flood levels.

The impact of the additive downstream wave in the case of a failure of the barrage system at Čunovo in the least favourable and most adverse conditions, that is when the entire efficient volume in the storage reservoir including the additional volume of the by-pass canal is added, did not reduce the flood control safety of the site. The additive flood wave exceeds the water level of the Grade I flood control preparedness (91.50 mBf) for a short period of time, but it does not affect any object on the site and requires no special action to be taken.

The Danube 1500-1530 river km section was assessed by two dimensional (2D) model for extreme flood conditions (recurrent in every 20 000 years). Partial closure of the main channel as an impact of a landslide downstream of the hot water canal was discussed as a failure event in the design situation of 2032 with respect to Danube water extraction and return.

The hydrodynamic modelling of the impact of operating troubles, accidents and failure events requires the assessment of a longer Danube section, therefore the 1D hydrodynamic model was used for this purpose.

IMPACT OF THE FAILURE OF WATER GOVERNING STRUCTURES ON THE UPSTREAM SIDE

The peak discharge rate of the 1965 flood wave transformed to a peak discharge rate of 14 000 m³/s staying within the flood control embankments was assessed as the worst case scenario. No more than the 96.30 metres above Baltic sea level equalling the crest of the flood control embankment on the right bank of the Danube can be formed in the environment of the Paks Nuclear Power Plant site even as a result of the extreme high water exposure assessed.

ASSESSMENT OF THE IMPACTS ORIGINATING FROM STEEP BANK SLIDES CAUSING ROVER MORHOLOGY CHANGES IN THE DANUBE

Landslide incidents were investigated by model simulation at two locations, one upstream of Paks Power Plant and another at Dunaszekcső. Landslides causing major channel closure were assumed in both cases in a length of approximately 1 000 metres, and the flood wave of 1926 transformed to the 12 200 m³/s level deemed to be the design level (recurrent in every 20 000 years) was used. It could be concluded in both cases that the impacts of the assumed landslides were not significant, maximum water levels dropped by 5 cm in the case of the landslide upstream Paks, and cumulating water heights were increased by 13 cm in the case of the Dunaszekcső landslide.

FORECAST OF THE FORMATION OF ICE GORGES AND ASSESSMENT OF ITS IMPACT IN HIGH WATER USING THE FLOW MODEL

The purpose of this assessment was to determine the exposure of the Paks Power Plant area in case of ice high water as a consequence of packed ice downstream of the power plant in the case generated by the situation deemed to be the least favourable when the level of water is increased to a high extent by the ice flood, packed ice or the formation of a continuous ice cover (which usually occurs in the low and medium water discharge rate periods of the winter season).

Disregarding the current climate change tendencies the design ice situation of 1965 was taken as the baseline (including packed ice) for the purposes of the studies and in addition to the design ice flood elevations the formation of an approximately 5 kilometres long continuous ice cover was generated in line with the former experiences in spite of the fact that the formation of a continuous ice cover is not very probable due to the channel conditions of this Danube section.

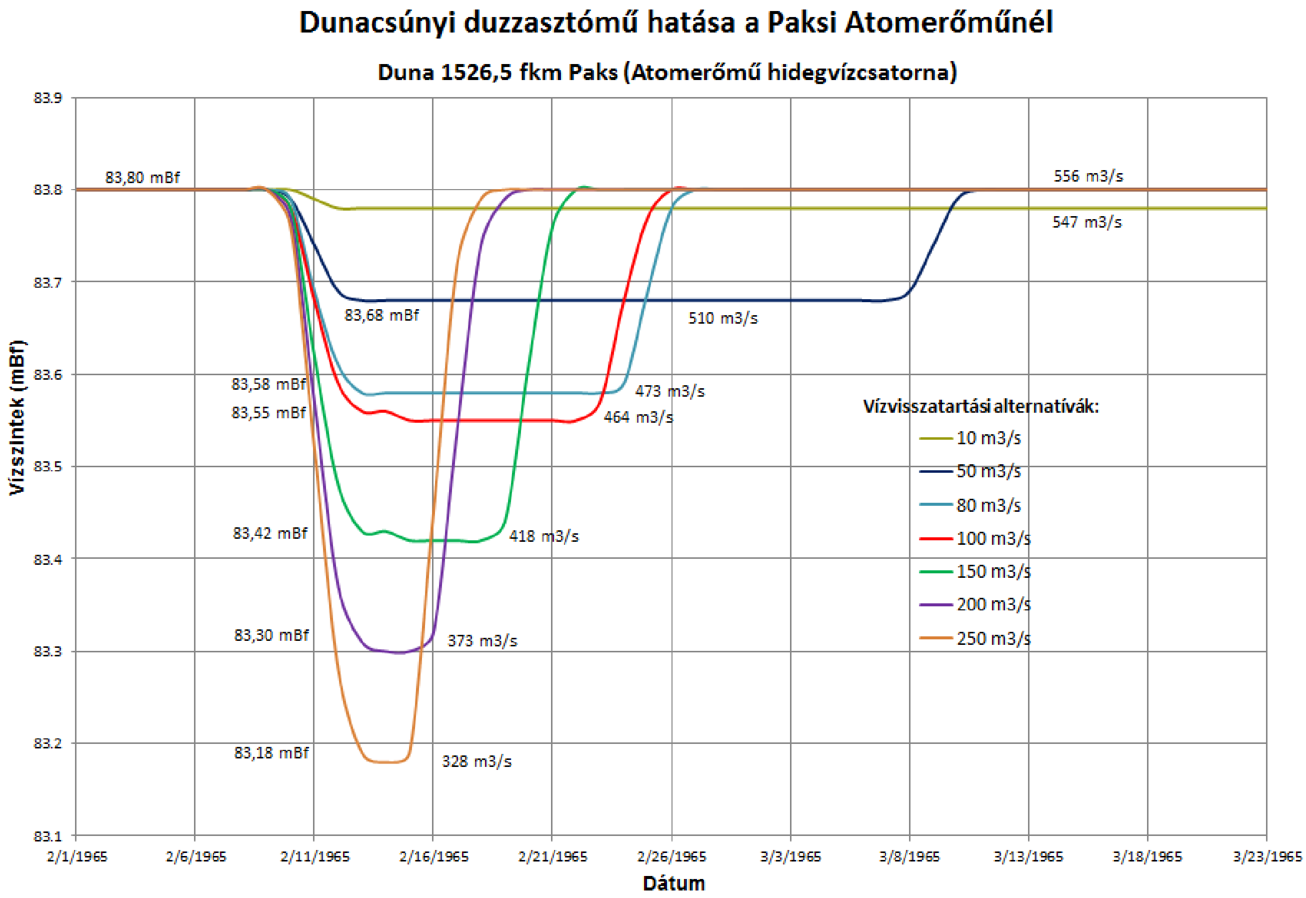
It can be concluded from the hydraulic simulation that the ice flood water levels deemed to be least favourable in the environment of the Paks Power Plant levelled with the crest of the flood control embankments (95.90 metres above Baltic sea level). It can be stated from earlier ice hydraulic tests that the duration and length of an adversely large continuous ice cover is not more than 2-3 days, following which the ice pack or ice gorge causing the trouble will collapse. No ice flood should be reckoned with in the environment of the Paks Power Plant.

The last incident of ice flood was in 1956. Any ice flood should be reckoned with in the environment of the Paks Power Plant only with a very low probability level due to the climate change and the operation of the barrage systems upstream, and taking into account the deployment of the ice breaker fleet. The ice-breaker fleet is currently maintained by the water management bodies (National Directorate of Water Management: OVF and the Water Management Directorates: VIZIG). The ice-breaker fleet on the Danube consists of 9 ships.

12.2.6.2 The impact of extreme natural and artificial circumstances on the safety of cooling war extraction at times of extreme low Danube water stages

IMPACTS OF THE DAMAGE AND ABNORMAL OPERATION OF THE UPSTREAM WATER LEVEL CONTROLLING STRUCTURE

Subsidence waves are formed and propagating downstream on the Danube in the event when the Čunovo barrage system carries out water retention in a non-operational manner at extreme low Danube water discharge rates. Subsidence waves calculated by the one dimensional (1D) flow model are illustrated on the following figure.



Dunacsúnyi duzzasztómű hatása a Paksi Atomerőműnél – impact of water retention by the Čunovo / Bősi barrage system at Paks Nuclear Power Plant
Duna 1526,5 fkm Paks (Atomerőmű hidegvíz csatorna) – River Danube 1526.5 river km Paks (Nuclear Power Plant cold water channel)
vízszintek (mBf) – water levels
vízvisszatartási alternatívák – water retention alternatives

Figure 67: The impact of water retention by the Čunovo / Bősi barrage system in low water stage situations characterised by a recurrent period in every 20 000 years on the security of the water extraction operations of the Paks Power Plant (Danube, 1526.5 river km)

Operational and reserve water extraction levels in the embayment of the existing water extraction plant are as follows:

- Critical water extraction level of the operational cooling water (condenser cooling water) pumps: 83.60 metres above Baltic sea level measured on the embayment watermark post, 83.60 metres above Baltic sea level in the Danube 1526.5 river km profile and 83.71 metres above Baltic sea level (at the Paks watermark post in the Danube 1531.3 river km: 83.98 metres above Baltic sea level), respectively.
- Water levels critical to operational water extraction can be observed only when the Gabčíkovo barrage system retains water in excess of approximately ~50 m³/s during permanent extreme low Danube water discharge rates of 556 m³/s recurrent in every 20 000 years,
- The critical water extraction level of the operational cooling water pumps: 83.50 metres above Baltic sea level measured on the embayment watermark post, 83.50 metres above Baltic sea level in the Danube 1526.5 river km profile and 83.61 metres above Baltic sea level (at the Paks watermark post in the Danube 1531.3 river km: 83.88 metres above Baltic sea level), respectively.
- Water levels critical to safety (emergency) water extraction can be observed only when the Gabčíkovo barrage system retains water in excess of approximately ~70 m³/s during permanent extreme low Danube water discharge rates of 556 m³/s recurrent in every 20 000 years,

IMPACTS OF THE SITUATION ENCOUNTERED IN CONSEQUENCE OF ICE GORGES AND PACKED ICE

The purpose of this assessment was to determine the exposure of the Power Plant area in case of ice high water as a consequence of formation of a continuous ice cover upstream of the power plant water extraction plant in order to characterise the safety of cooling water supply.

An ice gorge is the most extreme variation of packed ice which closes the entire cross sectional profile of the watercourse. In such cases (at least in principle) flow-through would be eliminated for a period of time and the passing rate of flow drops to zero. This state will be maintained until the level of the water impounded behind the ice gorge reaches the crest of the ice gorge and water overspills the packed ice. After this point the water discharge rate along the downstream section is gradually increased until reaches the initial discharge rate.

The current model calculations were carried out for two different heights of the ice gorge. The first one was ice packed up to a 15.34 m high (crest level at 93.0 metres above Baltic sea level) gorge, closing the main channel entirely from the deepest point up to the edge of the main channel shoreline. In the second case a lesser and more reasonable gorge size was selected which was however still 10.34 m high (88.0 metres above Baltic sea level crest level).

Both calculations were conducted for the extreme low discharge rates associated with the water height at 84.24 metres above Baltic sea level recurrent in every 20 000 years once: 544 m^3/s (Danube 1580.6 river km, Dunaújváros watermark post). After the extreme low Danube water stage in 1983 VITUKI carried out calculations for critical low water stages in 1985 (VITUKI, 1985) upstream of the cold water canal Danube mouth, assuming packed ice on the Danube.

In order to be on the safer side, the assessment did not take into account the increasing effect of the discharges flowing from the underground waters towards the Danube. Also for the sake of safety, the possibility of reducing the impacts of the packed ice following its onset by the appropriate measures (ice breakers, explosions), was also disregarded.

If you look at the duration of each water level, serious changes can be observed in the impacts of the depression waves launched by the two ice gorges with the respective different crest levels. In the event of an ice gorge with a crest level of 93.0 metres above Baltic sea level a duration of $\Delta t = 60$ hours had to be calculated with. In the event of an ice gorge with a crest level of only 88.0 metres above Baltic sea level the duration of the water levels below the permanent low water level was dropped to a period of $\Delta t = 40$ hours.

Only the ice gorge formed directly upstream of the cold water canal may cause serious problems in the cooling water supply of the power plant, in particular at extreme low water Danube hydrological conditions. However, such an event can be prepared for with certainty. As much as 10 or 15 very cold days must pass just as well between the breaking-up and floating of ice and the formation of continuous ice cover (with a daily average temperature of less than -10 C°). If all these situations occur at an extreme low water discharge rate recurrent in every 20,000 years (544 m^3/s), it must have been preceded by a several months long period without precipitation.

An ice breaker fleet provides assistance to the fight against the ice along the Hungarian Danube-section. Provided the aforementioned unexpected events occur, the formation of the continuous ice cover and the gorge could be prevented by the work of the ice breakers.

It should be noted that after the completion of the Čunovo barrage system and the Gabčíkovo power plant ice formation starts afresh from 'zero" on the upper Hungarian stretch of the Danube. Any ice formed upstream on the Austrian or Slovak sections would be trapped by the Hrušovo reservoir, therefore a clean and ice free water flows all the time downstream of the hydropower plant/barrage system. Ice forming thus starts again downstream of the power plant, and only after the end of a very cold period can as much and as strong ice be produced which leads to the formation of packed ice or the formation of a continuous ice cover or a gorge. No experience currently exists as to how cold this period must be.

In the event the cooling water supply is lost on a temporary basis when the water heights of 83.60 metres above Baltic sea level and 83.50 metres above Baltic sea level water level can not be provided any more to the service pumps and reserve pumps, respectively, and water levels on the Danube vary around the bottom level of the cold water canal, in other words 81.0 – 81.5 metres above Baltic sea level, the water base available for the purposes of safety cooling may be envisaged as the bank filtrated wells to be installed on the Danube and the water body of the Danube itself. The water production capacity of the bank filtrated wells does not reduce substantially in the extreme situation where the extraordinary low water stages on the Danube prevail for a period of 3-4 days, since groundwater replenishment is reinforced in these cases from the background. Depletion and replenishment of the underground water reserves is a significantly slower process influenced by other factors beside the Danube.

EVALUATION OF THE IMPACT OF RIVER WALL COLLAPSES AND RIVER WALL SLIDES

The model simulation assessed the consequences of a landslide at one location – in spite of the fact that the occurrence of such an event can be practically excluded –, which is assumed to happen upstream of the Paks Power Plant water extraction site. A large scale landslide causing the closure of the Danube river bed was assumed in a length of approximately 1 000 metres, and a state of the Danube was simulated which is considered to be the design state (a low water discharge rate recurrent in every 20 000 years at the Dombori watermark post, Danube 1506.8 river km) corresponding to an extreme low discharge rate of 579 m^3/s. It can be stated that the impacts of the assumed landslide were insignificant and some 1 cm water level subsidence is experienced downstream of the landslide and the water level increased by some 30 cm upstream of it, which however completely levels out into the original water surface some fifteen kilometres upstream

Therefore, the impact of the extreme level Danube river wall collapses, slides of steep banks on the security of cooling water extraction is negligible and transient in nature because they are gradually eroded and removed by the flow of the Danube.

12.3 EXPECTED IMPACTS OF THE ABANDONMENT OF PAKS II ON THE DANUBE

The impacts expected upon the abandonment of Paks II fall short of the impacts at the time of establishment and operation. Any more detailed analysis will be possible on the basis of the dismantling plan of the site (proposed interventions including their time schedule).

13 WATER QUALITY ASSESSMENT OF THE DANUBE AND OTHER SURFACE WATERS PURSUANT TO THE WATER FRAMEWORK DIRECTIVE

As part of the environmental impact study for the implementation and operation of Paks II, tests with a view to the Water Framework Directive (WFD) were carried out in the years 2012 and 2013 in the profiles of the Danube between river kilometres 1560.6 and 1481.5, as well as in several water bodies having direct or indirect communication with the Danube.

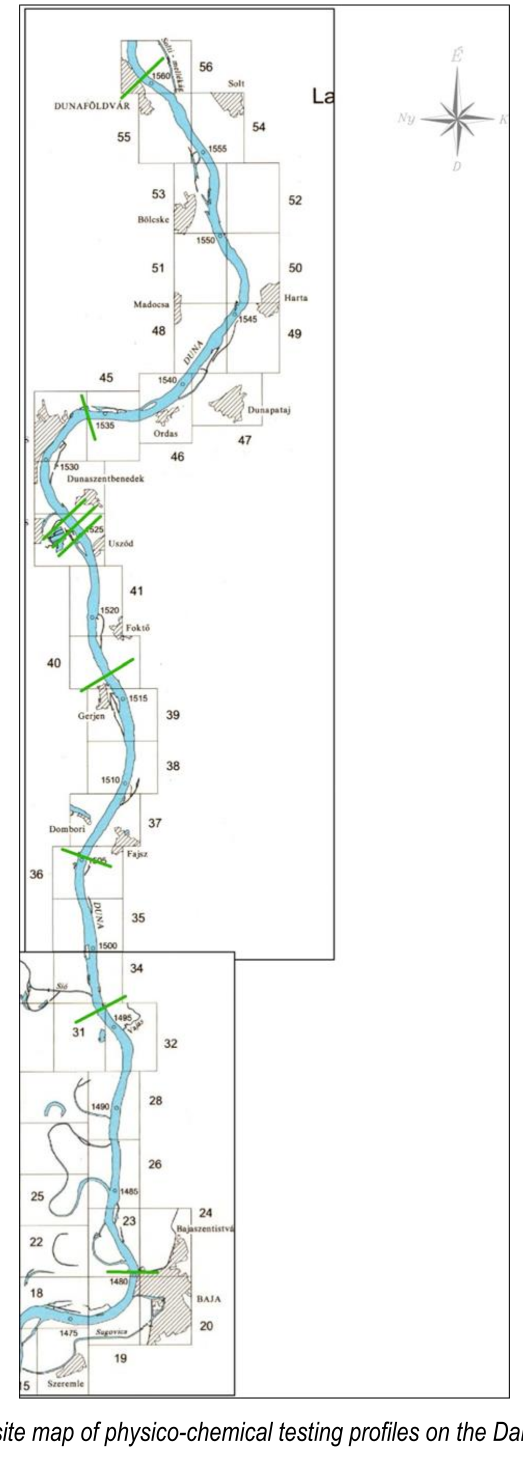


Figure 68: General site map of physico-chemical testing profiles on the Danube 2012. and 2013

The purpose of the study is to assess the environmental impacts associated with the establishment, operation and dismantling of the Paks II project, and the specification thereof pursuant to the aspects applied by the Water Framework Directive.

According to this fundamental requirement the study plan was set up so that all the following considerations were taken into account and harmonised:

(1) the contents of Government Decree No 314/2005. (XII.25.) on the Environmental Impact Assessment and the integrated licensing procedure for the utilisation of the environment,

(2) the set of criteria laid down in the Water Framework Directive No 2000/60/EC, the domestically developed National River Basin Management Plan and of the standards and recommendations for monitoring included therein,

(3) the rules pertaining to the Ministerial Decree No 31/2004 (XII. 30.) KvVM of the Ministry of Environment laying down certain rules for monitoring and status assessment of surface waters, furthermore

(4) the findings of the research conducted within the area earlier on,

(5) the official opinion of the authority (DdKTVF) with the reference number 8588-32/2012 in the course of the EKD and last but not least

(6) theoretical and practical considerations of the monitoring process of the biological elements assessed.

13.1 BASELINE SURVEYS

Under the assessment of the Danube the following chemical and physical elements were analysed in 2012 and 2013.

Elements	**Unit of measurement**	**Water quality groups under the WFD**
pH		Acidification status
Conductivity	µS/cm	Salinity
Dissolved oxygen	mg/l	Oxygenation conditions
Oxygen saturation	%	Oxygenation conditions
BOD5	mg/l	Oxygenation conditions
CODk	mg/l	Oxygenation conditions
Ammonium-N (NH4+-N)	mg/l	Nutrient conditions
Nitrite-N (NO2--N)	mg/l	Nutrient conditions
Nitrate-N (NO3--N)	mg/l	Nutrient conditions
Total nitrogen	mg/l	Nutrient conditions
Orto-phosphate (PO4-P)	µg/l	Nutrient conditions
Total phosphorus	µg/l	Nutrient conditions
Cd	µg/l	Metals
Hg	µg/l	Metals
Ni	µg/l	Metals
Pb	µg/l	Metals
As	µg/l	Specific pollutants (hazardous chemical elements)
Zn	µg/l	Specific pollutants (hazardous chemical elements)
Cr	µg/l	Specific pollutants (hazardous chemical elements)
Cu	µg/l	Specific pollutants (hazardous chemical elements)
TPH	µg/l	
Water temperature	0C	
Total suspended matter	mg/l	
Total alkalinity	mmol/l	
Nitrate (NO3-)	mg/l	
Nitrite (NO2-)	mg/l	
Orto-phosphate	µg/l	
Ammonium (NH4+)	mg/l	
Total cyanide	mg/l	

Table 43: Listing of the physical and chemical elements applicable to the Danube, including the WFD water quality groups

For the elements it was specified to which WFD quality group the element tested belonged. In the former studies qualification was not only done pursuant to the WFD, this is why elements are included in the studies which have not been classified in any quality group by the Decree.

All biological elements included in the Water Framework Directive (Commission Directive 2000/60/EC), and in Ministerial Decree No 31/2004 (XII. 30.) KvVM of the Ministry of Environment laying down certain rules for monitoring and status assessment of surface waters and all the groups of biological organisms such as - phytoplankton (FP); phytobenthos (FB); macrophyte (MF); macroscopic aquatic invertebrates (MZB); and fishes have been tested.

As for the physical and chemical parameters, Danube profiles where the studies made in 2012 and 2013 under the programme (PR) and where the results from the water quality backbone network (VmTH) were processed are described in the table below.

No	Name of section	Danube river km	Profile number	Year	PR_study No.	Note
1	Dunaföldvár (road bridge)*	1560.6	0	2013	2	*Distant Danube upstream profile.* **PR+VmTH studies.**
2	Paks (ferry)	1534,0	1	2012	12	*Near Danube upstream profile.* **PR tests.**
3	Paks hot water canal	1526,0	2	2012	12	*Direct impacts downstream profile.* **PR tests.**
4	Nagysarkantyú	1525.3	3	2012	12	*Direct impacts downstream profile.* **PR tests.**
5	Uszód	1524.7	4	2012	12	*Direct impacts downstream profile.* **PR tests.**
6	Gerjen-Foktő	1516,0	5	2012	12	*Direct impacts downstream profile.* **PR tests.**
7	Fadd-Dombori*	1506.8	6	2013	6	*Distant downstream profile.* **PR+VmTH tests**
8	Sió-South (Gemenc)	1496,0	7	2013	6	*Distant downstream profile.* **PR tests**
9	Baja (road bridge)	1481.5	8	2013	2	*Distant downstream profile.* **PR tests**

Table 44: Test profiles on the Danube and other characteristics

With respect to biological elements the demarcation of the study area was carried out in nine profiles, dividing the stretch of the Danube between river kilometres 1560.6 and 1481.5 to an upstream (Dunaföldvár, Paks ferry), a near downstream (hot water discharge, Nagysarkantyú, Uszód), a medium-distant (Gerjen, Dombori), and a distance downstream (Sió-South, Gemenc) section.

The number of sampling sites in each of the profiles was three (left bank, midstream, right bank) for phytoplankton and two (left bank, right bank) for the rest of the groups of living organisms. The Danube section investigated belongs to the water body called "Danube between Szob and Baja" marked HURWAEP444. Beside this Danube section is part of the NATURA 2000 SCI area identified as HUDD20023 Tolnai Danube. Beside the Danube the Dead Danube of Fadd (HULWAIH066 water body) was tested in two profiles, Kondor Lake and the Paks Fishing Ponds (HULWAIH005 water body) in one profile each, Tolnai-Dead-Danube (HULWAIH136) in two profiles and Sió canal (HURWAEP959) in one profile.

The date of sampling was 2012, and additionally as an extension of the scope samples were taken from the medium-distant downstream and distant downstream section of the Danube, furthermore on the Dead Danube of Tolna North and the Sió-canal. Sampling was in compliance with the WFD requirements and quantitative for all groups of organisms. Classification of the water bodies was also made in accordance with the set of criteria laid down in the WFD. For those type of water bodies where no approved classification method exists, individual classification was carried out with a view to the WFD. Such methods included the classification of lakes in terms of macrozoobenthos on the basis of the family score system generally recognised in the international references, and the classification of lakes in the case of fishes based on the method included in the river basin management plan (Halasi-Kovács et al 2009).

13.1.1 EVALUATION OF THE NATIONAL ARCHIVE DATA OF THE DANUBE SECTION ASSESSED

13.1.1.1 Physico-chemical variables

The assessed Danube Section is situated up to 34 kilometres from the Paks Nuclear Power Plant – relative to the Danube – to the north – which is the upstream section, and up to a distance of 45 km to the south – which is the downstream section. Two core network profiles fall within this stretch, Dunaföldvár and Fajsz stations. The classification of this Danube section according to the requirements of the WFD was characterised and completed by processing the archive water chemistry data sets for the period between 2007 and 2011 (Fajsz-2012).

Processing of the test results using the linear trend assessment method provides the basis for studying the chronological changes of the chemical elements in the water expected due to the increase in Danube water temperature.

The following groups of components are assessed as part of the study on changes caused by increased water temperature.

Acidification status: pH

Salinity: Conductivity

Oxygenation conditions -- Dissolved oxygen, Oxygen saturation BOD_5, COD_k, Ammonium-N (NH_4+-N), Nitrite-N (NO_2^--N)

Nutrient conditions Nitrate-N (NO_3^--N), Total nitrogen, Total phosphorus, Orto-phosphate (PO_4^{3-}-P),

Metals: Cd, Hg, Ni, Pb

Specific pollutants (hazardous chemical elements): Zn, Cu, Cr, As

THE CLASSIFICATION OF THE DANUBE SECTION ASSESSED (DUNAFÖLDVÁR-FAJSZ) ACCORDING TO THE REQUIREMENTS OF THE WFD BASED ON ARCHIVE DATA SETS

Classification of the assessed Danube section (1560.6-1507.6 river km) was made based on the average values of tests between 2007 and 2011, in the case of Fajsz up to 2012, on the basis of the limit values specified in Table 12.1.3 1. Data classified in accordance with the WFD, containing the number of studies and average results were summarised in Table 12.2.1 1.

For the purposes of evaluating archive data the classification concerning physico-chemical components, completed in 2007, for the body of water marked HURWAEP444 the Danube between Szob and Baja (Type 24) from the national status assessment table of water bodies according to the WFD limit value system included in Annexes of VGT-k 5_1 (Table 12.2.1 2). In this table, the classification for the body of water marked HURWAEP445 Danube between Baja and Hercegszántó was also included for information.

- The **acidification status** can be classified as **good** on the basis of the average values of the assessment results throughout the period under consideration.
- The **salinity status** can be classified as **high** on the basis of the average values of the assessment results throughout the period under consideration.
- The average of **oxygenation conditions** status per class is 4.5. It is deemed to be of **good status** based on the WFD requirements.
- The average of **nutrients** status per class is 4.2. Based on the methodology specified by the WFD it is deemed to be in good ecological status.

– The average of **metals** status per class is 4.5. Based on the methodology specified by the WFD it is deemed to be in good ecological status.

The ecological status of the Danube between Dunaföldvár and Fajsz was classified as good, in terms of specific pollutants (hazardous chemical elements) good and acceptable on the basis of the water quality tests carried out in the period of 2007-2011 (2012). The ranking of the Danube Baja-Hercegszántó body of water in terms of physico-chemical element groups equals with that of the Dunaföldvár-Fajsz section.

This classification result **(with the exception of acidification - good)** concurs with the findings of the 2010 assessment of water bodies carried out in accordance with the limit values of the WFD and attached in the annex 5_1 of the VGT which is enclosed here in Table 46.

	Code of sampling site		101180039		101178210		101178933		101179653		101178232		Water quality
	Monitoring place		**Dunaföldvár**						**Fajsz**		**Hercegszántó**		**groups according to the WFD**
			left bank		**mainstream line**		**right bank**						
	Number of Danube river km profile		**1560.6 river km**		**1560.6 river km**		**1560.6 river km**		**1507.6 river km**		**1433.0 river km**		
KAJ	**Water quality parameters**		db	average	db	average	db	average	db	average	db	average	
156075	pH (laboratory measurement)		97	**8.2**	97	**8.2**	97	**8.2**	87	**8.3**	140	**8.3**	**Acidification**
155201	Chloride (Cl^-)	mg/l	86	**23.7**	86	**24.1**	86	**24.4**	49	**22.7**	121	**22.9**	**Salinity**
159469	Conductivity	µS/cm	97	**405**	97	**414**	97	**424**	87	**403**	140	**405**	**Salinity**
158420	Oxygen (dissolved) (O_2)	mg/l	97	**10.0**	97	**10.0**	97	**9.8**	75	**10.1**	140	**10.0**	**Oxygenation conditions**
159487	Dissolved oxygen (percent of oxygen saturation)	%	97	**91.9**	97	**91.9**	97	**90.5**	75	**95.0**	140	**93.8**	**Oxygenation conditions**
158970	Biochemical oxygen demand (BOD_5)	mg/l	97	**2.7**	97	**2.7**	97	**2.7**	75	**2.7**	140	**2.7**	**Oxygenation conditions**
159001	Oxygen consumption(COD_d) original	mg/l	97	**12.0**	97	**11.9**	97	**11.9**	75	**11.3**	140	**11.4**	**Oxygenation conditions**
156754	Ammonia-ammonium-nitrogen (NH_{3-},NH_4^+-N)	mg/l	97	**0.074**	97	**0.064**	97	**0.064**	75	**0.072**	140	**0.063**	**Nutrient conditions**
160551	Nitrite-nitrogen (NO_2-N)	mg/l	97	**0.026**	97	**0.020**	97	**0.019**	75	**0.017**	140	**0.016**	**Nutrient conditions**
160560	Nitrate-nitrogen (NO_3-N)	mg/l	97	**2.0**	97	**2.0**	97	**2.0**	75	**1.8**	140	**1.9**	**Nutrient conditions**
159405	Total nitrogen (N)	mg/l	97	**2.6**	96	**2.7**	97	**2.7**	87	**2.4**	139	**2.5**	**Nutrient conditions**
	Orto-phosphate-P (PO_4-P)	µg/l	97	**57.1**	97	**58.0**	97	**53.5**	75	**61.6**	140	**47.4**	**Nutrient conditions**
158154	Total phosphorus (P)	mg/l	97	**0.11**	97	**0.11**	97	**0.11**	87	**0.11**	140	**0.12**	**Nutrient conditions**
157601	Cadmium (dissolved) (Cd)	µg/l	57	**0.090**	56	**0.060**	57	**0.062**	22	**<0.05**	92	**0.125**	**Metals**
157472	Mercury (dissolved) (Hg)	µg/l	57	**0.075**	56	**<0.05**	57	**0.050**	23	**0.063**	92	**0.1**	**Metals**
157885	Nickel (dissolved) (Ni)	µg/l	57	**0.7**	56	**0.8**	57	**0.7**	22	**0.9**	92	**0.8**	**Metals**
158099	Lead (dissolved) (Pb)	µg/l	57	**1.9**	56	**<0.5**	57	**<0.5**	24	**<0.5**	92	**4.3**	**Metals**
157665	Chlorophyll-a	µg/l	96	**28.0**	96	**27.9**	96	**28.3**	74	**28.4**	140	**26.4**	
120498	Arsenic (As)	µg/l	6	**1.8**	6	**1.6**	6	**1.6**	0		6	**1.6**	**Specific pollutants (hazardous chemical elements)**
157050	Zinc (dissolved) (Zn)	µg/l	57	**4.9**	56	**5.5**	57	**4.7**	25	**4.4**	92	**6.2**	**Specific pollutants (hazardous chemical elements)**
120434	Chromium total (Cr)	µg/l	6	**0.6**	6	**0.7**	6	**0.5**	0		6	**0.7**	**Specific pollutants (hazardous chemical elements)**
156204	Copper (dissolved) (Cu)	µg/l	57	**3.7**	56	**1.8**	57	**1.7**	25	**1.3**	92	**2.1**	**Specific pollutants (hazardous chemical elements)**

Table 45: Average values from the Core Network studies completed between 2007 and 2011 in a classification structure according to the WFD

VGT Annex No - 5-1.1: Status of surface water bodies - Ecological status of watercourse water bodies

Subunit	KÖVIZIG	Water body category	vt-VOR	Water body name	**Physico-chemical elements**					
					Organic matter	**Nutrients**	**Salt content**	**Acidity**	**Status of the physico-chemical elements**	**Reliability of physico-chemica classification**
1-10	**3**	**natural**	**AEP444**	**Danube Szob-Baja**	**good**	**good**	**high**	**high**	**good**	**medium**

Table 46: Ecological status assessment of the HURWAEP444 Danube Szob-Baja section (Type 24) body of water according to the limit value system of the WFD

13.1.1.2 Biological elements

Besides the evaluation of the findings of the examinations, we compiled and evaluated the archive data concerning the Dunaföldvár-Baja study section of the Danube. The following statements can be done based on these.

- The Danube-section concerned – with special emphasis on the environs of the Paks Nuclear Power Plant – was subjected to regular hydro biological testing in the past 15 years. As a result, historical phytoplankton, phytobenthos, macrozoobenthos, and fish community data are available. Former macrophyte assessments provide information only to the terrestrial vegetation of the Paks Nuclear Power Plant area.
- Full sets of coherent historical data allowing ecological status determination pursuant to the Water Framework Directive are available as a result of the studies carried out in 2009 and 2010 (Kék Csermely Kft. [12-22]), while data lending themselves to evaluation according to the WFD are available sporadically for individual groups of living organisms.
- Status evaluation of the assessment results from 2009 and 2010 in accordance with the WFD aspects indicated that FP was in a good status; FB in moderate, MZB in moderate, and the fish community in good status in the Paks Danube-section. Following the classification principle of "one bad means all bad" on this basis the ecological status of the Danube is moderate. According to the classification efforts made in accordance with the WFD aspects there is not detectable difference between the upstream and downstream section relative to the nuclear plant discharge which would cause a leap in grades.
- Historical data suggest that the Danube-section marked HURWAEP444 between Dunaföldvár and Baja was of moderate ecological status. Within this, phytoplankton and fishes typically reflect good, while phytobenthos and macrozoobenthos typical reflect moderate statuses.
- Based on the partial river basin management plan of the Danube the entire domestic stretch of the Danube has a moderate ecological status. This can be attributed partly to quality related but also at the same weight hydromorphological reasons. Good ecological status of the water body of the Danube marked HURWAEP 444 between Szob and Baja can be achieved by 2027 according to the plans (VKKI [12-45]).
- Historical data are also available for the impact of cooling water discharges from Paks Nuclear Power Plant on the Danube. Physiological testing of algae indicate that the algal intensity of photosynthesis in the hot water canal was lower than in the cold water canal, demonstrating that algal biomass of the cooling water is damaged to a certain extent while passing the cooling system. At the same time samples from the Danube did not confirm the impact of the discharge in the case of phytoplankton or phytobenthos. Based on the findings from the fine resolution ecological assessments of macrozoobenthos and fish communities the impact of the cooling water load discharged into the Danube was detectable along an approximately 2 km long longitudinal profile (Halasi-Kovács [12-14], Kék Csermely Kft. [12-22]). This resulted in mainly qualitative and mainly quantitative changes in the case of the MZB and the fish community.
- Fishing and angling catches were investigated in the Paks section of the Danube from 2000 on. They all reflect a gradual decline of both fishing and angling yields. The decline stopped in 2011 and 2012, and a slight increase could be observed in these years. All in all, no correlation can be demonstrated between the operation of the Paks Nuclear Power Plant and the quantitative changes in the utilisation rates of fishes in the Danube partly because of the uncertainty of the catch data which concern a very small area only and partly because the catching structure typical for the Danube, which is different from other large rivers to a great extent (Halasi-Kovács and Váradi [12-19]).
- Conclusions which could be drawn from the historical data were taken into account, but for the purposes of analysis only the results of the 2012 and 2013 studies were used in the course of the Paks II environmental impact study, partly because the historical data are scarce and sporadic, have a lower confidence level and partly because the studies carried out in the years 2012 and 2013 provided data sets of appropriate quality and quantity which were in addition entirely coherent, in contrast to the earlier investigations. We used the results of the sampling of 2009-2010 as control values for the purpose of the assessment.

13.1.2 BASE STATE OF THE DANUBE SECTION ASSESSED (1560.6 RIVER KM-1481.5 RIVER KM)

The assessed Danube section was characterised on the basis of historical data 2006-2011, and those obtained as part of the current project in 2012 and 2013. On the Figures below the hydrological characteristics of this period are presented.

The profiles were classified according to the WFD derived limit values for the Danube.

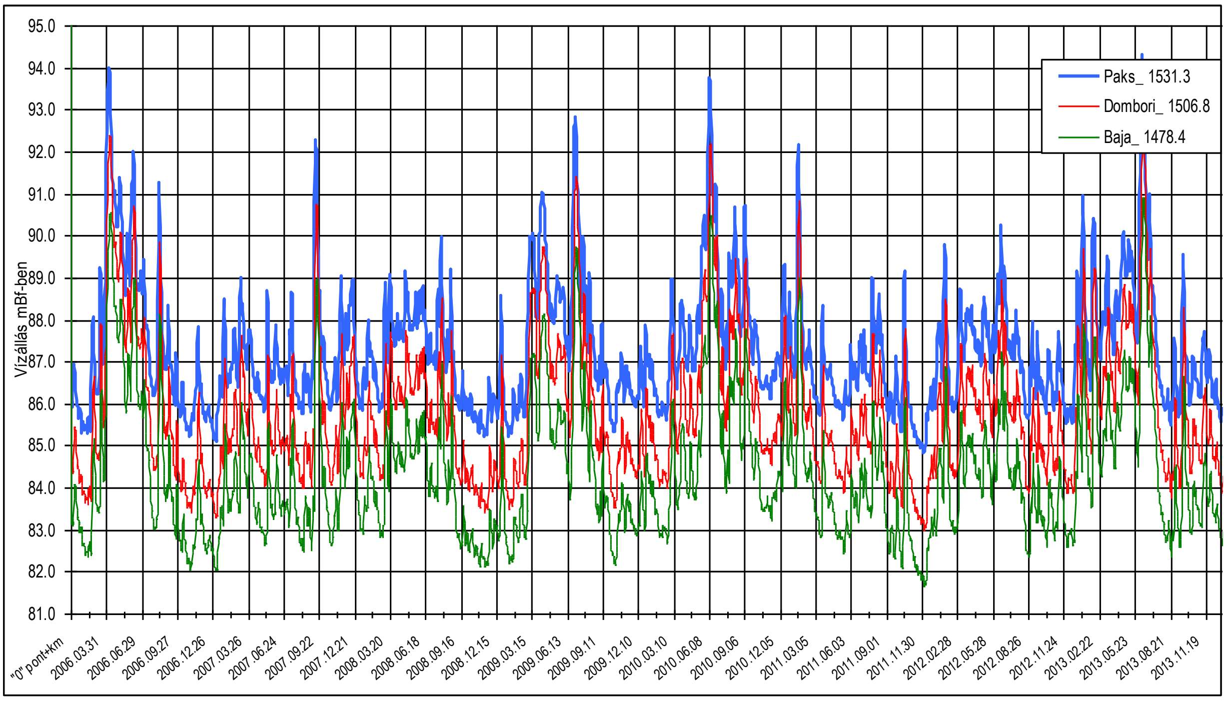


Figure 69: The water regime of the Danube (Paks-Dombori-Baja) between 2006 and 2013

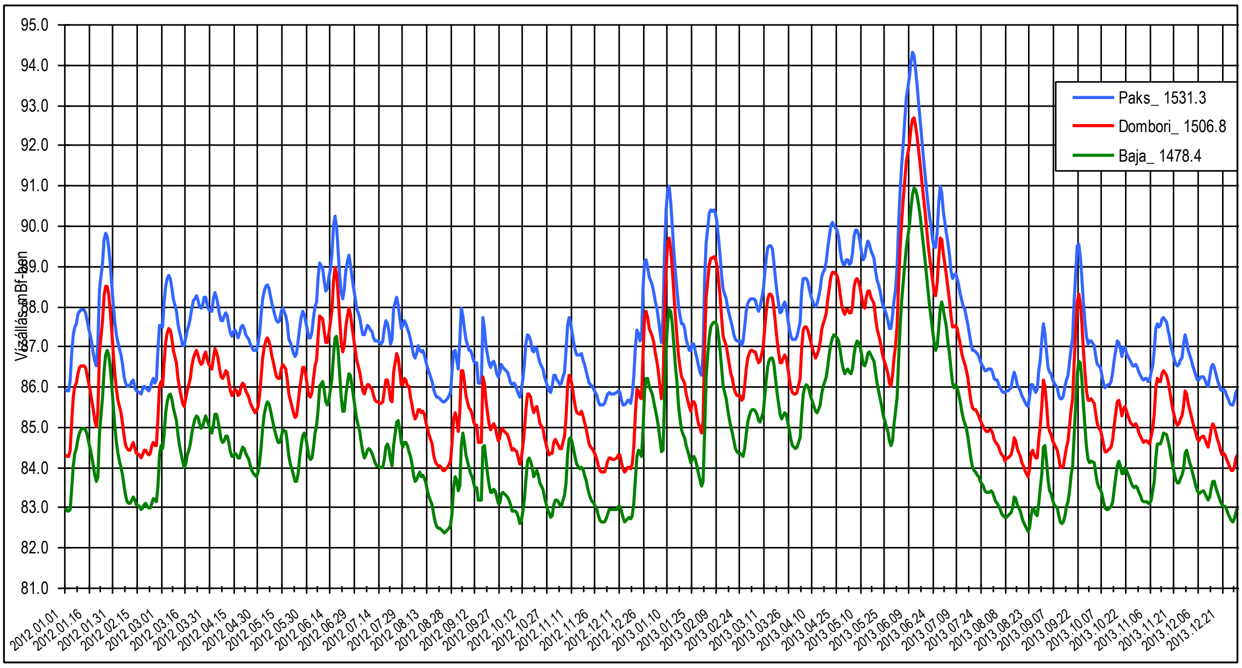
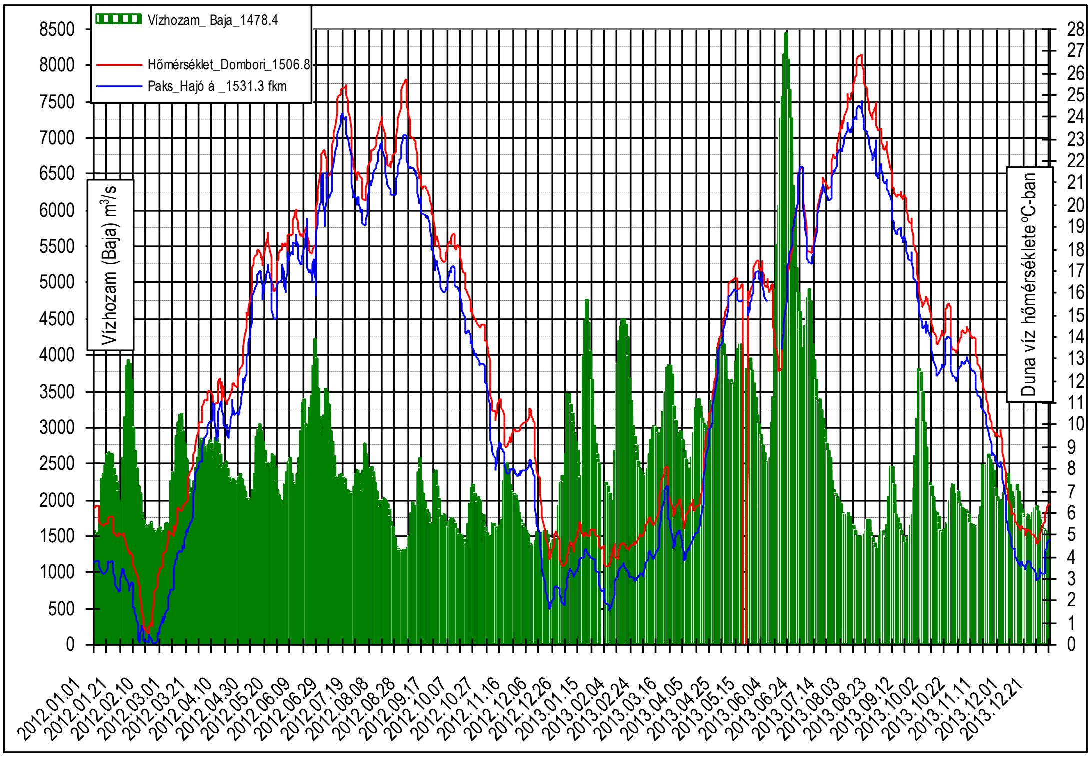
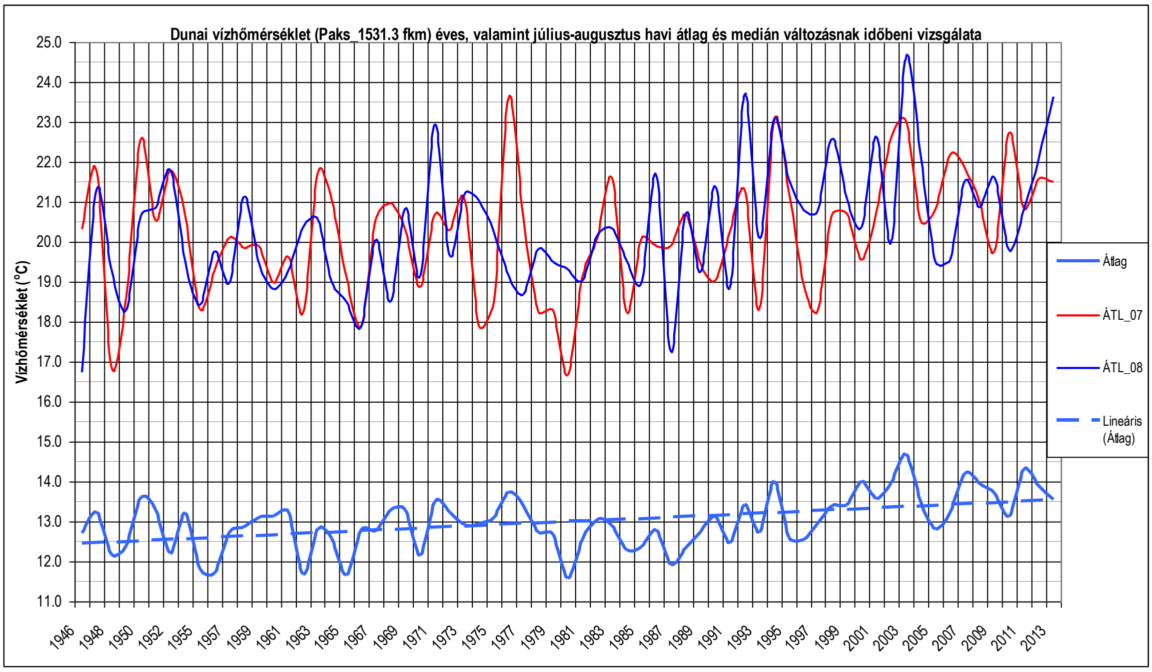


Figure 70: Water regime of the Danube (Paks-Dombori-Baja) between 2012 and 2013



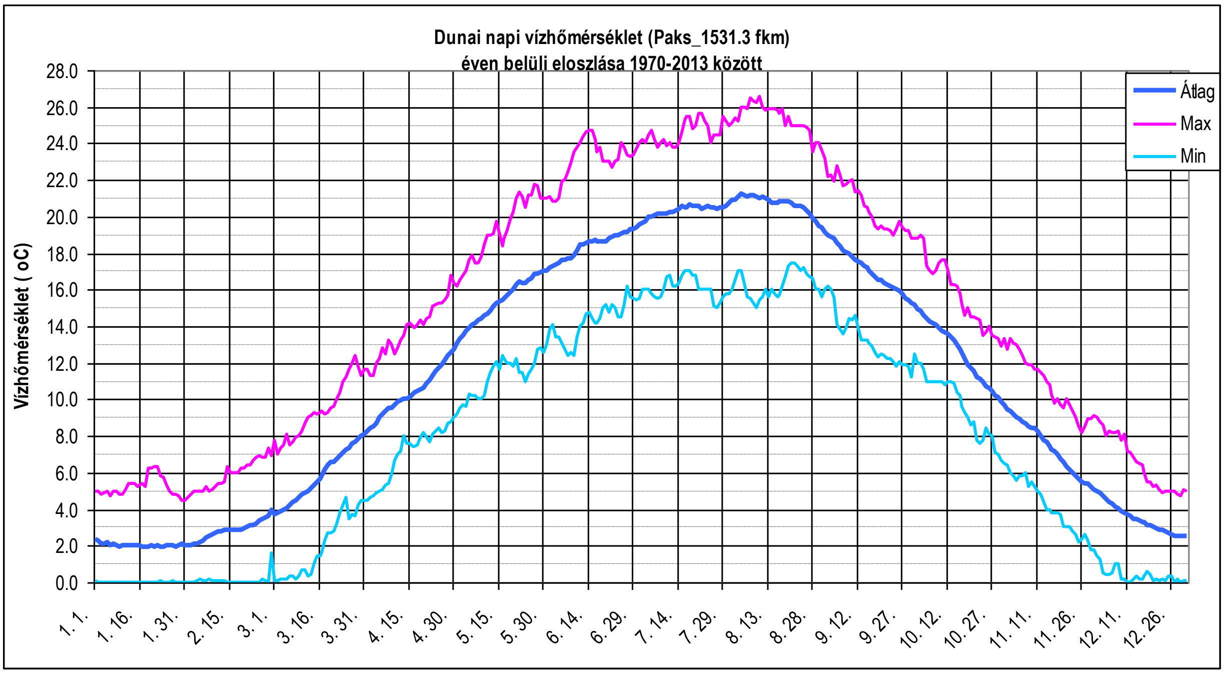
Vízhozam – discharge rate
Hőmérséklet – temperature
Hajó á – port
Duna víz hőmérséklete – water temperature of the Danube

Figure 71: Changes in the discharge rate and water temperature of the Danube (Paks-Dombori-Baja) in 2012 and 2013



Vízhőmérséklet – water temperature
Dunai vízhőmérséklet (Paks, 1531,3 fkm) éves, valamint július-augusztus havi átlag és medián változásnak időbeli vizsgálata – Chronological changes of the annual average and median water temperature of the Danube (Paks, 1531.3 river km) in the period of July-August
átlag – average
lineáris – linear

Figure 72: Chronological changes of thge annual average water temperature of the Danube (Paks) between 1970 and 2013



Vízhőmérséklet – water temperature
Dunai napi vízhőmérséklet (Paks, 1531,3 fkm) éven belüli eloszlása 1970-2013 között – Annual distribution of daily water temperatures of the River Danube (Paks 1531.3 river km) in the period 1970-2013
fkm – river km
átlag – average
max – maximum
min - minimum

Figure 73: Annual distribution of the daily water temperatures of the Danube (Paks) in the period between 1970 and 2013

CLASSIFICATION OF THE UPSTREAM DANUBE PROFILES

Dunaföldvár	1560.6 river km	**good status**
Paks ferry	1533.5 river km	**good status**

Table 47: Upstream Danube section (1560.6-1533.5 river km) WFD classification

Based on the outcome of the classification pursuant to WFD the Danube (HURWAEP444 WATER BODY) 1560.6-1533.5 river km section belongs to good status in terms of physico-chemical parameters.

The highest ratios in the composition of the phytoplankton biomass on the upstream section were diatom species in the Centrales order in all times. Biomass and chlorophyll-a concentration of the sampling units shows a significant deviation even within the same period. Sampling results from the years 2012 and 2013 indicate that higher level of biomass was present in 2012 in the same period. At the same time major changes can be recorded for each period in terms of differences across years. This confirms the statement that test results from samples taken in two different years reinforce each other, and projected on a longer time horizon they provide adequate results. The periods characterised by the highest level of biomass are March and August, while the biomass index is the lowest in the months of September/October and November.

Based on the ecological status assessment of the sampling units from the upstream section the following statements can be made.

(1) Differences in grades can occur between individual sampling units within the same sampling period.

(2) The highest level of biomass can typically be measured in the main stream line in the assessed profiles in all seasons, but the difference is not of the extent which would cause a grade leap in accordance with the cross profile.

(3) Grade level differences could be detected across samples taken in the same period of different years.

(4) Seasonal dynamics of the FP biomass is adequately reflected in the classification results.

(5) The robust five grade scale of the WFD is not sensitive to any more delicate changes.

(6) The summer period is most critical from the point of view of the impact study. The ecological conditions in the section are good.

Based on the findings of the phytobenthos test the following statements can be made. (1) grade level differences could be detected across samples taken form the right and left bank the same period; (2) in the summer season the Dunaföldvár profile sampled in 2013 indicated one grade lower status as the Paks ferry profile sampled in 2012, while no such grade level difference exists in Autumn, although the Dunaföldvár profile reflects a somewhat better status. (3) The classification results of the section concur with the outcome of the assessments in 2009 and 2010. The facts above – as it was stated for the phytoplankton – substantiate that a stable outcome can be derived by making the classification with the use of average values of the most possible parameters. At the same time the robust five grade scale of the WFD is not sensitive to any more delicate changes. The ecological status of the upstream section based on the phytobenthos was moderate.

A total of nine species were identified on the upstream section of Danube during the summer and autumn sampling operations. None of the species found in the sampling profile was protected. Several species can be considered to be introduced (red ash, panicled aster), the abundance of which refers to the disturbed nature of the area. Creeping marshwort (Apium repens) is the indicative NATURA 2000 species of the area. The species was not found at the sample section. From the professional perspective, the findings are of limited reliability for the purposes of status assessment, since macrophyte communities appear along large rivers – such as at the sampling site – only in small quantities and therefore the ecological status defined by the evaluation of them is uncertain. The number of plant species and their abundance did not allow exact classification, since they did not reach the minimum level necessary. The data obtained this way are for information only. Due to these uncertainties a finer resolution analysis of the data was also carried out for the whole study section. The ecological status of the upstream section was moderate according to the macrophyte analysis.

A substantial part of the macroscopic invertebrate taxons identified were invasive, intensively and aggressively penetrating introduced elements. The gravel snail (*Lithoglyphus naticoides*) which comes sometimes in large numbers, zebra mussel, (*Dreissena polymorpha*), Asian clam (*Corbicula fluminea*) and from the crabs the *Dikerogammarus villosus* can be highlighted from them. The protected dragonfly species named *Gomphus flavipes* was identified in small numbers in the sampling sessions. The thick shelled river mussel (*Unio crassus*), the macrozoobenthos species indicating the HUDD20023 SCI area, was not found during the sampling procedure. The ecological status assessment carried out based on the HMMI (Hungarian Multimetric Macroinvertebrate Index) revealed a seasonal difference: the values in autumn samples are lower, which however, did not cause any quality grade leap in this case. Based on the findings of the assessment it can be stated that the ecological status of the upstream section was moderate according to the aquatic macroscopic invertebrate analysis.

A total of 2 489 individuals of 28 species were identified during the summer and autumn sampling operations in the four sampling units designated along the Paks Danube section. Four: the Danube whitefin gudgeon (*Romanogobio vladykovi*)*,* the European bitterling *(Rhodeus amarus),* the Balon's ruffe *(Gymnocephalus baloni)* and the Striped ruffe

Gymnocephalus schraetser) of the species identified in the sample profile were protected and two of them, the Ukrainian brook lamprey (*Eudontomyzon mariae*) and the zingel *(Zingel zingel*) strictly protected. Of the NATURA 2000 indicator species only *Eudontomyzon mariae,* balin *(Aspius aspius), Zingel zingel, Gymnocephalus baloni and G. schraetser* were found in the section assessed. On this basis it can be claimed that the indicator fish species characterising the mainstream channel bottom of the NATURA 2000 area can be detected on the upstream section. Young individuals of 24 species from the total of 28 identified species were found in the samples. This means that 86 % of the species is present in the section in the form of progeny, indicating the stability of their respective populations. Thus the assessment of the upstream Danube-section shows that the species inventory of the catch was substantially similar to the results of former assessments. The findings of the samplings made in the summer and autumn period supply proper data for the WFD-based qualification of the water. Ecological water quality of the section on the basis of fish communities was carried out in accordance with the EQIHRF method established in Hungary. For the purposes of the outcomes, the summer results were accepted as relevant**.** The ecological status of the upstream section not affected by hot water discharge according to the aquatic fish community analysis was good.

CLASSIFICATION OF THE DIRECT DOWNSTREAM DANUBE (1534-1516 RIVER KM) PROFILE

Paks hot water canal	**1526.0 river km**	**good status**
Nagy sarkantyú	1525.3 river km	**good status**
Uszod	1524.8 river km	**good status**
Gerjen-Foktő	1516.0 river km	**good status**

Table 48: WFD classification of the direct downstream Danube section (1526-1516 river km)

Based on the outcome of the classification pursuant to WFD the Danube (HURWAEP444 WATER BODY) 1534-1516 river km section belongs to good status in terms of physico-chemical parameters.

Sampling results downstream reflected a status a great extent similar to the upstream status.

(1) Components of phytoplankton biomass in the highest ratio included diatom species from the order Centrales all times.

(2) Biomass levels indicate seasonal trends.

(3) The period characterised by the highest biomass level is March and August, while the lowest biomass levels were found in the months September and November.

The ecological status of the near downstream section according to the assessment of the phytoplankton indicated a good status in March and June, and high status in September and November. The ecological status was moderate during the August season. The seasonal fluctuations on the near downstream section are entirely in line with the experiences gained on the upstream section. Values characterising the statuses per season – and hence, on an annual basis – are identical with the results measured on the upstream section. The ecological status of the near downstream section based on the phytoplankton was good.

Based on the classification of the phytobenthos community, the ecological conditions of the downstream section were moderate in the summer and poor in the autumn. At least one grade difference was found between the right (affected by the hot water discharge) and left (not affected by the hot water discharge) sampling units for all sampling efforts. The sampling units affected by the discharge of hot water has a tendency to show lower values. However, a similar picture is drawn up by the autumn sampling from the upstream section at the Paks/ferry profile. The low - moderate – grade falls in line with the results of the assessments made earlier on. The overall status grade matches that of the upstream section. When data from both periods are considered together, an average value is given, corresponding to a moderate ecological status.

A total of 51 macrophyte species were found in the six sampling units during the summer and autumn surveys. None of the species found in the sampling profile was protected. Several species can be considered to be introduced (red ash, panicled aster), the abundance of which refers to the disturbed nature of the area. The indicator species of the area was not found in this section, either. The outcome of the classification procedure for the near downstream section is identical with that for the upstream section. Based on the findings of the assessment it can be stated that the ecological status of the near downstream section of the Danube according to the macrophyte analysis was moderate.

During the summer and autumn sampling seasons a total of 44 different macroscopic invertebrate taxons could be detected from the samples taken at six sampling sites. Just like in the case upstream, a substantial part of the macroscopic invertebrate taxons identified were invasive species. Of them, *Dikerogammarus villosus* was found in great numbers in the profile drawn up directly beside the cooling water discharge on the right bank. The large number of the empty shells found on the banks downstream the outflow (e.g. *Corbicula fluminea, Dreissena polymorpha, Sinanodonta woodiana)* can be explained basically with the current. The shells drifting in the river are deposited in large numbers in the low-current, revolving areas behind the spurs. A few individuals of the protected dragonfly species named *Gomphus flavipes* as well as the protected snail species *Fagotia acicularis* were identified on the near downstream section also. The thick shelled river mussel (*Unio crassus*), the macrozoobenthos species indicating the NATURA 2000 area, was not found during the sampling procedure. Several species (for instance *Lithoglyphus naticoides*, *Corophium curvispinum)* express avoidance near the hot water outflow. The multimetric HMMI indicator, similarly to the indicators used in the EU, is sensitive to overall degradation, which makes the demonstration of the individual impact of heat contamination with the quality indexes available quite doubtful. Therefore we conducted an ecological evaluation of the sections on a finer scale as well, but the result of the evaluation was the same as that of the evaluation calculated upstream. The ecological conditions of the near downstream section affected by warm water were moderate with respect of the aquatic macroinvertebrate community.

A total of 3 679 individuals representing 51 species were found in the six sampling units on the near downstream section. The structure of the species of fish in this section of the Danube was found to be very similar to the findings of earlier examinations conducted for similar purposes (Halasi-Kovács 2005, SCIAP Kft. 2010) and our own findings on the upstream section alike. We identified five protected species, namely Danube whitefin gudgeon *(Romanogobio vladykovi),* amur butterling *(Rhodeus amarus),* golden loach *(Sabanejewia balcanica),* balon's ruffe *(Gymnocephalus baloni)* and striped ruffe *(Gymnocephalus schraetser)* and two highly protected species, namely Ukrainian brook lamprey *(Eudontomyzon mariae)* and common zingel *(Zingel zingel)* in the section subject to the sampling. The same five indicator species of the NATURA 2000 area were found as upstream *(Eudontomyzon mariae, Aspius aspius, Gymnocephalus baloni, Gymnocephalus schraetser, Zingel zingel)*.

On the basis of the analysis of the species structure in the current sampling units it can be assumed that Ukrainian brook lamprey *(Eudontomyzon mariae),* burbol *(Lota lota)* and racer goby *(Babka gymntrachelus)* show a slight avoidance of hot water, while balin (*Aspius aspius),* small river bleak *(Alburnus alburnus),* silver bream *(Blicca bjoerkna),* nose carp (*Chondrostoma nasus),* barbel *(Babrus barbus),* the Prussian carp (*Carassius gibelio),* perch (*Perca fluviatilis),* and monkey goby (*Neogobius melanostomus)* prefer it. This result is in harmony with the findings of the 2010 studies. Young individuals of 27 species were found in the samples. This means that 82 % of the species is present in the section in the form of progeny. This ratio is similar to the other section upstream and can also be considered a very high level. Total (adult plus offspring) catch per unit effort (CPUE) on the 100 metre units reflected the highest value in the sampling units on the right bank of the near downstream section effected by hot water discharge in 2012. At the same time CPUE values of the sampling units on the left bank, which is not exposed to hot water showed a somewhat lower level, similar to those sampling units which were affected by the hot water. Based on the findings of the fish community the ecological status of the near downstream section of the Danube was good.

CLASSIFICATION OF THE DISTANT DOWNSTREAM SECTION (1506.8-1481.5 RIVER KM) PROFILE

Dombori profile 1506.0 river km	**Class II**	**GOOD status**
Sió South (Gemenc) 1495 river km	**Class II**	**GOOD status**
Baja profile 1481.5 river km	**Class II**	**GOOD status**

Table 49: Classification of the dDistant downstream Danube section (1506.8-1481.5 river km) in accordance with the WFD

Based on the outcome of the classification pursuant to WFD the Danube (HURWAEP444 WATER BODY) 1506.8-1481.5 river km section belongs to good status in terms of physico-chemical parameters.

Phytoplankton findings of the two subsections of the distant downstream section, midstream-distant and distant, respectively, show very similar results. At the same time, the findings on phytoplankton in this section indicate a very similar status and tendency to the upstream and near downstream section as well. Diatom is a decisive factor in phytoplankton biomass, March is the period characterised by the highest level and August as the second, while the lowest biomass levels can be observed in the months of September and November. The ecological status of the near downstream section according to the assessment of the phytoplankton indicated a good status in March and June, and high status in September and November. The lowest levels were observed during the August season. In this period the ecological status was moderate. Values characterising the statuses per season – and hence, on an annual basis – are identical with the results measured on the upstream and near downstream section. The ecological status of both the midstream-distant and distant downstream sections based on the phytoplankton was good. In summary it can be stated that no grade level changes were caused by the Paks Nuclear Power Plant hot water discharge in the phytoplankton downstream when compared to the status upstream.

Diatom based classification findings of the two subsections of the distant downstream section show very similar results to the upstream and near downstream section as well. Classification tendencies also match with those experienced on the upstream sections. Both subsections reflect moderate ecological status. In summary it can be stated that no grade level changes were caused by the Paks Nuclear Power Plant hot water discharge in the phytobenthos downstream when compared to the status upstream.

A total of 31 and 19 species were identified in the midstream-distant and distant subsections, respectively. None of the species found in the sampling profile was protected. At the same time invasive species (red ash, panicled aster) are abundant. The indicator species of the area is the creeping marshwort was not found on the distant downstream section. The ecological status of the midstream-distant and distant downstream section of the Danube according to the macrophyte analysis was moderate. the classification status is identical with that experienced upstream and near downstream**.** In summary it can be stated that no grade level changes were caused by the Paks Nuclear Power Plant hot water discharge in the macrophyton downstream when compared to the status upstream.

During the summer and autumn sampling seasons a total of 42 and 37 different macroscopic invertebrate taxons could be detected from the samples taken at the distant downstream and distant sections, respectively. The presence of the invasive taxons detected in the previous sections could be confirmed in this section as well, in particular the snail species *Lithoglyphus naticoides* which comes in great numbers. he presence of the brittle worm species named *Hypania invalida* and a kind of mussel, known in this country only from a few places so far, *Dreissena bugensis* should be noted (this is the only location where the latter was found). Note that a few individuals of the protected dragonfly species called *Gomphus flavipes*, as well as the protected snail species named *Fagotia acicularis* were also included. The indicator macrozoobenthos species of the NATURA 2000 area, thick shelled river mussel (*Unio crassus*) was never found in the samples. The midstream-distant downstream section on the basis of the macrozoobenthos was in moderate ecological state. The distant downstream section was also of moderate state. The grade of this section is identical with that recorded upstream and near downstream. In summary it can be stated that no grade level changes were caused by the Paks Nuclear Power Plant hot water discharge downstream when compared to the status upstream.

A total of 3 367 individuals of 34 species and 4 151 individuals of 34 species were identified along the midstream-distant and distant subsections, respectively. Five of the species identified in the sample section were protected species, namely common roach (*Rutilus virgo*), Danube whitefin gudgeon *(Romanogobio vladykovi),* amur butterling *(Rhodeus amarus),* balon's ruffe *(Gymnocephalus baloni)* and striped ruffe *(Gymnocephalus schraetser)* and two highly protected species, namely Ukrainian brook lamprey *(Eudontomyzon mariae)* and common zingel *(Zingel zingel)*. Of the indicator species of the NATURA 2000 area common roach (*Rutilus virgo*) was found only in this section while the other indicators were identical with those detected upstream. Young individuals of 27 species were found in the mid-distant downstream samples. This means that 79 % of the species is present in the section in the form of progeny. Young individuals of 26 species were caught distant downstream, representing 79% of all species detected. These ratios are similar to the other sections upstream and can also be considered a very high level. Based on the sample findings it can be stated that the species composition of the distant section did not show much deviations compared to the upper sections and the fish species structure of the sections assessed is uniform. The hot water discharge from the Paks Nuclear Power Plant did not cause any changes in the species inventory. No species disappeared and none appeared as a result of it. During the summer sampling periods higher number of individuals could be observed in both years. This was typical to all profiles assessed.

All in all, the outcome of the sampling efforts carried out in both seasons resulted an appropriate data set for the purposes of water quality classification according to the WFD requirements. The ecological status of the midstream-distant section equals with that of the upstream, as well as the near downstream section, showing a good ecological status. In summary it can be stated that no grade level changes were caused by the Paks Nuclear Power Plant hot water discharge downstream when compared to the status upstream.

It was clear from the earlier – 2009-2010 – study findings that the robust five grade scale of the WFD is not sensitive to any more delicate structural changes just as it was seen in the most recent results. Therefore the more finer resolution ecological evaluation of the sections was also completed.

COMPREHENSIVE ASSESSMENT OF THE DANUBE SECTION BELONGING TO THE BODY OF WATER MARKED HURWAEP444 FROM THE WILDLIFE CONSERVATION AND WFD PERSPECTIVE

When the Danube section assessed was evaluated, basically the fundamental principles included in the ECOSTAT guidance document no. 13. (ECOSTAT 2005: Common Implementation Strategy for the Water Framework Directive (2000/60/EC) were taken into consideration, as well as the domestic national guidance specified in the course of the planning process of the national river basin management plan in 2008. During the assessment of the Danube in accordance with WFD the classification principle of "one bad means all bad" formulated in the Water Framework Directive was taken into account at the level of qualitative elements and groups of elements. This means the classification status will be determined by the lowest score component. The findings of the macrophyte classification process is given only for information.

Danube sections	Physico-chemical properties	Phytoplankton	Phytobenthos	Macrophyte	Macrozoobenthos	Fishes
Upstream	good	good	moderate	moderate	moderate	good
Near downstream	good	good	moderate	moderate	moderate	good
Distant downstream	good	good	moderate	moderate	moderate	good
		good	moderate	moderate	moderate	good

Table 50: WFD classification of the assessed Danube section (HURWAEP444)

Based on the evaluation results of the water quality assessment pursuant to the requirements laid down in the WFD carried out in 2012 and 2013 the ecological status of the water body marked Danube HURWAEP444 between Szob and Baja was **moderate**.

The outcome of the current study is in line with the status grade based on the available historical data. It can be stated that the discharge of the Paks Nuclear Power Plant into the Danube does not cause grade level changes in any of the study groups.

However, the finer resolution analysis of the data points out that the discharge does have impacts on the structure of the wildlife communities downstream, and that the WFD based classification method in itself is therefore not suited to judge the exact impacts of the power plant discharge. Therefore we find it of paramount importance that during the additional studies the design of the sampling sessions remained on the basis of the WFD, the classification be completed, but at the same time the design and execution of the sampling procedure should allow the implementation of finer resolution ecological analysis, and hence the more accurate evaluation of the ecological impacts the discharge may cause.

THEORETICAL IMPACT OF THE WARMED COOLING WATER FROM PAKS NUCLEAR POWER PLANT ON THE WATER QUALITY PARAMETERS OF THE ASSESSED DANUBE SECTION

On the basis of the test results obtained from Core Network study profiles between 1979 and 2004 **it can be stated that water quality changes appear in the case of most elements more expressively as a function of time than as a function of the place**. Changes in the physico-chemical parameters are influenced by various processes in space and time, including the following key factors:

When the sampling points situated upstream and downstream of the Paks Nuclear Power Plant are taken into account, *water quality conditions showed a favourable tendency in terms of time* for most sampling sites and quality parameters. Quality at the sampling sites situated downstream of the Paks Nuclear Power Plant (Fajsz, Baja, Mohács, Hercegszántó) usually no difference could be detected in water quality compared to that upstream (Dunaföldvár). This means that **with respect to the elements assessed the Nuclear Plant did not play any significant role in the tendencies observed in the water quality of the Danube**.

13.2 THE IMPACT OF THE ERECTION OF PAKS II ON THE DANUBE

In the course of the environmental impact assessment concerning the impacts of the investment project Paks II – including its erection, operation and abandonment - on the ecological status of the Danube the potential active impact factors, expected impacts, the nature of the impact and the bearers of the effects are identified and evaluated. Additionally, recommendations will be made to suggest measures for the preservation of the ecological status of surface waters.

Based on the baseline assessments made it can be stated that even potential impacts of the investment project Paks II will extend to the adjacent surface water bodies and correspondingly in the impact assessment stage only statements concerning the body of water on the Danube potentially effected by Paks discharges (HURWAEP444) will be made.

In terms of impacts and impact areas, under the relevant applicable Government Decree No (314/2005 (XII. 25.) the law makes a distinction between direct, indirect and transboundary impacts and their respective areas. The nature of the impact in the impact assessment was determined with the living organisms in the focus (that is, investigating them from the perspective of aquatic organisms) based on the durability, strength and significance thereof. Taking into account the aspects laid down in the WFD wildlife is considered to be the entity exposed to the impacts. During the impact assessment biological elements relevant with respect to the WFD based status classification are identified as bearers of the impact. Although the physical and chemical properties of the water or the Danube water as such is not considered to be a bearer of the impact, they provide essential information for the evaluation of the ecological status.

Potential impact factors during the investment project of Paks II were summarised in the table below.

Potential impact factor	Erection/construction	Operation	Decommissioning	Failure event
Groundwater extracted during groundwater depression	X		X	
Discharge of treated municipal wastewater	X	X	X	
Implementation of the Recuperation Hydropower Plant	X			
Damage to the Diesel oil tank during construction				X
Failure type operating trouble of the municipal waste water treatment plant				X
Water extraction from the Danube		X		
Discharge of warmed up cooling water into the Danube		X		
Discharge of process wastewater into the Danube		X		
Discharge of treated rainwater into the Danube		X		
Damage to the fuel tank of the Diesel generator set				X
Spill of spent oil or other liquid waste				X
Escape of untreated municipal wastewater				X

Table 51: Potential impact factors in the course of the Paks II investment project

Implementation

Groundwater extracted during groundwater depression

During the construction works of the Paks II units there are several buildings which will be built on deep foundations, consequently the works have to be carried out below groundwater level. In this period dewatering is necessary in the work pit during the foundation works. The volume of the groundwater to be extracted will be – according to the calculations made by Isotoptech Zrt. – 13 000 – 18 000 m^3/day, max: 0.2 m^3/s. Extracted groundwater is discharged into the cold water canal, passes the cooling circuit and gets into the hot water canal to be discharged finally into the Danube. Nutrient contents of the groundwater from the dewatering efforts and in particular that of nitrogen form is expected to be higher than those of the Danube water, and as a consequence, the wildlife in the cold water canal will be exposed to it. However, as a result of the more than five hundredfold dilution and mixing it can be expected that any impact in addition to the base state would be present on the ecological status of the wildlife in the Danube.

Discharge of treated municipal wastewater

Maximum drinking water needs and hence, the resulting waste water volumes necessary in the construction period of Paks II will be present for a five years period than the first unit is already commissioned and operating and the second unit is being erected at the same time, during a five years period as planned. According to the calculations made by VITUKI Hungary Kft. the maximum volume of municipal waste generated in this period amounts to 614 m^3/day. The average volume of municipal wastewater in the Paks Nuclear Power Plant area is currently ~300 m^3/day. Thus the design volume of municipal wastewater to be treated is thus, rounded upwards for the sake of safety: 1000 m^3/day. The own waste water treatment plant of the Paks Nuclear Power Plant is equipped with total oxidation and sewage treatment by sludge activation, and has a nominal capacity of 1870 m^3/day (657 thousand m^3/year). Purified wastewater is led in a pipeline to the hot water-canal, and from here into the Danube. Based on the mixing model prepared by VITUKI Hungary Kft. for the extreme low water discharge rate of the Danube – 579 m^3/s – recurrent in every 20 000 years once only it can be stated that they remain below the detection limit values laid down in the Hungarian standards used for their identification already within a 10 metres distance calculated from the Danube discharge point. The concentration and composition of the residual nutrients in the treated wastewater is expected to exceed that of the Danube in a slight extent, and deviated from that typical for the Danube naturally, respectively. The large scale, approximately nine thousand fold dilution taking place in the hot water canal and the natural purification process experienced in the course of the blending phase decreases this impact even further. Due to the volume of the purified wastewater discharge no detectable hydrological impact will be felt.

Implementation of the Recuperation Hydropower Plant

The erection of Paks II is accompanied by the establishment of a recuperation hydropower plant, therefore it was included as an active impact in the impact matrix, but it is an activity subject to an environmental impact study and water rights establishment permit itself, therefore no further assessment will be made with respect to it in this document.

Damage to the Diesel oil tank during construction

Migration of pollutant emissions occurring eventually at the site and the consequences of such incidents were investigated by Isotoptech Zrt. As a summary of this study it can be established that the migration time between the site and the river falls within the 10 to 20 years range. Through instant local containment of the spilled oil in the event of eventual damage to the Diesel oil tank used during the power plant erection it can be ensured that the pollutants escaped never reached the Danube. Correspondingly, such potential failure events occurring at the time of construction in the construction site represent no direct or indirect risk to the surface waters.

Failure type operating trouble of the municipal waste water treatment plant

The potential failure event during the construction period from the perspective of the Danube is when the municipal wastewater generated is released into the Danube as a result of the breakdown of the municipal wastewater treatment plant. The highest volume in such a case is expected in the 5 years period of construction. Correspondingly, modelling of the failure event was made for the **extreme low water level** on the Danube recurrent in every 20 000 years, 579 m^3/s and 1000 m^3/day municipal wastewater volumes, taking the highest concentration of the discharged raw wastewater measured in the last two years as the applicable concentration. In such a case all of the parameters achieve the detectability level according to the relevant Hungarian standard only in the 1500 metres downstream section of the Danube.

Breakdown of the wastewater treatment plant during the construction period may represent a realistic threat to the wildlife in the Danube. Provided the approximately 1000 m^3/day municipal wastewater generated during the construction phase is discharged into the hot water canal and later the Danube untreated, this will represent a higher nutrient concentration as well as increased levels of suspended loads and turbidity in comparison to those during normal operation. Having regard to the approximately nine thousand dilution in the hot water canal and an addition dilution factor of an additional approximately ten fold dilution in the Danube even in case of the critical low water stages, any untreated wastewater exposure might not have more serious than a slight, sub lethal impact on the Danube wildlife. Phytoplankton biomass will have an augmented level in the plume of the contamination water. In principle the biomass of fishes may be increased in the plume. As a result of the contamination species less sensitive to organic nutrient loads may appear in greater numbers on a temporary basis among the organisms of the phytobenthos in the proximity of the discharge site as a result of the contamination. Due to the dilution effect the lethal threshold is not reached by the untreated wastewater discharge for macrozoobenthos organisms, either. Species in the macrozoobenthos will react to increasing nutrient loads partly by avoidance and partly by an increase in the number of individuals, pending on their tolerance against declining oxygen levels. Untreated wastewater causes rather avoidance by more sensitive fish species in the discharge area while other species tolerant against nutrients may even appear in higher numbers of individuals. For reasons of the great difference in the volumes of the wastewater generated and the cooling water discharged only local impacts can be reckoned with even in this case. Correspondingly, the impact is short term, medium strength and low significance. Yet, the setup of a buffer capacity in the wastewater treatment plant may be recommended which allows the prevention of direct discharge. The area of direct Danube impact is <500m. No more extensive indirect impact area can be reckoned with.

Operation

Water extraction from the Danube

Water is extracted from the Danube through the cold water canal in order to provide cooling water for the power plant. The water volumes extracted are identical with the volume of hot water returned through the hot water canal. In the current operating state of Paks Nuclear Power Plant this level is 25 m^3/s for each unit, representing at the time being a total of 100 m^3/s. For the newly constructed units this value is expected to be 66 m^3/s for each unit, a total of 132 m^3/s. The highest amount is expected during the period of joint operation of the two facilities between 2030 and 2032. At this time the volume of water extracted is 232 m^3/s. Water extraction will have any impact on the rate of flow in the Danube only between the cold water canal and the hot water canal. The amounts extracted will not have any significant impact on this section of the river even in case of low water stages. Based on the extent of the river morphology changes calculated by VITUKI Hungary Kft. no direct or indirect impacts are reckoned with for the wildlife.

Discharge of warmed up cooling water into the Danube

The cooling systems of the proposed new nuclear power plant units can be divided up into three main parts: (1) condenser cooling water, (2) process cooling water, (3) backup cooling water. From the perspective of heat loads the decisive volume is represented by the condensers need of a total of 132 m^3/s cooling water volume in the units of Paks II.

The highest volume rate of flow for hot water is expected to be present in the 2030-2032 period.

Cooling water and other wastewater discharged into the main riverbed of the Danube across the approximately 1500 metres long profile of the hot water canal. This will change the flow conditions in the Danube at the outlet. As a consequence, the findings of the research laying the foundations for the impact study suggest that in the surrounding of the discharge point the species composition of the phytobenthos conditionally and that of the macrozoobenthos as well, as of the fish community decidedly will be modified and their abundance levels increased at least partially. This impact is long term, medium strength, but low significance. The area of direct and indirect impact is <250 m. During operation a ban on fishing and angling may be suggested in a 250 radius circle around the discharge point for the purposes of protecting the fish community.

Adverse changes in the water quality are continuously dealt with ever since the commissioning of Paks Nuclear Power Plant. The statements can be summarised as follows:

(1) The maximum water temperature of the Danube water indicative with respect to the heat loads it is exposed to is usually 21-24 °C in summer, or exceptionally it reaches a level above 25 °C. Time series of water temperature are typical, the well established season of maximum levels lasts from the beginning of July up to the end of August.

(2) The annual course of the Danube rate of flow (volume flow) is less regular, yet it is clear that the low water stages representing the heat load maximum periods of the river occur in the autumn and winter seasons with the greatest degree of probability;

(3) A typical feature of the Danube reducing the risk rate of heat loads is that high water temperature levels occur exclusively in July and August, while low water levels approaching the 1000 m^3/s volume are encountered mostly only from September on.

This statistically substantiated probability scenario was modified by the dry and warm summer weather conditions in the years between 1992 and 2003, because the water temperature varied between 20 – 26 ^{0}C in July and August.

All in all the former assessment reported that no such water quality changes are expected until 2015, which would be caused directly by the discharge of the treated and used waters of the Paks Nuclear Power Plant into the Danube causing the modification of the classification grade of the Danube water quality.

Investigation of the relationships between the Danube water temperature and Danube water chemistry parameters and forecast for the design dates in the Dunaföldvár, Fadd and Hercegszántó area

Predicted values and the with the interval of their degree of probability of the changes occurring in the water chemical parameters of the Danube associated with the critical water temperature levels specified were determined by statistical methods. Under the core network measurement sessions tests were carried out for the various elements on a monthly basis, usually twelve times a year. The monthly tests allowed monitoring of the annual seasonal changes. Under the study carried out on a large number of elements it was determined on the basis of the linear trend deviation analysis, whether or not the linear trend in question is correlated with temperature changes or is independent from them. Provided such correlation exists, the predicted value associated with each of the difference temperature levels can be determined by statistical methods. In this case, when no correlation exists between the element in question and the Danube water temperature, it can be assumed that the average and distribution pattern of the element measured in the past seven years equals with the average and distribution pattern expected for the future period.

For this purpose the correlation factor and the parameters of the equalling linear trend were determined. The correlation factor parametered the closeness of the correlation and the function of the equalling linear line provided the opportunity to determined the expected predicted value for various temperature scenarios. Under the statistical analysis the deviation of the element in question was determined which was influenced by the seasonal temperature fluctuations, water levels on the Danube, including the associated volume rate of flow values, furthermore the minimum and maximum levels for the element in the period under investigation. Taking into account the correlation factor representing the correlation the expected value of the occurrence of the element in question and its value interval were predicted on the basis of the coefficient of standard variation figures as well as the minimum-maximum values encountered so far.

The classification process according to the WFD requirements was carried out for both the predicted value and the calculated predicted range.

Of the downstream profiles calculations on the maximum permitted heat load of 30 ^{0}C at the Nagysarkantyú were carried out on the basis of the water quality data at the Fadd profile for the purposes of comparison.

Summary of the consequences of letting warmed up cooling water into the Danube

Based on the summary of former studies on the water quality, water discharge rate and water temperature conditions of the Danube the increase of heat generation can be implemented in a manner which does not violate any restrictions intended to protect the water quality of the receiver and does not contradict the interests of nature conservation. Provided the limits contained in the applicable provisions are met during operation, the water quality and physical quality of the Danube will not be changed compared to the current status with respect to heat generation as a result of the discharges from the Paks II Nuclear Power Plant even under adverse conditions.

In summary, it can be concluded from the water quality testing of the Danube carried out at the Core Network points in the 2006-2011 period and in 2012-2013 that the heat load will be slightly increased according to the calculations after the implementation of the increase of the proposed power output.

However, no substantial changes are expected to occur as a result of the increase of the output in the future in terms of the level of the indicators showing acidification status, salinity status, oxygenation conditions status and nutrients status characterising the water quality of the Danube, that is in terms of the indicators depending on the increase of temperature to a major or lesser extent.

Although decomposition processes of organic matter in the river are accelerated by the impact of the warmed up cooling water discharged into the river from the Nuclear Power Plant which are accompanied by oxygen consumption and oxygen abstraction, they are offset by the hydraulic and mixing conditions in the river as well as by the typically high dissolved oxygen content. The aforementioned impacts are not expected to be considerable in their extent yet they can not be disregarded for water quality reasons and their future monitoring is recommended.

When the base state was assessed, the impact of hot water in a length of approximately 2 kilometres on the right bank profile could be demonstrated conditionally in the case of the phytobenthos and beyond doubt for the macrozoobenthos and the fish. It means the detection of a Δt=2.5 °C temperature increase for these taxons. At the same time the growing temperature did not cause any detectable change on the structure of the plankton algal community. The findings of the ecological analysis indicate that the impact demonstrated can seen as a long term consequence. It is demonstrated by the analyses that the impact of hot water varies at the detection level even under optimum sampling conditions, because the impact of the Paks Nuclear Power Plant discharge is superseded by the natural diversity of the environmental conditions on the Danube. The impact itself bears significance more for the duration and permanent manner of the exposition rather than due to its extent.

Baseline studies on the Danube sections affected for the physical and chemical properties demonstrated that no substantial changes are expected to occur as a result of the increase of the output in the future in terms of the level of the indicators showing acidification status, salinity status, oxygenation conditions status and nutrients status characterising the water quality of the Danube, that is in terms of the indicators depending on the increase of temperature to a major or lesser extent.

The most significant impact on the ecological status of the Danube is represented by the discharge of the warmed up cooling water. This impact will be the strongest in the 2030-2032 period. Most probably no other group of organisms will be exposed to the impacts in this period beyond the three taxons already specified in the course of the baseline assessment (phytobenthos, macrozoobenthos, fishes) The impact caused by the heat load on the impact area is long term, strong and high importance. It can be concluded on the basis of the findings obtained from the ecological status assessment that the impact of heat loads (in aggregate, when all the six units operate jointly) will not cause any grade level impairment of the ecological status in any of the groups along the affected Danube-section when classified according to the WFD. Operation of the recuperation hydropower plant might be assumed as favourable for the purposes of the discharge temperature. Deloading of the unit may become necessary in the summer low water stage periods. According to the model prepared for the joint operation period the total direct impact area of the heat load can be specified as a maximum 11 km distance on the Danube downstream section. This profile is found at Danube 1515.8. river km. Based on the model calculations the heat plume characterised by the Δt=2.5 °C isotherm reaches the main current line of the Danube but does not cross it significantly.

Indirect impacts transmitted through the living communities are partly represented by the structural modifications encountered in the communities concerned resulting from the competition and rivalry seen as a consequence of changes in the community of consumer organisations due to changes in the nutrient turnover and partly as a consequence of growing relative or absolute abundance of invasive species. As a result of the former studies (Halasi-Kovács 2005, SCIAP 2010) and of the baseline assessment the fact can be stated that the water spaces of the affected section may function as the breeding ground for invasive species as an indirect impact of the hot water discharge, thus contributing to the further penetration of invasive species. For biological elements the indirect impact area determined for heat loads in the period of stand alone operation of Paks II does not differ from the direct impact area in terms of nutrient turnover. However, the expanse of the impact area can not be interpreted at the supra-individual level for the release of the invasive species, therefore the impact is recorded but no associated impact area was determined. Accordingly, the entire impact area is identical with the direct impact area.

During the stand alone operation period of Paks II (2037-2085) heat loads lower than the baseline levels are to be calculated with. Beside this, the impact caused by the heat load is also long term, medium strong and high significance in this period as well. Based on the baseline study findings it can be stated that the impact of the heat loads during the stand alone operation will not cause grade level changes in any of the study groups along the affected Danube section in accordance with classification scheme of the Water Framework Directive (WFD). According to the calculations made with the model prepared by VITUKI Hungary Kft. the direct impact area in this period on the downstream Danube section will be identified in a distance of approximately 1 000 m, where its width reaches the mid stream line of the river. The statements written in the paragraph before apply to the indirect impact and its respective area.

Discharge of process wastewater into the Danube

During the use of process water a number of different radioactive and conventional industrial waste water flows are generated in a total amount of 50 m^3/h. Ten 10 m^3/h of this is radioactive, while the volume of conventional wastewater is 40 m^3/h. Under standard operating conditions these contaminations are removed by specific purification processes. Waste water thus generated with contaminant concentrations below the respective limit values are discharged into the Danube through the hot water canal. A part of the contaminants introduced in the wastewater might be present in detectable concentrations after treatment as well. At the same time a further part of the contaminants undergoes further biological degradation when passing along the hot water canal and is discharged into the Danube as the receiver diluted to a great extent (1:0.0001). When the benchmark data were assessed, this impact of the Paks Nuclear Power Plant on the ecological status of aquatic organisations could not be demonstrated. The wastewater flows discharged will not have any detectable impact on the aquatic organisations of the Danube under standard operating conditions. Throughout the entire standard operating period efforts should be made to achieve ever higher efficiency rate of purification and to monitor discharges on an ongoing basis.

During the joint operation period the amount of industrial wastewater discharged is increased to double in this period (~90 m^3/h), but the concentration does not change as a result of the purification process. Based on this the same statements can be made for joint operation which was made to the stand alone operating period of Paks II.

Discharge of treated rainwater into the Danube

Rainwater fallen onto the plant site is passing oil traps and is collected by the northern and southern intercepting ditches where from it is transferred into the cold water canal on the north and the hot water canal in the south. Based on the baseline assessment discharge of the discharge of the hot water into the Danube had no detectable impact on petrochemical products.

Damage to the chemical storage tanks, unloading stations, fuel tank of the Diesel generator set, spill of spent oil or other liquid waste

The chemical storage containers, unloading station, spent oil or any storage facilities for other liquids are designed to be kept indoors. The fuel tank for the diesel generating set is found outdoors. As a summary of the migration tests carried out for the eventual pollutant releases at the site it can be concluded that migration times between the site and the Danube are in the 10-20 years range. Through instant local containment of the spilled oil in the event of eventual damage to the chemical storage containers, fuel tank for the diesel generating set, unloading station, spent oil or any storage facilities for other liquids it can be ensured that the pollutants escaped never reached the Danube. Correspondingly, potential failure events of this kind represent no calculable risk to the surface waters either directly or indirectly.

Escape of untreated municipal wastewater

The breakdown of the waste water treatment plant of the industrial wastewater in itself does not cause the escape of untreated industrial wastewater directly into the Danube or other surface waters, since it is transferred first into the hot water canal first through sludge storage ponds and from there into the Danube. Final treatment takes place in the sludge pond area. Their injury may realistically no contamination in surface waters, rather soil contamination may occur instead. Approaching the issue of discharge of untreated industrial wastewaters into the Danube from the theoretical side the following can be stated. Contamination by discharge into the Danube through the hot water canal is assumed not to result in the destruction of any living being because of the substantial level of dilution (1:0.0003) even in the case of untreated discharges, the impact is thought to be sub lethal, and temporary avoidance of organisms capable of active locomotion can be observed. However, the effects of the toxic substances emitted might have a long term impact on aquatic organisms due to their slow decomposition. This impact, taking into account the extent of dilution in the Danube can not exceed 50 kilometres according to the estimates of the experts.

13.3 Evaluation of the Paks II project in the light of the River Basin Management Plan

Based on the river sub-basin management plan of the Danube (VKKI 2010) the entire domestic section of the Danube has a moderate ecological status, and does not reach the good status. This might partly be derived from qualitative, but also from hydromorphological causes of the same or similar weight, since in terms of chemical status the Danube is classified good. Based on the phytoplankton and phytobenthos none of the classification grades of the Danube Szob-Baja and south of Baja sections are good. This is predominantly due to the hydromorphological impacts originating from flood control works, embankment, channel bottom alterations, since in terms of other elements indicating organic matter contamination all sections received good grade. Macroscopic invertebrates in the macrozoobenthos show a medium-critical contamination level in the Danube and most of its tributaries on the basis of the assessment method approved by the ICPDR. Based on the facts stated in the VGT it can be stated that the achievement of the good ecological status on the Hungarian Danube section is feasible only by a joint effort of all riparian countries. The moderate ecological status experienced as a result of the hydromorphological interventions and pollutant emissions can be improved by a grade level only through large scale and expensive interventions. According to the plans the good ecological status of the Danube water body in the Szob-Baja section marked HURWAEP 444 can be achieved by 2027 as an environmental target (VKKI 2010).

The findings of the benchmark assessment carried out as part of the environmental impact study in 2012 and in 2013 based on the WFD criteria demonstrated that the classification grades of the study elements (physical and chemical parameters of the water: good; FP: good; FB: moderate; MF: moderate; MZB: moderate; fish: good) were appropriate compared to the levels included in the VGT, none of them reflected any worse conditions. All in all the status of the assessed Danube-section defined in the VGT was moderate.

Finer resolution analysis pointed out that the operation of the Paks Nuclear Power Plant causes detectable impact on the ecological structure of the macrozoobenthos, as well as the fish community by the head load from the hot water discharge, while the same impact in the event of phytobenthos could not be excluded. The impact manifested in the structural parameters of the community can be demonstrated up to a temperature differential of $\Delta t=2.5°C$. Temperature change is observed during the operation of the Paks Nuclear Power Plant in a 2 km length along the affected right bank profile of the Danube. As a result of the studies it could also be confirmed that the extent of the impact will not cause any grade level impairment of the ecological status in any of the groups along the Danube-sections concerned.

The key environmental impact in the course of the Paks II investment project is represented by the heat loads. The highest detectable heat exposure is expected to be present in the 2030-2032 period. At this time all the four units in Paks Nuclear Power Plant and the two new units of Paks II will be operational. The total impact area of the heat load can be specified as a maximum 11 km distance on the Danube downstream section. This profile is found at Danube 1515,8. river km. Therefore it can be stated that no transboundary contamination can be reckoned with for heat loads.

Based on what was discussed in former chapters the group of organisms bearing the direct impacts will be the phytobenthos, macrozoobenthos, as well as fishes. Indirect bearers of the impact include mainly consumer organisations - macrozoobenthos, fishes. The most intensive indirect impact of hot water is thought to be the role played in the penetration of invasive species. The impact caused by the heat load on the impact area is long term, strong and high importance. It can be concluded on the basis of the findings obtained from the ecological status assessment that the impact of heat loads will not cause any grade level impairment of the ecological status in any of the groups along the affected Danube-section when classified according to the WFD. The same applies to the aggregate ecological status.

During the stand alone operation period of Paks II (2037-2085) heat loads lower than the baseline levels of Paks Nuclear Power plant will be present according to the model calculations. The impact area in this period on the downstream Danube section will be in a distance of approximately 1 000 m. This also means that a better than present environmental status can be anticipated from the year 2037 on the downstream section of the discharge point.

Based on the studies it can be stated that the investment project Paks II has no influence on the objectives set for the water body of the Danube concerned, and on the attainment of the good ecological status for the Danube water body affected, the date of the target objective should not be amended for this reason.

14 GEOLOGICAL MEDIUM AND UNDERGROUND WATER ON THE SITE AND IN THE IMMEDIATE VICINITY

Definition and characterisation of the condition of the geological medium and underground waters in the area of the Paks Nuclear Power Plant cover the assigned extension site and its local area (3 km, the nearest drinking water base is Csámpa).

The characterisation of the underground water environment extended to the groundwater, potential water bases of the bank filtrated wells and confined groundwater (aquifer) storage layers located within the area surveyed. With respect to groundwater and confined groundwater, the horizontal extent of the study area was determined by the underground water level and water quality detection network consisting of more than 220 wells and operating currently on the site and in the vicinity of the nuclear power plant, as well as the wells of the Csámpa Waterworks. Taking into account the position of the confined groundwater aquifer, the studies affected the vertical geological section extending down to a depth of 210 meters when calculated from the surface.

Two types of underground water occur in the region: confined groundwater in the Pannonian sand layers which is located deeply under aquitards, and above the latter, contiguous groundwater in the Pleistocene-Holocene beds.

On the site, a filled-up layer of varying thickness and composition is situated up to the groundwater, under which new Holocene casting clay, casting sand and casting sludge are located. When moving away from the Danube bed, a lower holocene quicksand bed covers the original ground level. Through the above layers, precipitation may reach the groundwater while leaking vertically. The low floodplain is covered by a network of former meanders (ox-bow lake) filled up. Currently, the area is protected from flooding by flood-control dams built at a 96-97 mBf level, but changes in the Danube water level - primarily through the material of a former bed being disconnected - vividly influence the evolution of the groundwater level.

About 6-8 m above the upper and middle Pleistocene alluvium of the Danube, the latter's lower Holocene terrace rises up, which is made of riverine small and medium-grained sand interspersed with small gravel layers. The latter's surface is covered by upper Holocene quicksand. The Danube has little or no effect on the groundwater conditions of the terrace.

The Danube valley is flanked from the northwest by a loess plateau rising to a height of 160-180 mBf. Precipitation falling on the surface of the loess plateau, seeping in the soil and gathering above the clay zones is led to the erosion base (Danube) in the more porous layers. This is the feeding area of the Danube Valley groundwater. The aquitard bedrock of the groundwater storage layer is composed of upper Pannonian sedimentary material which consists of sand, clay marl, marly rock flour, i.e. alternating aquifer and aquitard layers of different thickness and development levels in the whole area. The vertical infiltration coefficient of the upper, 20-30 m thick part is 10^{-6}-10^{-7} m/s. The thickness of the Upper Pannonian formations in the area is around 500 m. Due to the pressure conditions of the water stored in the aquifer, groundwater cannot flow down to the confined groundwater under natural condition.

Within the area, the groundwater forms a contiguous system, the average groundwater level is located in the upper fine debris (sandy, rock flour) formations, at an 8-10 meter depth under ground level. The prevailing groundwater level is mainly regulated by the current water level in the Danube.

In the event of high water levels and floods, the river feeds into the groundwater aquifer layers, and groundwater seeping from the background swells back with an increased groundwater level. According to data obtained from groundwater monitoring wells, the effect of water level changes in the Danube - water fluctuation exceeds 8.5 meters – is mostly manifest in a ca. 200-500 m strip lining the river, but this effect is also detectable at a 1,500 meter distance from the riverbank edge. This effect is delayed and occurs only during long-term floods, the rate of water level increase is getting smaller when moving away from the riverbank. During short-term flood waves, it is insignificant. The increase of groundwater levels caused by floods is manifest ca. 2 days later at a 100-200 meter distance from the shore.

In the vicinity of the cold water canal, maximum groundwater levels are expected to be around 94 mBf. In the power plant areas situated more remote from the Danube, the multi-annual average seasonal water level fluctuation is around 2 m. The groundwater flow rate is not uniform, but it varies depending on the particle composition of the aquifer.

In terms of chemical composition, the groundwater has calcium hydrogen carbonate. The TDS content of the water on the average is 300-400 mg/l, with a slightly alkaline pH, a total average hardness of 15–25 nk^{o} (German hardness), a typical chloride ion concentration of 20–30 mg/l, and an average sulphate ion content of 100–150 mg/l. Typically, the iron (0.5–1.0 mg/l) and the manganese (0.3–0.8 mg/l) content is higher.

14.1 MAIN PROCESSES OF THE UNDERGROUND WATER FLOWS IN THE VICINITY OF THE SITE

Groundwater

The complex groundwater and confined groundwater flow model studies of the immediate vicinity of the Paks Power Plant site, as well as the analysis of the spread of the most mobile related radioactive material, namely, tritium (^3H) have been completed. Since the power plant is located on the bank of the Danube, the main contributor of the groundwater and confined groundwater flow prevailing in the vicinity is the Danube itself and the closely related cold water canal (HVCS). In addition to the two main factors, Lake Kondor and the western loess plateau have a strong impact. In the vicinity of the site, all of these together determine the flow conditions of underground water for the given period.

The area can be characterised with the following comprehensive velocity spaces:

- In the vicinity of the northern side of the main building and the HVCS, velocities are significantly higher in most cases than on the south side. The difference may even be up to 1 - 2 orders of magnitude.
- Two zones moving in the opposite directions meet on the southeastern side. For this reason, a slow-moving zone is formed to the north of the O5 well.
- For the T battery of wells (east of the O battery of wells) a flow away from Lake Kondor has evolved (southern) during the entire examined period.

By comparison of maximum velocities it can be stated that the lowest velocity evolves during medium Danube levels, Vmin = V_{min} = $7{,}7 \cdot 10^{-6}$ m/s. The highest velocities are seen during minimum Danube water levels, V_{max} = $1{,}6 \cdot 10^{-5}$ m/s. The above velocities are typical along the Danube and the HVCS, groundwater flow is slower in the immediate vicinity of the main building. The above velocities mean a travel distance of 0.66 - 1.38 meters in the vicinity of the HVCS. The difference between speeds measured next to the HVCS and the main building may be greater by an order of magnitude. The calculated daily distances travelled in the vicinity of the main building fluctuated between 0.028 – 0.53 meters as a function of time and place. Vertical displacements and oscillating movements are also seen in the unsaturated zone. The velocities are several orders of magnitude smaller than those in the saturated zone.

To evaluate the mutual impact of groundwater and surface water, we have created a hydrologic model applying conditions present in the event of extreme Danube water levels for the site and its direct vicinity. We have selected the relevant extreme values from a thirteen-year (2000-2013) dataset of the Paks watermark post and the waterworks at the HVCS. The lowest water level occurred on 03/12/2011. At the Paks watermark post, a 84.81 mBf level was measured, whereas at the HVCS, a water level of 84.3 mBf was detected. The highest value occurred on 11/06/2013. At the Paks watermark post, a 94.29 mBf level was measured, whereas at the HVCS, a water level of 94.01 mBf was detected.

In case of extremely low water levels in the Danube, the relevant processes follow those defined during the low water level, i.e. an eastern flow from the Fish ponds to the Danube, and a northwestern flow to the HVCS can be observed. A northeastern flow can be observed from the site of the current power plant, whereas groundwater flows to the HVCS in an eastern direction from the western loess plateau. This means that in case of low HVCS and Danube water levels, the fish ponds behave as sources, whereas the Danube and the cold water canal behave as sinks.

Although in case of extreme high water levels in the Danube, the relevant processes follow the trends defined during high water levels, but the backwater is much stronger. In the southern part of the Danube next to the site, a western dam effect can be observed towards the fish ponds. On the southern side of the HVCS, a southeastern dam effect can be observed in the direction of the ponds, as well. Flows to the west and the east (from the western loess plateau) meet south of the HVCS at the diversion ditch, thus the latter works as a sink. Northwestern flow is observed on the west side of the HVCS which subsides when meeting the southeastern flow arriving from the western loess plateau. In this case, the Danube and the HVCS represent the source and the fish ponds the sink components.

We have connected the model velocity space with places for which we have assumed that the given location, e.g. area under a block or a given section of a pipeline may function as a source of tritium. When calculating the tritium lens, we have assumed that at the selected locations, due to the tritium leak into the ground, a concentration higher than the value characterizing the unladen area emerges. The model calculated the further spread of the tritium amount introduced at these locations and introduced as an initial condition matched with the measured data. We have obtained the tritium lens given as an initial condition from a "steady-state" simulation before transient calculation, solving equations corresponding to a time-constant condition. In case of calculations related to tritium, we have primarily focused on the vicinity of the main building. The validating wells surround the main building. Access times between the main building and the nearest groundwater monitoring wells is 1-6 months, whereas these range between 12-20 years between the main building and the Danube, depending on the water level of the Danube. In addition to the model calculations we have validated these data by $^3H/^3He$ groundwater ages calculated from highly sensitive tritium and dissolved helium isotopes.

Confined groundwater

In the Paks region, the porous levels of the Upper Pannonian layers store confined groundwater. The average amount of confined groundwater is 1.0-1.5 l/s/km^2. The depth of tapped Upper Pannonian aquifers ranged between 60–229 m. At the time of their construction, the static water levels in the wells ended up above the given ground level, so we could speak of positive wells. Pressure levels varied between +0.1 – +6.7 m, characterised by a positive pressure gradient regardless of the depth of the aquifers. Specific discharge rates ranged from 5.2–87.7 l/min/m the temperature of groundwater extracted varied between 14-23°C depending on the depth of the aquifers.

Based on the above, the shallow confined groundwater of the Upper Pannonian sediments are likely to form several independent and separate hydraulic systems. Based on pressure conditions, communication is only possible from confined groundwater towards the groundwater.

The quality of confined groundwater is primarily dependent on the material composition of the aquifer. The usual type of water is based on calcium magnesium bicarbonate, with an alkaline pH. The TDS concentration is usually less than 1000 mg/l. Generally, water from deeper layers contains more dissolved salt. The chloride ion content (10-190 mg/l) increases as a function of depth. The water is practically free of sulphate. Due to the significant iron and manganese content, the water must be treated.

Drinking water supply for the Paks Nuclear Power Plant is provided by the Csámpa-puszta water base. Currently, the water extraction and monitoring system is composed of 4 producing wells and 3 reserve wells. The total yield of producing wells fluctuates around 800 m^3/day, which will increase to 1400-1500 m^3/day in the Paks II construction phase according to preliminary calculations. The increase amounts to 650 m^3/day. Over the past 10 years (period between 2004 and 2013), the rate of extraction exhibited a decreasing tendency with the result that both the resting and operating water levels increased. We have defined the flow directions in the vicinity of the wells, 50 years migration paths and depression cones developing upon the effect of increased extraction. Based on the hydrological model of the water base it is excluded that groundwater from beneath the Paks Nuclear Power Plant enters the Csámpa-pusztai water base, this is an upwelling area, so the pressure increases with depth. We have excluded the presence of any potential fresh water component in the confined groundwaters also by high accuracy laboratory control measurements at the locations of the confined groundwater wells in the area of Csámpa and the nuclear power plant.

14.2 Impact of construction and operation of Paks II on the geological medium beneath the site as well as the underground water

No serious large-scale works and thus, not even their impacts should be expected in the planning period. Only logging and minor earthworks related to the relocation of utilities can be expected. Several groundwater monitoring wells are located also in the investment and mobilisation area, their elimination/relocation must be provided.

Soils from the working pits to be used for the foundation of new facilities are regarded as wastes in general, however, their deposition can be provided at the construction site. A preliminary humus removal plan must be prepared for handling humus layers. The selectively depleted humus-based topsoil may end up in a landfill in the investment area and can be used in the future for landscaping. Another option is that after removal from the construction site, it can be utilised for thickening topsoil in an area with similar characteristics. The impact of preparatory works is neutral. During construction, the effect of extraction of humus-containing soils occurs on a one-off basis, it can be properly demarcated in time. The humus-containing soils currently in a buried state are utilised, so this can be regarded as an improving effect.

By construction of working pits, slopes and temporary roads, the dust management of soils comes to the foreground, as well. This effect applies only to a depth of 20 cm from the surface. The average design-based particle size of soils explored by working pits varies between 0.10.3 mm, so these soils tend to generate dust due to their grain composition. Soil dusting occurs especially in the dry, hot summer season. The phenomenon is not significant in the winter during lower temperatures and high relative humidity. Dust generation of soils as an effect can be regarded as negative with regard to air quality, especially in the narrow vicinity of earthworks, the impact area determines on the size of working pits. The phenomenon of dust generation is periodic, only related to open working pits, the negative affect can be reduced by watering or spraying the transport routes with gravel.

The stability of working pits for foundations - above the groundwater table - is mostly endangered by intense precipitation. Sandy soils are very sensitive to erosion, so a proper state of working pits can be only ensured by proper drainage of precipitation (trenches, pits, soil stabilization, sheet piling).

In the construction area, an increased layer load is expected due to the weight of facilities. Increased compaction of soils is a consequence of the growing layer load. Even after depositing, the volume of sandy sediments characterized by uniform particle size may even decrease by 20% by a simple rearrangement of particles. The largest extent of compression is exhibited by fine-grained pelite-based sediments containing organic matter, whereas the smallest extent by coarser-grained clastic sediments (sandy gravel). All of these formations can be found in the investment area, but the load effect of facilities may primarily affect sandy sediments. The impact of foundations on the subsoil can be regarded as neutral, moreover, some physical properties of the soil (e. g. compactness, water transport capacity) will be improved. However, uneven soil subsidence accompanying compaction may have an adverse effect on the structure of buildings.

During construction of the new power plant, dewatering of the working pit created for foundation will impact the groundwater level and a high amount of groundwater will be removed by dewatering which will end up in the Danube. We have placed the planned deep foundation buildings of the relevant blocks according to the technical layouts, which were taken into account as inactive cells (cells eliminated from the flow of groundwater) in the status after construction. Based on technical specifications, the foundation depth of the above-named buildings can be assumed to be between 16 and 20 m. In our study, we assumed a uniform depth of 20 m, in order to remain conservative. Foundation works for the new blocks is not likely to be performed simultaneously, therefore, in the model, we have examined their impacts separately (first Paks Block II. 1 then Block 2).

We have surrounded the working pit, taken into account by the model as an inactive cell by a drainage network. The amount of water passing through the drainage network is identical with the volume of water to be removed for the reason of dewatering. In practice, the placement of a kind of protective wall or a sheet pile will probably be necessary at the edge of the working pit, which will play a role in decelerating the backfilling effect and physical stabilization of the slope. In the model we have surrounded the excavation trench with a wall, the depth of which exceeded the 20 meter depth of the excavation trench by a few metres.

The average value of annual water level fluctuations measured in the observation wells in the entire area of the site is a little more than 3 meters. The average value of annual water level fluctuations measured in the monitoring wells in the northern party of the site, the construction and temporary construction site is a little more than 4 meters. For demarcation of the impact area, we have defined the impact of dewatering of foundation excavation trenches with the average value of annual water level fluctuations in all monitoring wells of the site (~3.12 m = 3 m).

Suction values of 3-3.5 meters are observed in the immediate vicinity of the northern side of the current power plant. These values are not likely to cause static problems at the northern side of the main building because during the years, the soil has consolidated under the weight of the building and impacts of at least this extent are still present as a consequence of fluctuations of the Danube water level. During dewatering of the working pit of the second block, a minor decrease of the water level can be observed because the floor areas of facilities belonging to the 2nd block are smaller. The impact area does not extend to the northern tip of the current blocks, so no effect whatsoever can be expected in the area of existing blocks. However, when making the foundation of the first block, the impact of dewatering of the second block must be taken into account.

The depression cone caused by dewatering of working pits "attracts" water from its environment, and the most mobile pollutant, notably tritium also moves along. Normally, the tritium plume flows towards the cold water canal in a north-northeast direction. As a result of dewatering, it will take a northerly direction.

The following two conclusions can be clearly drawn from the hydrological model of the site: dewatering has only a very limited impact (an impact area encompassing some 10 meters in diameter), and any contaminant entering the groundwater can only end up in neighbouring countries by an indirect route (groundwater→Danube). During normal operation, no contaminant release to the groundwater whatsoever is allowed. It can be generally said that even in the event of malfunction, the amount of contaminants entering the groundwater is only a fraction of the planned liquid release, so it does not have a transboundary impact, and it does not alter the effects arising from otherwise dominant atmospheric spread within a relevant margin of error.

Flow paths and access times derived from the modified hydrological model of the site (with the addition of the locations of new blocks, hot and cold water channel extensions and other buildings which may modify the current flow conditions) is aligned to the characteristic low, medium and high water levels of the Danube. The model runs show a permanent condition, which means that the Danube water level is constant throughout the period of operation. The independent operation of Paks II will extend from 2037 to 2090. There will probably be some overlap between individual operating periods. The effect of Paks II on the flow direction and velocity of the groundwater can be observed in the volume under buildings with deep foundations or their direct vicinity. Flow is diverted along the sides of buildings, but even this way, the prevailing direction will also point toward the cold water canal. The flow rate will increase in the volume under the relevant buildings because water can flow through the smaller volume between the clay layer and the foundations. In the case of low and medium water levels, the relevant directions do not deviate from the aforementioned direction, only the velocities will change in such a way that the greatest velocities towards the cold water canal will be manifest at low water levels. We wish to emphasize that the permanent model runs are pessimistic estimates and they refer to 53 years. Such low and high waters lasting even half a year longer can never develop along the Danube because the discharge rate and the water level of the river are constantly changing.

Based on the assumed position of calculated flow paths and technological systems, we submit proposals regarding the installation locations of the groundwater monitoring well network related to the monitoring system. Monitoring wells must be placed in such a way that no matter where there is uncontrolled leakage into the groundwater or into the unsaturated zone, the monitoring system must be capable of detecting it at a high level of security within the shortest time possible and well before entry of the contaminants to the Danube. When designing the relevant wells, it should be taken into account that the impacts of the two power plants should be clearly distinguishable. Wells located near the block buildings should be designed after completion of the foundation and subsequent landscaping works. For confined groundwater wells, it must be considered that a technical error in drilling or a drastic reduction of the pressure of confined groundwater should not be able to give rise to migration of potential contaminants to the water base even by their combined effect. Since these wells provide no additional information which is substantial in the construction and subsequent operational phases, we propose that confined water wells are installed only in a limited number.

Since in the event of normal operation, the radionuclides released from the two new blocks will by far not increase the total alpha activity of the Danube water by 0.5 Bq/dm^3, and the total beta activity 1 Bq/dm^3 activity concentration, tritium will be the only isotope with a measurable impact even in this case. The two blocks will be only capable of increasing the tritium activity concentration of the Danube by 0.96 Bq/dm^3 in the case of low water. For comparison, the tritium activity concentration of the current precipitation is 0.5-2 Bq/dm^3 and the drinking water limit is 100 Bq/dm^3, so it has no significant impact either on the Danube or the bank-filtered water resources utilizing water from the Danube, so the impact area cannot be properly interpreted.

14.3 OPERATING TROUBLES, FAILURE EVENTS

Since individual scenarios present the entry of radioactive contaminants into the groundwater as unlikely, contamination of groundwater is only possible in an indirect form. Atmospheric fallout and/or leaching to the soil surface → then spreading in the unsaturated zone until reaching the saturated zone. This process will not have an effect on the groundwater due to the large sorption capacity of the soil and the isotope specific access time which may be even hundreds of years (even for tritium, the infiltration time may range from a few years to 10 years). However, it is also true that after possibly reaching the saturated zone, the Danube will be the final destination of groundwater (and the material moving along) due to typical flow characteristics. However, since access times between the site and the Danube range between 12-20 years even for tritium flowing along with the groundwater, there is sufficient time for treatment handling and clean up of any potential event before the contaminants released could reach the Danube. Thus, this event will not affect the bank-filtered water bases.

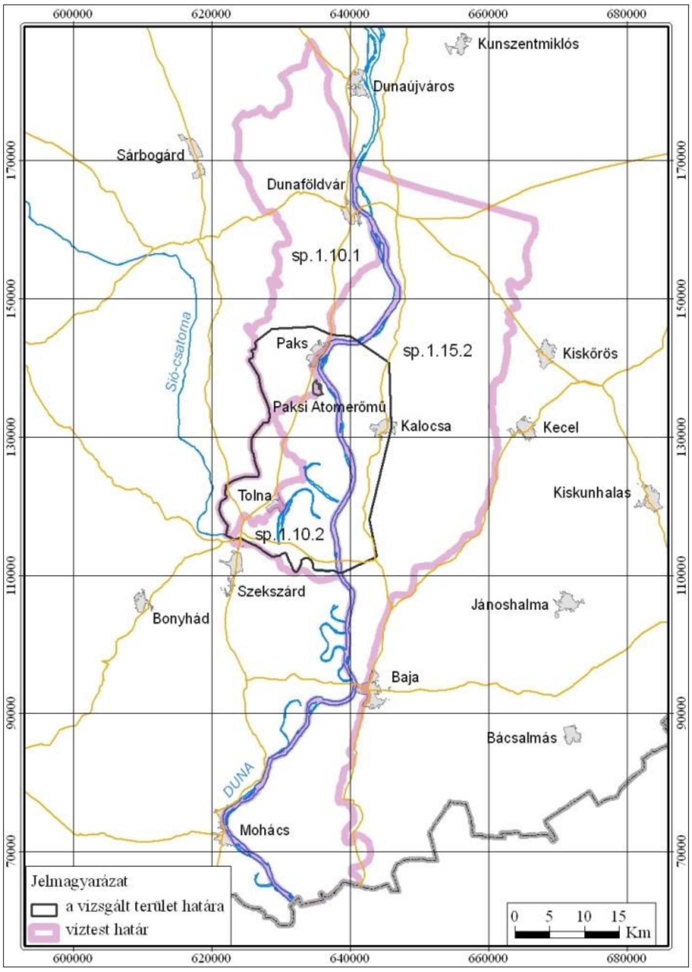
In the planned area of the new blocks, the storage of chemicals, oil content of transformers and diesel oil storage can be named as the most likely potential contamination sources.

The spread of oil contaminants is basically determined by 4 processes: advective transport, dispersion, sorption and biodegradation. While only the (relatively small amount of) oil content adsorbed to the soil particles remains in the drainage zone after completion of oil infiltration, the amount of free oil is enriched in the capillary zone and its movement is restricted by the impact of capillary source. While oil moves relatively quickly in the drainage zone, the capillary zone may retain higher amounts of oil even after months or even years. The maximum vertical velocity of oil lens spread may only fall to a maximum range of 10^{-8} m/s in the typical geological formation. The plant area is ca. 1000 meters away from the Danube riverbank edge, so the migrating oil lens would reach the Danube in ca. 3000 years. Since oil contaminants are less soluble in water (20-80mg/l), direct groundwater transport will not be a dominant factor, although event the latter would need 12-20 years to reach the Danube. The biodegradation half-life typical of oil derivatives is in the range of 1-2 years (while sufficient oxygen content is ensured) so sufficient time is available for demarcation and clean up of the assumed oil lens before it would reach the Danube.

The following chemicals are used (stored) in large amounts: Boric acid (in solid form and predominantly within containment), hydrazine, ammonia, sodium hydroxide, potassium hydroxide, hydrochloric acid and nitric acid. The unloading station will be designed in such a way to prevent chemical leaks or spills when unloading chemicals. In order to prevent chemicals from release to the environment in connection with failure events, proper secondary containment facilities will be formed and thus their soil and groundwater load should not be expected.

15 GEOLOGICAL FORMATIONS AND GROUNDWATER IN THE DANUBE VALLEY

Under section 2. c) of Appendix 2 to Government Decree 219/2004 (VII.21.) on the protection of groundwater, the surrounding of Paks Nuclear Power Station is to be treated as a sensitive area from the perspective of the condition of groundwater. But for the hydrogeological attributes of the Danube Valley, the impacts of Paks II. on subsurface water outside the site can spread only in an indirect way, via the Danube.

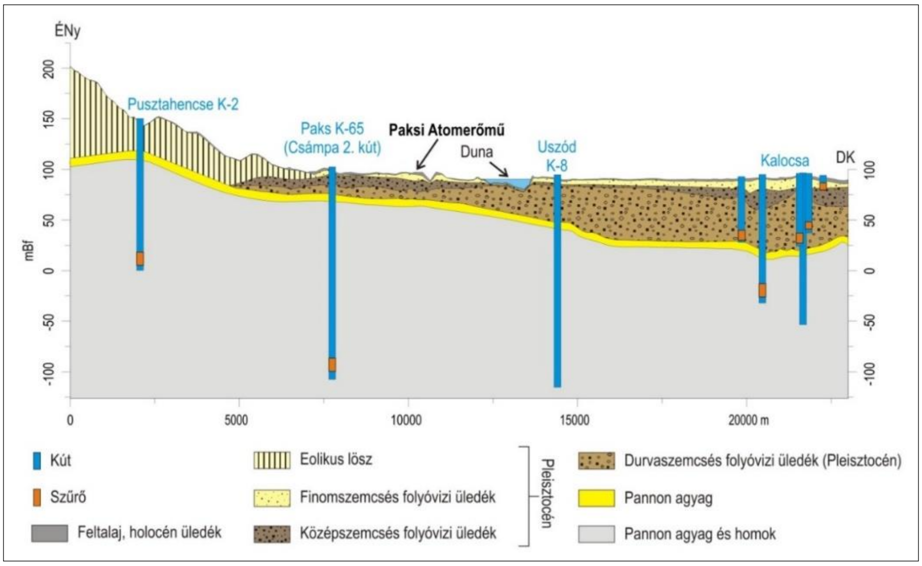


Paksi Atomerőmű-Paks Nuclear Power Plant
Jelmagyarázat-Legend
a vizsgált terület határa-Boundaries of the area under study
víztest határ-boundaries of a body of water

Figure 74: Relations between the affected bodies of water and the area under study

The relations between River Danube and the groundwater system are manifold, dependent on the water cycle of the Danube; they affect groundwater in different ways to different extents.

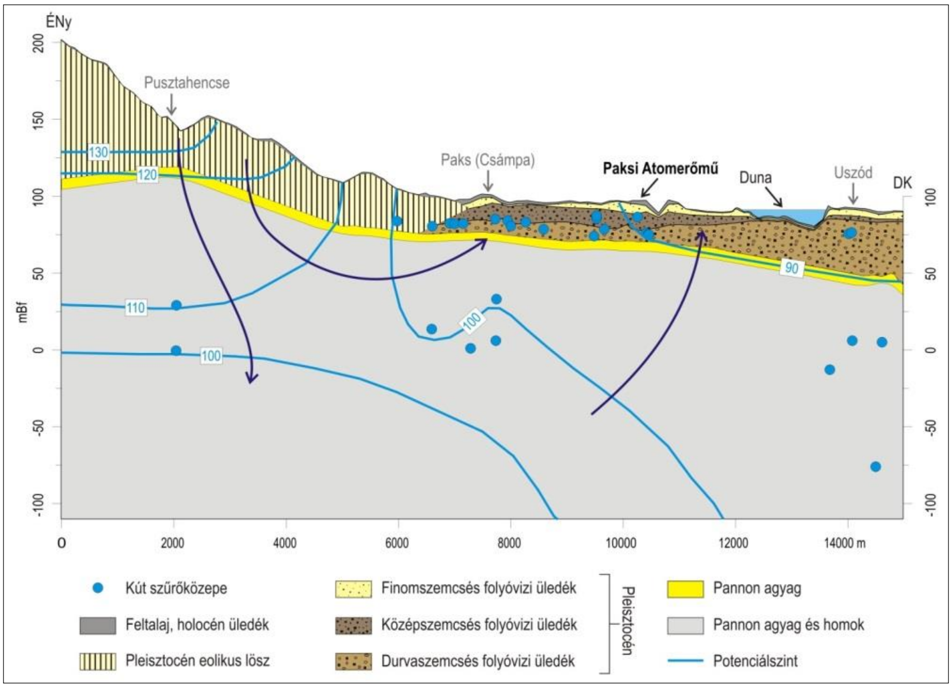
Groundwater in the Danube Valley is stored in a Danubian alluvial, pebbly, sandy sequence from Pleistocene and Holocene ages. The general direction of groundwater flow follows the descent of the terrain; the flow runs from NW to SE on the right bank while from East to West on the left bank. The highest groundwater levels can be found on the loess plateau West of Paks. The hydraulic gradient significantly declines from Mezőföld towards the Danube.



ÉNY-NW (Northwest)
Csámpa 2. kút-Csámpa 2. well
Paksi Atomerőmű-Paks Nuclear Power Plant
DK-SE (Southeast)
mBf - metres above Baltic Sea level
kút-well
Eolikus lösz-Eolic loess
Durvaszemcsés folyóvizi üledék (Pleisztocén)-Coarse-grained fluvial sediment (Pleistocene)
Szűrő-Filter
Finomszemcsés folyóvizi üledék-Fine-grained fluvial sediment
Pannon agyag-Pannonian clay
Feltalaj, holocén üledék-topsoil, Holocene sediment
Középszemcsés folyóvízi üledék-Medium-grained fluvial sediment
Pannon agyag és homok-Pannonian clay and sand

Figure 75: The NW-SE hydrogeological section crossing the area under study

In natural self-potential conditions, the Danube drains underground waters coming from tributaries. With the rapid changes in its water level as compared to changes in groundwater levels, River Danube controls groundwater levels along the bank. In natural seepage circumstances, pressure spread is rarely accompanied by an actual flow into the groundwater-bearing stratum. Danubian pressure waves typically have a backwater effect on groundwaters, rather than injecting them back into the strata.



ÉNY-NW
Paksi Atomerőmű-Paks Nuclear Power Plant
DK-SE
SE-SE
mBf - metres above Baltic Sea level
Kút szűrőközepe-Well filter centre
Finomszemcsés folyóvízi üledék-Fine-grained fluvial sediment
Pannon agyag-Pannonian clay
Feltalaj, holocén üledék-topsoil, Holocene sediment
Középszemcsés folyóvízi üledék-Medium-grained fluvial sediment
Pannon agyag és homok-Pannonian clay and sand
Pleisztocén eolikus lösz-Pleistocene Eolic loess
Durvaszemcsés folyóvízi üledék-Coarse-grained fluvial sediment
Potenciálszint-Self-potential level

Figure 76: Self-potential log crossing the Paks Nuclear Power Station

Based on an evaluation of water level time series measured in monitoring systems operated by the Paks Nuclear Power Station and by Water Management Directorates, the hydrodynamic impact area of the Danube in times of the highest floods extends to ca. 1000 metres and 1200 metres from the bankline on the right and left sides of the river, respectively.

The hydrodynamic impact area of the Danube is not identical with the range of contaminants from the Danube. In most of the year groundwater seeps from tributaries towards the Danube, and the Danube drains groundwater-bearing formations. In natural circumstances, water seeps from the Danube into the sequence containing groundwater in the course of steep surges (floods) only. The water moves towards tributaries only as long as the water level of the Danube maintains that reversed flow system.

In stretches where a series of producing wells operate along the bank, the flow from the Danube becomes permanent as a consequence of such production.

There is only one operating bank-filtered water resource within the assessed area, it is the Foktő-Baráka (Kalocsa-Baráka) water resource on the left bank of the Danube that supplies water to Kalocsa. For the time being, Gerjen North perspective water resource has only been given a preliminary building permit, meaning that it is a committed water resource where water works is envisaged to be erected to supply water to Szekszárd.

Due to its geological structure, the section of Danube downstream of Paks has a large quantity of good quality bank-filtered water reserves. Accordingly, the state treats that volume of water as potentially exploitable water reserve. The water reserve is to be protected in the long term, and “perspective water resources” were designated, whose protection zones were defined in Government Decree 123/1997 (VII.18.). Pursuant to the legislation, the zones of water resources are highly sensitive areas. In the perspective bank-filtered water resources within the area under study, the proportion of the Danube in the potentially exploitable volume of water is about 50%.

The hydrodynamic impact area of the Danube does not coincide with the area within which Paks II. may exert an impact on groundwater. The results from modelling the site and the surface water of the Danube show that no such contaminant will be transported in the Danube either in the course of its operation or in the event of its breakdown or failure that would have to be included in the study of indirect effects.

The indirect effects of Paks II. on groundwaters in the Danube Valley are manifested through the the thermal effect of the Danube.

The seasonally changing temperature of the Danube influences the temperature of groundwaters along the riverbank. The mode and extent of heat transport between waters flowing in the riverbed and under the surface may vary depending the current hydrological and temperature conditions. The thermal load generated by Paks II. will modify natural conditions. We used numerical hydrodynamic and heat transport modelling to examine the future changes occurring in underground water in terms of time and space.

Unlike for surface waters, the legislation fails to set out upper limit for groundwater temperatures, which, if achieved, would mean that the body of underground water is in poor condition, and therefore the impact of Paks II is evaluated on the basis of the temperature changes it causes (ΔT). The condition without the operation of Paks II. (2014) is considered as the baseline condition. The impact was studied for two scenarios: the joint operation of Paks Nuclear Power Station and Paks II in 2032 on the one hand and the single operation of Paks II (upon the shutdown of the first block) in 2085 on the other. The temperature parameters of the Danube in those periods came from the results of our efforts to model the Danubian surface water.

In assessing the impacts, we used conservative estimations, by looking at extreme hydraulic cases (permanent low water condition in summer, and flood wave passing after low water in summer) for a higher level of certainty.

It can be concluded that even conservative estimates suggest that the indirect impacts of Paks II. will not result in a monotonous, permanent temperature rise in the groundwater system. The groundwater temperature rise of a few ^{o}C may occur only in summer in the hydraulic situation of constant low water. According to the hydrodynamic modelling, in case of the joint operation of Paks Nuclear Power Station and Paks II. (2032), during peaks loads a groundwater temperature rise of only 2.8 ^{o}C is foreseeable even in the worst case in the vicinity of warm water inflows in the layers close to surface most impacted by the live stream of the Danube. At the same time a temperature rise of a few tenth of ^{o}C is likely to occur on the border of the area under study, along the line of the Sió channel.

In case of the single operation of Paks II. (2086), those values would decrease to a level nearly identical with the present baseline condition. The temperature rise does not appear in the line of the Sió channel.

Practically, temperature rise can be hardly detected in the sandy-pebbly layers that are of key importance for water producing sites; such temperature rise being less than 1 ˚C.

As far as we currently know, a few ^{o}C temperature increase in the temperature of the groundwater will not cause the quality condition of water bodies to change. It will not cause any damage either to natural systems or to the layers produced by water works. It has no detrimental effect on the production of water works.

16 NOISE- AND VIBRATION

16.1 NOISE- AND VIBRATION LOAD BASELINE MEASUREMENTS

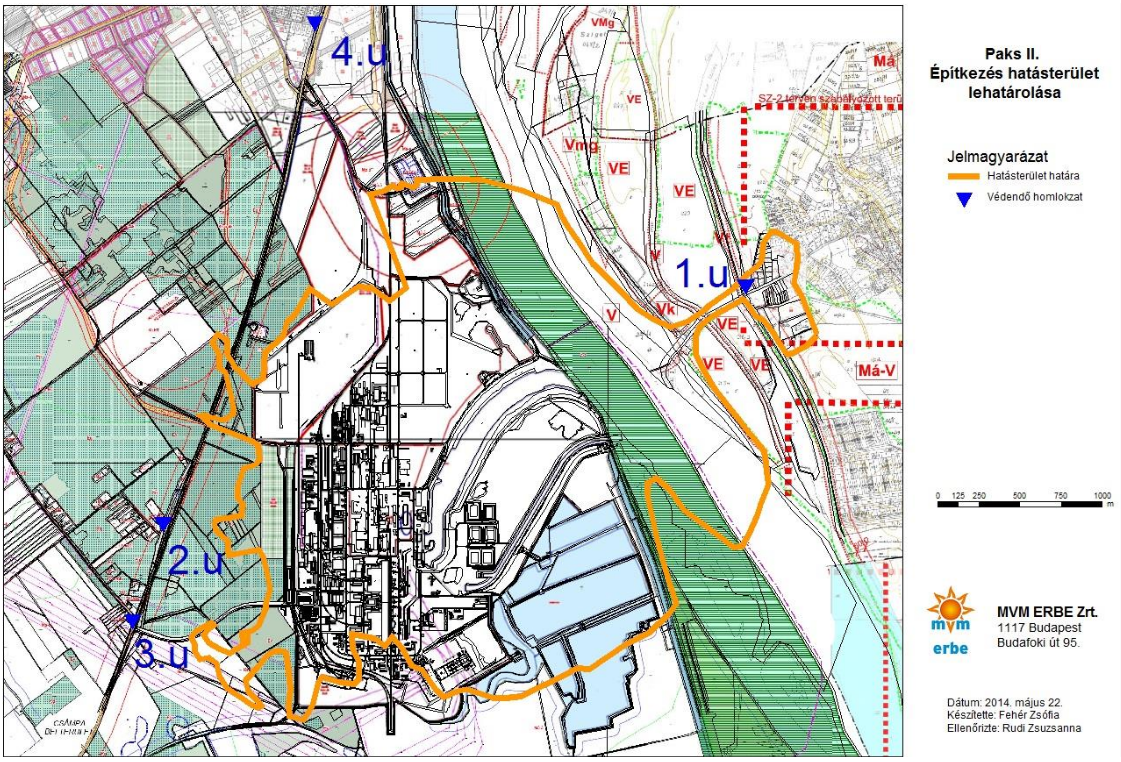
Regarding the ambient noise in the vicinity of the power plant caused by traffic we can in general state that the noise caused by traffic on the frequented roads along residential areas is quite significant, and the traffic distribution and density can primarily determine the ambient noise status of areas exposed to traffic. The baseline noise load of residential areas located next to heavy traffic roads is often in excess of the noise load limits in effect in these areas. The heaviest traffic periods are between 05:00 and 08-09:00 a.m. and 15.00-18.00 hours in the afternoon, but in all other periods traffic keeps on receding in most measuring points and comes to a halt at night. Consequently, noise load and limit can usually be exceeded during these peak periods. The baseline noise load in the environment of residential buildings at the Duna embankment area is at all points below the permitted noise load limits.

Regarding all vibration measuring points studied in connection with the project implementation we can state that vibration from the source of vibration and road and railway vibration induced from sources of vibration in the potential impact zone of Paks II. due to higher vibration load. After the assessment of all data measured during the baseline vibration load study we can state that the vibration load for the measuring/judging time is lower in all the three orthogonal directions than the vibration load limit.

16.2 IMPACTS AND IMPACT AREAS OF PAKS II IMPLEMENTATION

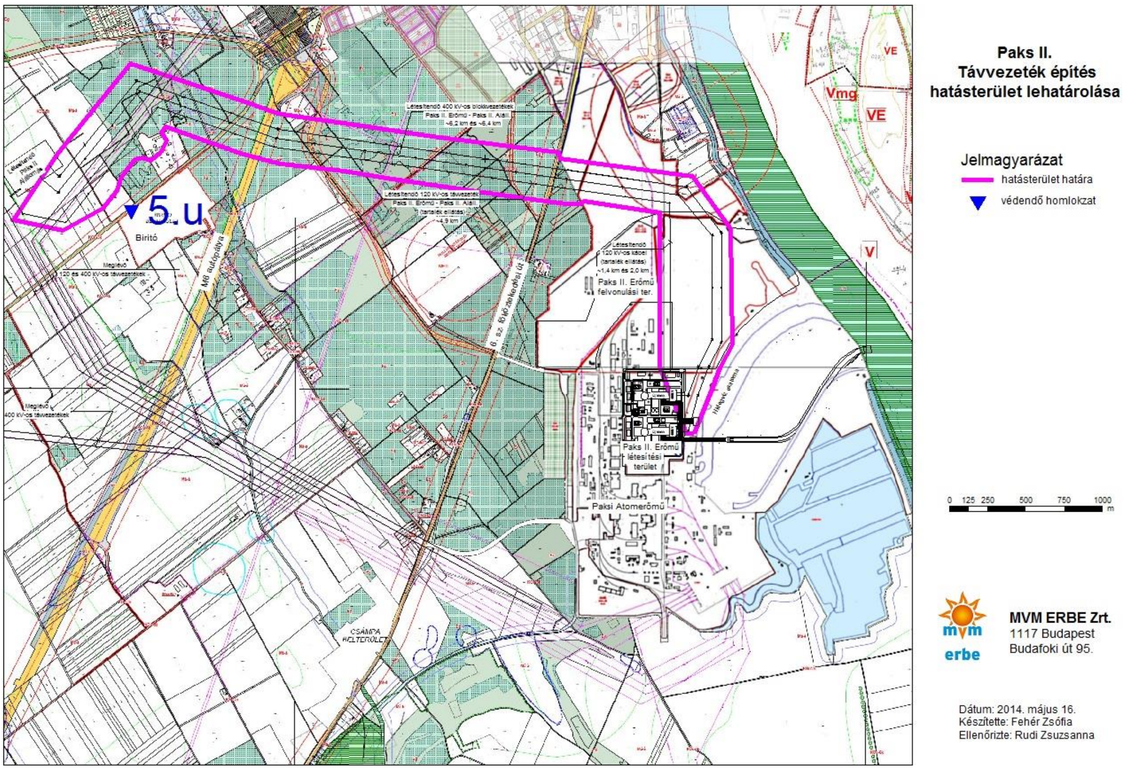
The noise load limits set out for the protected areas and buildings can be observed in every phase throughout the construction works in the plant area and along the transmission lines. Noise load limits can be also observed at the protected points along M6 motorway including the baseline load and the 0,6-0,8 dB noise load increment arising from the higher traffic rate due to Paks II implementation. Calculation results at the protected points along road no. 6 (and also the baseline measurements) can verify limit excess in the current baseline status. The traffic increment arising from Paks II implementation would most presumably increase the baseline values with 0,8-2,1 dB. During the construction phase daily one (1) freight train would cross the area so the noise limits can be observed.

The aggregated construction impact area covers the Paks Nuclear Power Plant site and non-residential adjacent areas, and the residential buildings along the Duna river and on the western side of Dunaszentbenedek village (Figure 77). The aggregated impact area for the transmission line construction is located on a nearly 70 m business zone, cca. 100-150 m from these lines in the environment not to be protected from noise and 120-300 m towards Biritó (Figure 78). The change in noise load caused by road traffic during the demolishing and construction periods is between 0,6-2,1 dB, thus we cannot define as an indirect impact the road traffic impact area for the construction and demolishing phases of the project as specified in the Decree. The theoretical border of the impact area cannot reach the area or building on the area to be protected in any of the studied settlements, thus the barge traffic related to the foundation works – with very low intensity, and may include daily 1 towing ship with 6 barges) will have no impact area. There will be impact zone on the area or facade to be protected due to railway transportation during the implementation period – i.e. from daily one (1) freight train. We cannot predict any cross-border noise impact arising from the implementation of Paks II. Project.



jelmagyarázat – legend, védendő homlokzat - protected façade, hatásterület határa – borderline of impact area, dátum – date, készítette – prepared by, ellenőrizte – reviewed by

Figure 77: Total impact area of implementation

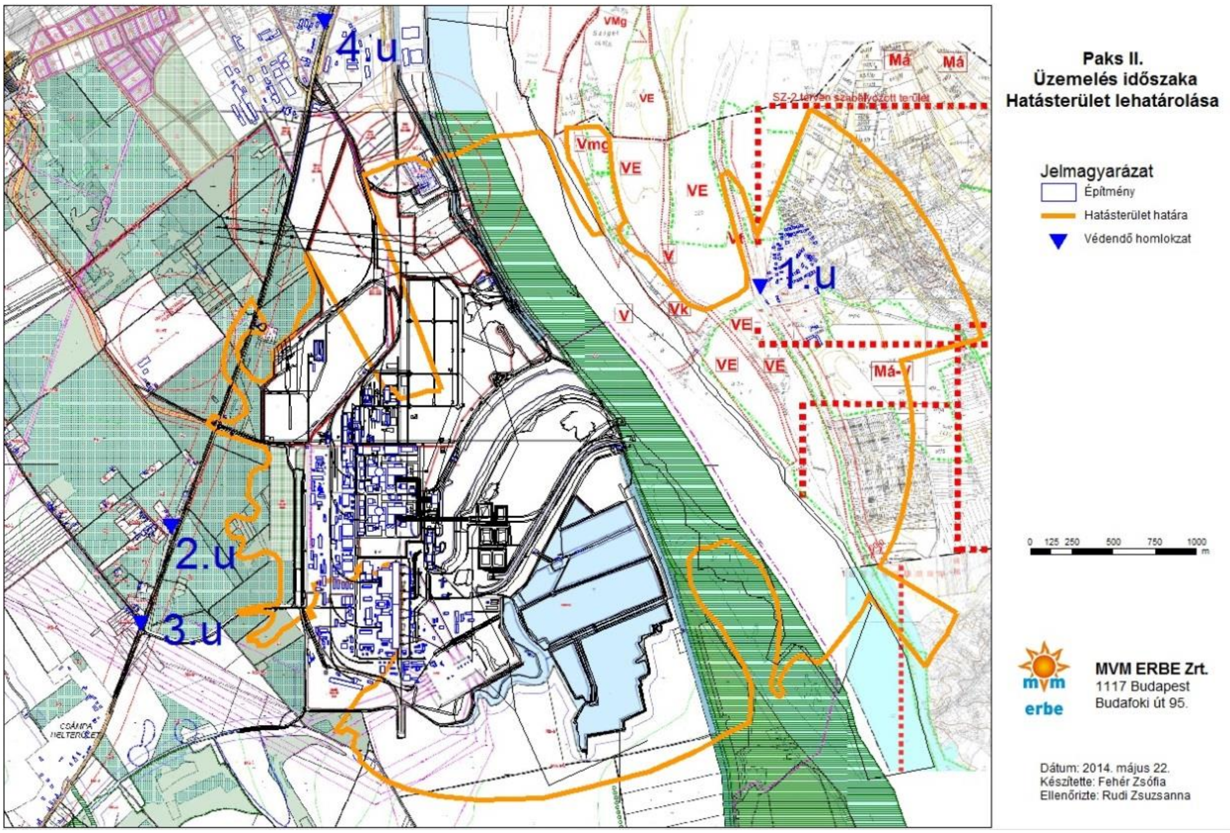


jelmagyarázat – legend, védendő homlokzat - protected façade, hatásterület határa – borderline of impact area, dátum – date, készítette – prepared by, ellenőrizte – reviewed by

Figure 78: Transmission line construction aggregated impact area

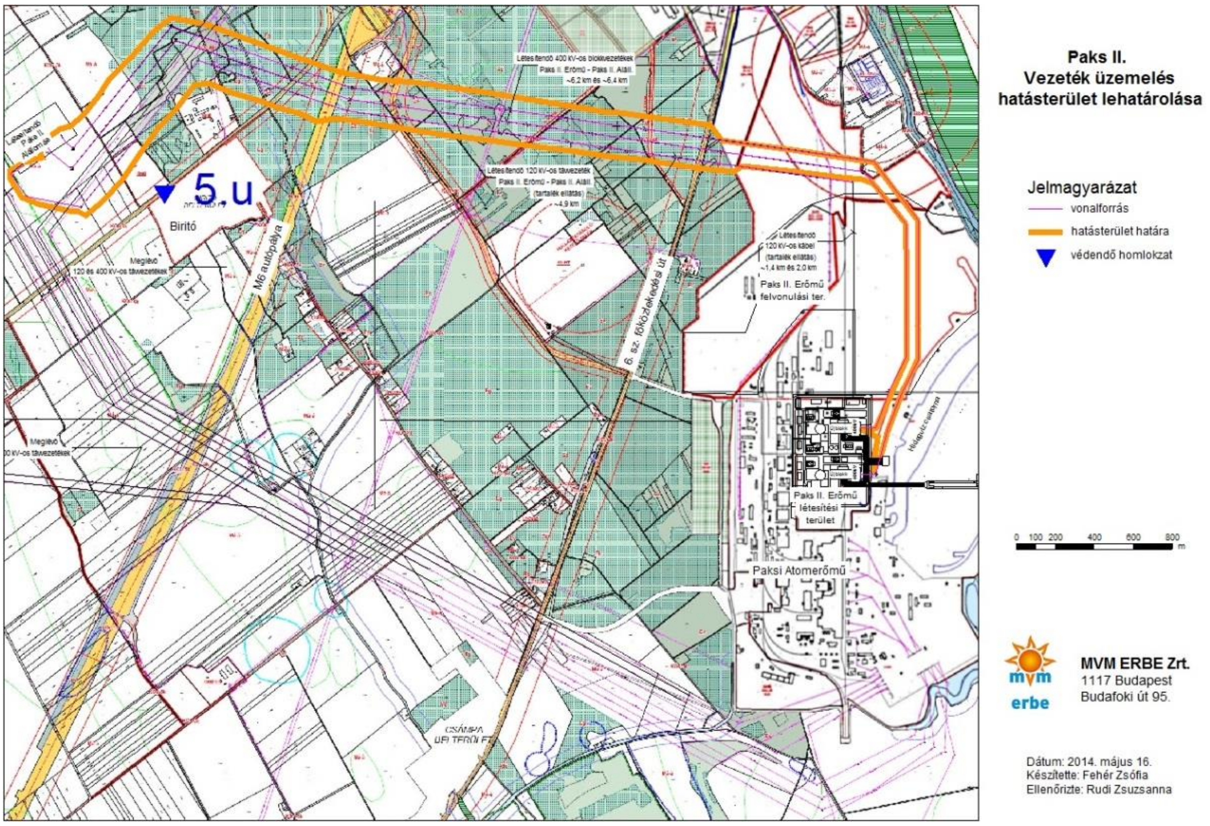
16.3 IMPACTS AND IMPACT AREAS OF PAKS II OPERATION

The noise emission of the power plant will remain within the noise in effect for residential area as a result of implementing the required noise mitigation actions. The expected level of noise load arising from the transmission line operation will be minimum at the facade to be protected. The traffic increment arising from the additional traffic during Paks II. operation will cause no detectable change in the noise load.



SZ-2 terven szabályozott terület – regulated area as per drawing No. SZ-2, jelmagyarázat – legend, építmény - structure, hatásterület határa – borderline of impact area, védendő homlokzat – protected facade, datum – date, készítette – prepared by, ellenőrizte – reviewed by

Figure 79: Impact area of operation



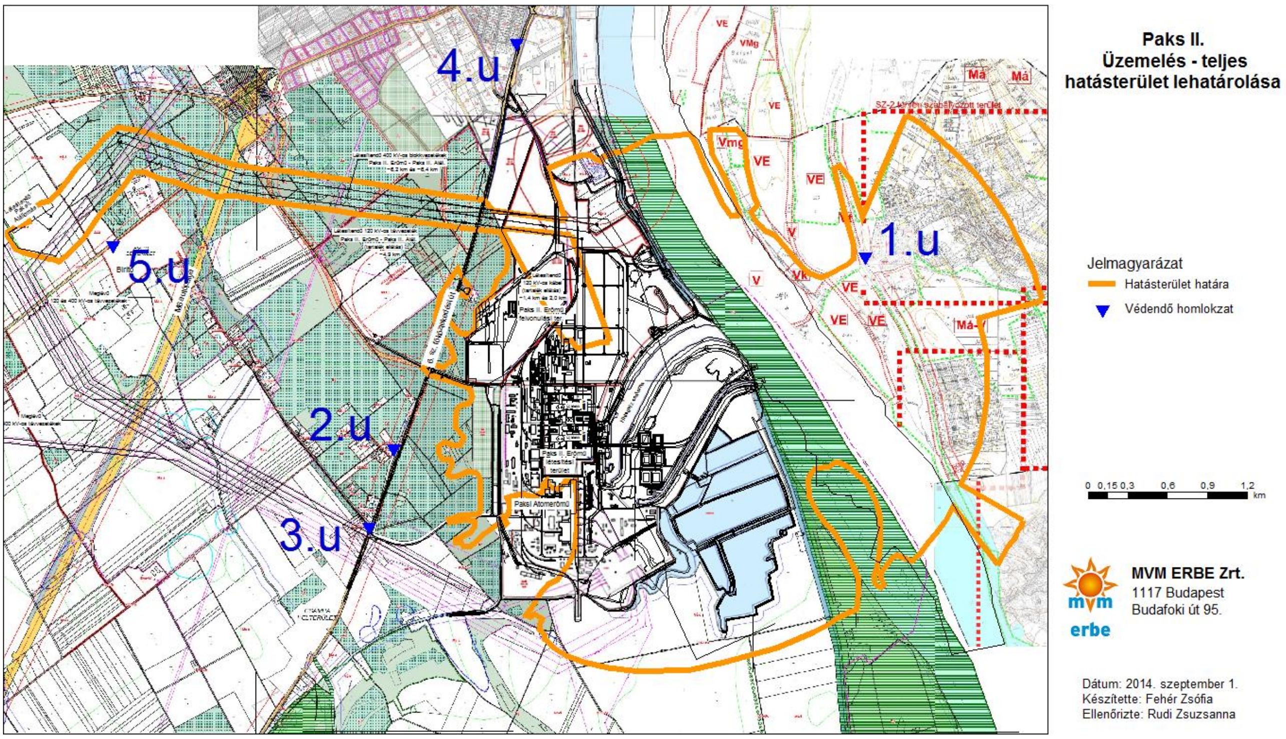
Létesítendő Paks II alállomás – envisaged Paks II substation, meglévő 120 és 400 kV-os távvezetékek – existing 120 and 400 kV transmission lines, létesítendő 120 kV-os távvezeték – envisaged 120 kV transmission line, létesítendő 120 kV-os kábel (tartalék ellátás) – envisaged 120 kV cable (reserve power supply), létesítendő 400 kV-os blokkvezetékek – envisaged 400 kV unit lines, Paks II erőmű felvonulási terület: temporary construction area of Paks II, Paks II létesítési terület – construction area of Paks II, Paksi Atomerőmű – Paks Nuclear Power Plant, 6. sz. főközlekedési út – Highway No. 6, jelmagyarázat – legend, vonalforrás – line sources, hatásterület határa – borderline of impact area, védendő homlokzat – protected facade, datum – date, készítette – prepared by, ellenőrizte – reviewed by

Figure 80: Impact area of transmission line operation

Impact area of Paks II. operation (without transmission lines) will cover Paks Nuclear Power Plant site, the adjacent non-residential areas, Duna river, certain real properties in Dunaszentbenedek village and partly NW corner of Uszód village. The impact area during the transmission line operation in the business zone is the area located directly below the transmission lines, and in not protected areas it is 40-70 m measured from the lines, and towards Biritó max. 80 m. (80. figure) No impact zone can be defined for the additional noise impact from traffic during the operation period of the project. We cannot predict any cross-border noise impact arising from Paks II. operation.

16.4 TOTAL IMPACT AREA OF PAKS II. OPERATION

The total impact area of the operation will be the totality of direct and indirect impacts areas, as presented on Figure 81

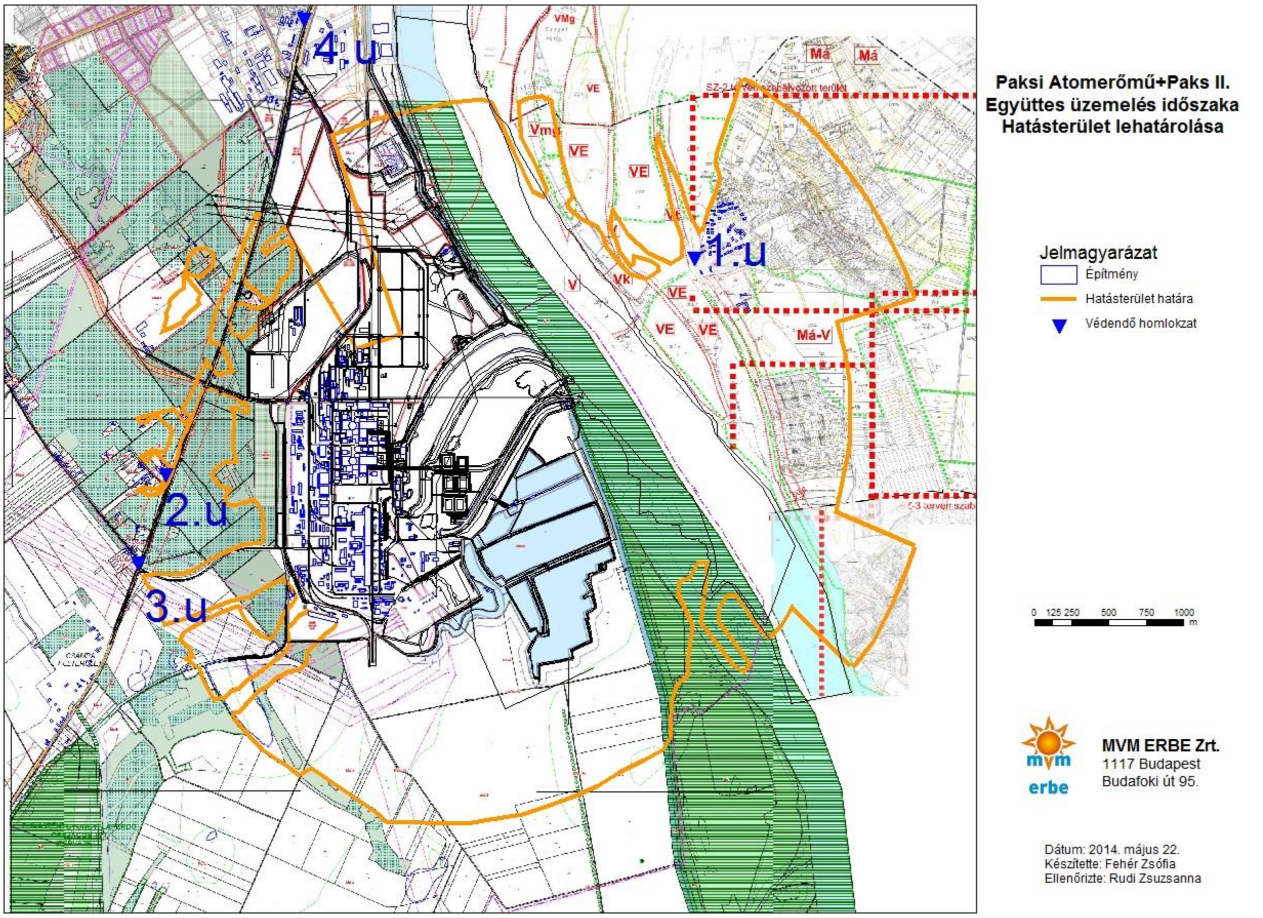


Létesítendő Paks II alállomás – envisaged Paks II substation, meglévő 120 és 400 kV-os távvezetékek – existing 120 and 400 kV transmission lines, létesítendő 120 kV-os távvezeték – envisaged 120 kV transmission line, létesítendő 120 kV-os kábel (tartalék ellátás) – envisaged 120 kV cable (reserve power supply), létesítendő 400 kV-os blokkvezetékek – envisaged 400 kV unit lines, Paks II erőmű felvonulási terület: temporary construction area of Paks II, Paks II létesítési terület – construction area of Paks II, Paksi Atomerőmű – Paks Nuclear Power Plant, 6. sz. főközlekedési út – Highway No. 6, jelmagyarázat – legend, hatásterület határa – borderline of impact area, védendő homlokzat – protected facade, datum – date, készítette – prepared by, ellenőrizte – reviewed by

Figure 81: Total impact area of operation

16.4.1 TOTAL IMPACT AREA OF SIMULTANEOUS OPERATION OF PAKS II. AND PAKS NUCLEAR POWER PLANT

The expected noise load from the simultaneous operation of Paks II and Paks Nuclear Power Plan will remain within the noise in effect at the facades in the given area as a result of implementing the required noise mitigation actions. To aggregated impact area of simultaneous operation of Paks Nuclear Power Plant + Paks II. (disregarding the transmission lines) will cover the site of Paks Nuclear Power Plant, the un-populated areas in the region, Duna river, and certain lands in Dunaszentbenedek and Uszód village. (Figure 82)



jelmagyarázat – legend, építmény – structure, hatásterület határa – borderline of impact area, védendő homlokzat – protected facade, datum – date, készítette – prepared by, ellenőrizte – reviewed by

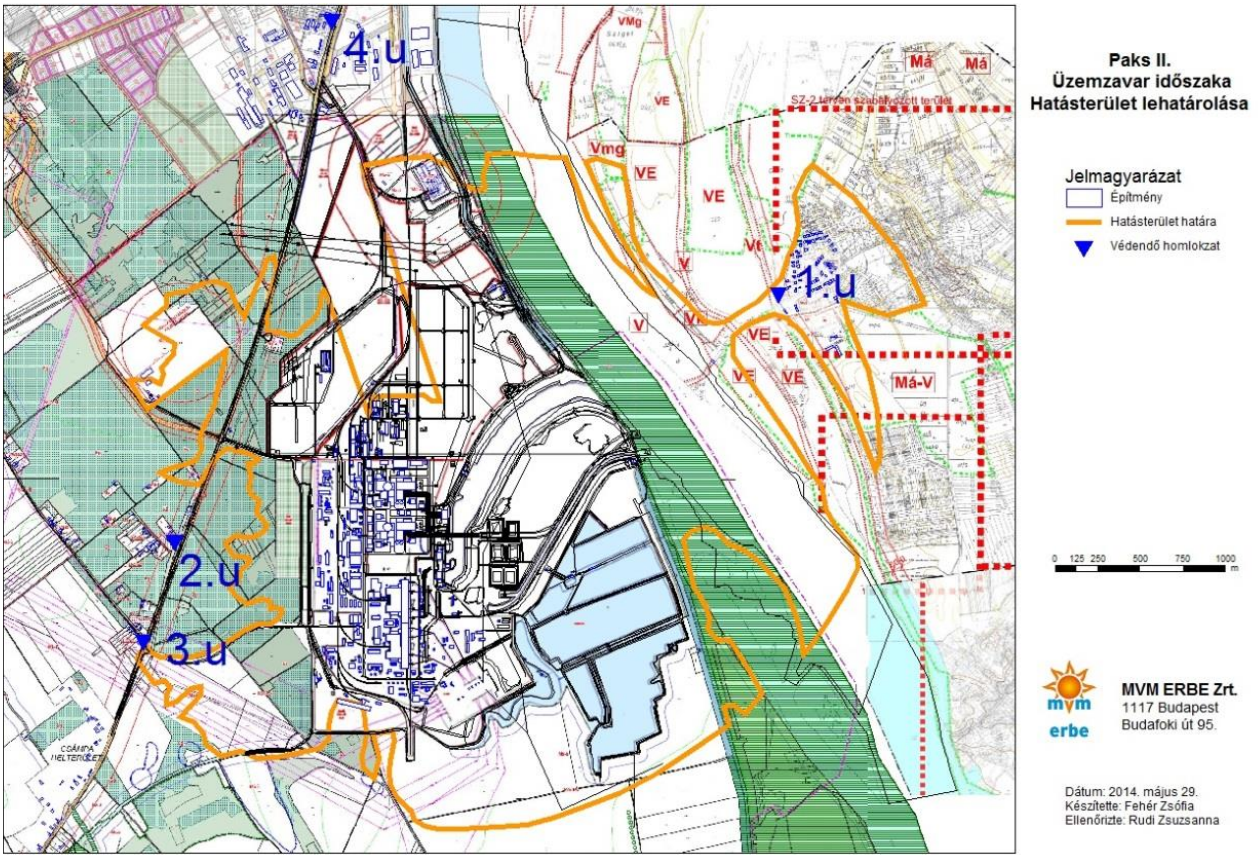
Figure 82: Aggregated impact zone of Paks Nuclear Power Plant and Paks II.

If we compare the headcount of the presently operating power plant with that of the planned power plant we can see that the latter is lower, thus noise load arising from traffic of commuting staff will be also most presumably lower, and this would lead to higher traffic load and larger impact zone but this growth will be too small for detection. We cannot predict any cross-border noise impact arising from standalone operation of Paks II. and simultaneous operation of Paks II and Paks Nuclear Power Plant.

16.4.2 IMPACTS AND IMPACT AREAS OF CASES OF EMERGENCY

Regarding noise emission from operation significant deviation can be expected and can occur only in case of operational disturbance (emergency) that may happen only at very low frequency. If this still happens, electric energy supply is typically interrupted. In such cases diesel generators will be used for providing power supply for the relevant units to implement the shutdown operation.

The noise emission of the power plant will remain below the limit permitted for residential areas even during operational disturbance. ***The impact area of Paks II. operational irregularity will cover the site of Paks Nuclear Power Plant, and neighbouring unpopulated areas, Duna river, and certain lands in Dunaszentbenedek village***. (Figure 83)



jelmagyarázat – legend, építmény – structure, hatásterület határa – borderline of impact area, védendő homlokzat – protected façade, datum – date, készítette – prepared by, ellenőrizte – reviewed by

Figure 83: Operational irregularity impact area of Paks II.

16.5 IMPACT AND IMPACT AREA OF PAKS II. ABANDONMENT

When abandonment operations are performed on the power plant area, the noise load limits applicable onto areas and buildings to be protected can be maintained. The direct impact area during the abandonment period will cover the site of Paks Nuclear Power Plant, the un-populated areas in the region, Duna river and residential building at the western side of Dunaszentbenedek village. No increment in noise load levels arising from road traffic can be defined onto the impact area.

17 AMBIANT AIR

17.1 BASELINE STUDIES

In 2012-2013 we prepared baseline measurements to describe the baseline status of the area in the environment of the site. Based on these measurements we defined the baseline air pollution status of the area, and using this data, the loadability of the area.

The following measurement points were defined for measuring the baseline air pollution:

- 1 point on the Plant site (1. LMp – area selected for Plant development)
- 1 point next to the northern access road (2. LMp – next to the northern access road)
- 1 point next to the southern access road (3. LMp- next to the southern access road, Meteorological Station)
- 1 point in Paks-Csámpa settlement, residential buildings along highway nr. 6 (4. LMp - Csámpa, Kis street)
- 1 point at the left bank of Duna river (5. LMp - Dunaszentbenedek, 2/3 Dam keeper house)
- 1 point in Paks city, next to Kölesdi road (6. LMp - OVIT site, Dankó Pista u. 1.)

The primary criterion for selecting the measurement points was to ensure that the measurement points are located as close as possible to the sites defined in the technical appendix of the contract, and the secondary criterion was the availability of power supply and security of the equipments and instruments used for the measurements/tests.

Location of measuring points

The following Google Earth picture presents the location of the selected measuring points.

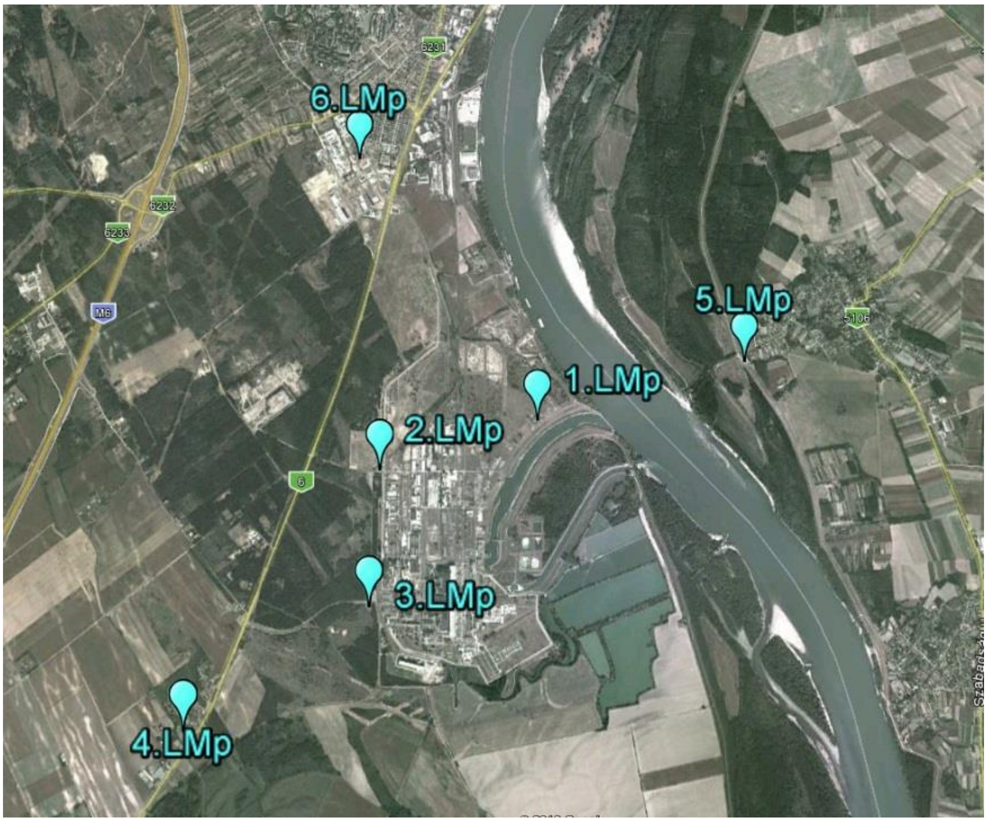


Figure 84: Location of air pollution measuring points

NO_2, NO_x, SO_2, CO, PM_{10}, TSPM, settling dust, and O_3 concentration values measured between January 24, 2012 and March 28, 2013 were low, and cases when limits permitted for PM_{10}. were exceeded were also lower than the permitted level.

Based on these measurement results we may state that the ambient air quality was excellent in respect of SO_2, CO air pollutants, and fair regarding NO_2, PM_{10} and O_3 pollutants.

Based on the assessment of measurement results we determined the loadability values of the area in accordance with Article 2. § 40 of Government Decree 306/2010. on air protection measurements.

The air loadability level is the difference between the air pollution limit and the baseline air load as it follows.

Air pollutant	Baseline air load	Hourly air pollution limit	Loadability
	(µg/m^3)		
Sulphur-dioxide (SO_2)	2	250	248
Nitrogen dioxide (NO_2)	24	100	76
Nitrogen oxides (NO_x)	30	-	-
Carbon monoxide (CO)	525	10 000	9 475
Particulate matter (PM_{10})	27	-	-
Particulate matter TSPM	35	200	165

Table 52: Summary assessment of 2012 baseline measurements/tests

17.2 DIRECT IMPACTS AND IMPACT ZONES OF PAKS II. IMPLEMENTATION AND OPERATION

We estimated the distribution of non-radioactive polluting materials arising from implementation and operation of Paks II., the air quality prognosis and impact area definition using the Gauss-type model.

We applied the climatic data typical for the area, and the *average and most characteristic* figures for preparing the conservation estimates.

Using real meteorological database we prepared the model simulations for one full year, based on hourly emission values. Data of the meteorological measuring tower (120 m high) located at the site of Paks Nuclear Plant provided partly the meteorological data for the stimulation. Wind direction and wind speed values were available from the Paks measuring tower. We generated all other meteorological data that were required for the stimulations (as they were not available from the measurements held in the tower) from the output fields of the freely accessible American Global Forecast System (GFS) numeric forecasting model (http://www.emc.ncep.noaa.gov/GFS/doc.php [16-9]). GFS provides the meteorological database which is most widely used in the world and available free-of-charge, offering both archive data and forecasts alike. The hydrostatic GFS model output fields are available in 0,5 × 0,5 degree spatial and 3 hour time resolution.

We used meteorological data of 2011 for the simulation, because during that year there were several weather conditions unfavourable for aspects of air pollution propagation and dilution (so-called cold cushion remaining for long time in 2011 November), thus results represent some over-estimation. 2011 had an extremely dry summer with 1–3-week heat waves that are favourable for enriching the air pollutants.

Emission data of stationary points (point and local sources) related to construction works were available for the modelling process, and emission data related to transportations of supplies. The quantity of soil moved during the landscaping and foundation works could be also calculated.

We calculated with the emission from the defined point sources and transportation (supplies) for the operation phase.

We prepared the propagation simulation for carbon monoxide (CO), nitrogen oxides (NO_x) hydrocarbons (C_xH_y) and particulate matter (PM_{10}).

During the model simulations we defined the concentration fields, limit excesses and impact areas arising due to emission for various periods and various emission levels.

We used the limit values required for preparing the studies as determined in Decree 4/2011. (I.14.) VM on air pollution limits and emission limits of stationary air polluting and point sources. We used conservative approach for estimating limits that can be matched only partially. Thus we assumed the total quantity of nitrogen oxides (NO_x) as NO_2, because the Decree defined the limit only for NO_2. We assumed the total quantity of hydrocarbons (C_xH_y) in benzene, because the Decree defined the limit for benzene.

We defined the impact area for the studied air pollutants in accordance with Government Decree 306/2010. (XII.23.) on the protection of clean air.

17.3 DIRECT IMPACTS AND IMPACT ZONES OF IMPLEMENTATION

Implementation

During the implementation phase we differentiate the following four periods: *demolishing, landscaping (terrain arrangement), foundation and structure construction*.

The impact area will remain within 500 m distance from the source points regarding every polluting material and work phase in case of calculating with real meteorological database.

If calculating with conservative meteorological database the impact area during the implementation phase will remain within 1000 m distance from the source points regarding every polluting material and work phase.

The impact area of pollution arising from traffic for NO_x will be approximately a zone in 100 m radius, and for the other pollutants no other impact area can be detected and presented. No impact area of pollution arising from traffic can be detected and presented during the operation phase. The annual average pollution level regarding CO is lower than 0,1 % of the limit, and in case of NO_x (NO_2) and C_xH_y (benzene) lower than 10 %.

Under extremely unfavourable meteorological conditions the health limit values might be also exceeded during the implementation phase. The most unfavourable meteorological conditions typically occur during the winter season, when the implementation works might be or might need to be suspended due to the meteorological forecasts. It must be noted that health limits are exceeded all over the country under similar unfavourable situations (i.e. cold cushion).

Monitoring system during the implementation period

The nearest residential building at Csámpa is located 1 330 m, in Paks 2 960 m. and in Dunaszentbenedek 2 590 m from Paks II. construction area. With regard to these significant distances there is no need and argument for establishing stations for pollution monitoring at the test points.

However, considering the size and extension of the project and ~10 years of the complex implementation process it is reasonable, for the sake of security, to monitor air pollution ***on residential areas located nearest to the planned site***.

The proposed measurement points are the following:

- 1 point at the left bank of Duna river,
- 1 point in Paks city in the vicinity of Kölesdi road.

The proposed air pollution monitoring is the following:

- Continuous test of concentration of nitrogen dioxide (NO2), nitrogen oxides (NOX), and carbon monoxide (CO) integrated onto one hour average time using an analyser installed into a mobile measuring station.
- Duration of measurements for every measuring point: 14 days, twice in each season, total 8 times per annum (8 x 14 days)
- Particulate matter fraction below 10 µm (PM10), total particulate matter (TSPM) pollution test applying 24-hour exposition time and phased active test technique.
- Duration of measurements for every measuring point: 14 days, twice in each season, total 8 times per annum (8 x 14 days).
- Continuous test of concentration of ozone (O3) integrated onto one hour average time using an analyser installed into a mobile measuring station.
- Duration of measurements for every measuring point: 14 days, twice in each season, total 8 times per annum (8 x 14 days).
- Settling dust pollution test applying passive test technique.

Duration of measurements for every measuring point: 30 days, once in each season, total 4 times per annum (4 x 30 days).

Parallel with air pollution test we also propose to continuously register the values of meteorological characteristics (temperature, humidity, wind speed, wind direction) integrated for 1 hour interval.

Accredited laboratory may perform the test applying approved instrument types.

It is advisable to launch the tests one year prior to starting the implementation, as thus we can ensure that the baseline pollution of the area is recorded as the reference point. The test program ought to continue throughout the entire implementation phase as thus we can ensure recording and documentation of the actual states.

Operation

We used the emissions by the defined point sources and supply transports for the operation period.

Four diesel generators each with ~7,5 MW_e capacity will provide power supply for every block for the safety systems during operational disturbances (outage, the delivered combustion heat will be 18,75 MW_{th} per unit. Any diesel generator shall be able to secure the required power supply in case of an eventual emergency shutdown. According to plans, these diesel generators will under ordinary operation circumstances operate only in test or pilot operation mode. The stationary air polluting point sources will be the chimneys of the diesel generators. Based on the emission time and the quantity of the emitted polluting materials the limit values will not be exceeded in any of the air polluting materials.

	CO	**NO_x**	**C_xH_y**
max. conc. (μg/m^3):	107,2	15,3	3,8
value higher than the limit	none	none	none
impact zone	none		

Table 53: Impacts of pilot operations of diesel generators

Based on impacts of transportation during the operation phase we can state that no value higher than the limit will occur irrespective whether we use for the calculation real or conservative meteorological conditions, and the emerging atmospheric concentration values are so small that we do not even present them in separate figures.

Impacts of simultaneous operation of Paks II. and Paks Nuclear Power Plant

The baseline air pollution load measured in the ambient air in 2012-2013 also includes the impacts of non-radioactive emissions of a Paks Nuclear Plan. If we add the results of modelling of Paks II. independent impacts to the baseline measurement results, then we can have the combined impact of simultaneous operation of Paks II. and Paks Nuclear Plant .

Air pollutant	**Baseline air load**	**Max. hourly concentration of test run of Paks II diesel generators**	**Combined impacts of Paks II. and a Paks Nuclear Plant a**	**Air pollution limit hourly**
	(μg/m^3)			
Nitrogen oxides (NO_X)	30	15	45	100
Carbon monoxide (CO)	525	107	632	10 000

Table 54: combined impact of Paks II and a Paks Nuclear Plant simultaneous operation onto air quality

As the results can demonstrate, neither will impacts of non-radioactive emissions from Paks II. standalone operation or combined and simultaneous operation of Paks II. and Paks Nuclear Plant substantially modify the existing air pollution conditions, and it will be qualified as *tolerable-neutral* for the residential areas.

17.4 SUMMARY

Based on the detailed modelling results we can state that impacts of implementation will cover the site and its direct environment even under conservative meteorological conditions.

No cross-border air pollution impacts can be defined as potential danger arising from radioactive emission arising from either the implementation and operation of Paks II or the simultaneous operations of Paks II. and Paks Nuclear Power Plant.

18 BIOSPHERE, ECOSYSTEM

18.1 VEGETATION AND FLORA IN THE ENVIRONMENT OF THE POWER PLANT

The landscape structure of the 3 km radius of the Paks Nuclear Power Plant is rather heterogeneous. Deciduous and pine forest plantations as well as the agricultural areas play a major role. The different water surfaces and the valuable sand steppe grasslands more and more exposed to risk also represent a major share of the area. Built-up urbanised areas are also significant. Degradation, reduction and disappearance of the sand steppe grassland spots is a typical feature of the area. Presence of non-indigenous plant species and major proliferation of invasive species is a decisive feature of the area. Compared to the entire studied area, the Danube River and its banks and the swamp forest at Dunaszentgyörgy are major consistent natural areas.

It can be established that no major change has happened in the flora of the area in the more than 10 years. Species of the ruderal groups dominate the area, but the proportion of stress tolerant species is also significant. This is an evidence of the fact that the area is under strong anthropogenic impact.

On the site of the planned power plant dry and semi-dry grasslands can be found. With almost no exception, all grasslands are cultivated by cutting, having a lot of weeds species and although their soil is partly sand, species of sand grasslands are missing. Fresh disturbance of the communities is frequent.

Figure 85: Degraded grassland with stone plates in the area affected by the construction works

In the area to be occupied for the preparation and construction of Paks II, the most characteristic plant associations of the area are uncharacteristic dry and semi-dry grasslands, sandy steppe meadows and the indigenous soft wood uncharacteristic or pioneer forests, and open sandy steppe grasslands. In the unpaved parts of the environment of the cold and the warm water channel, we can find low cut grass or dry grasslands on secondary surfaces and weedy, fresh grasslands. The island between the channels is typically covered by willow poplar floodplain forest.

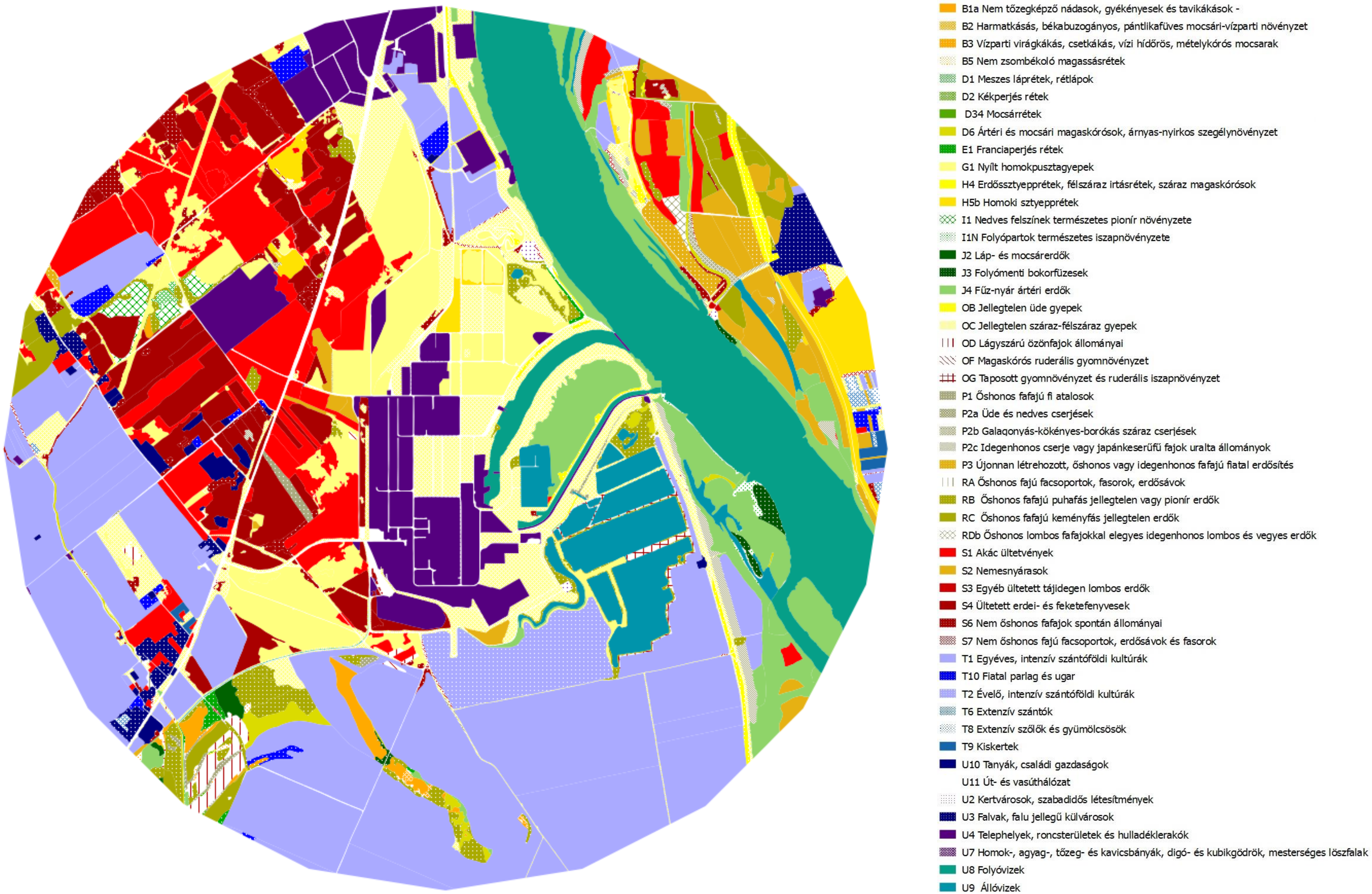


Figure 86: Map of vegetation map of the environment of 3 km diameter of the Paks power plant

B1a – Nem tőzegképző nádasok, gyékényesek és tavikákások - Eu- and mesotrophic reed and Typha beds
B2 – Harmatkásás, békabuzogányos, pántlikafüves mocsári-vízparti növényzet - Glyceria, Sparganium and Schoenoplectus beds
B3 – Vízparti virágkákás, csetkákás, vízi hídőrös, mételykórós mocsarak - Water-fringing helophyte beds with Butomus, Eleocharis or Alisma
B5 – Nem zsombékoló magassásrétek - Non-tussock tall-sedge beds
D1 – Meszes láprétek, rétlápok (Caricion davallianae) - Rich fens
D2 – Kékperjés rétek Molinia meadows
D34 – Mocsárrétek - Mesotrophic wet meadows
D6 – Ártéri és mocsári magaskórósok, árnyas-nyirkos szegélynövényzet - Tall-herb vegetation of floodplains, marshes and mesic shadowed forest fringes
E1 – Franciaperjés rétek - Arrhenatherum hay meadows
G1 – Nyílt homokpusztagyepek - Open sand steppes
H4 – Erdőssztyepprétek, félszáraz irtásrétek, száraz magaskórósok - Semi-dry grasslands, forest-steppe meadows
H5b – Homoki sztyeprétek - Closed sand steppes
I1 – Nedves felszínek természetes pionír növényzete - Natural pioneer vegetetion of wet substrates
I1N – Follyópartok természetes iszapnövényzete – Natural muddy vegetation of riparian sites
J2 – Láp- és mocsárerdők - Swamp woodlands
J3 – Folyómenti bokorfüzesek - Riverine willow scrub
J4 – Fűz-nyár ártéri erdők Riverine willow-poplar woodlands
OB – Jellegtelen üde gyepek - Uncharacteristic mesic grasslands
OC – Jellegtelen száraz-félszáraz gyepek - Uncharacteristic dry and semi-dry grasslands
OD – Lágyszárú évelő özönfajok állományai - Stands of invasive forbs
OF – Magaskórós ruderális gyomnövényzet - Ruderal tall-herb vegetation
OG – Taposott gyomnövényzet és ruderális iszapnövényzet - Trampled and ruderal vegetation
P1 – Őshonos fafajú fiatalosok - Saplings of native tree species
P2a – Üde és nedves cserjések - Wet and mesic pioneer scrub
P2b – Galagonyás-kökényes-borókás száraz cserjések - Dry and semi-dry pioneer scrub
P2c – Idegenhonos cserje vagy japánkeserűfű fajok uralta állományok - Stands of non-native shrubs or Reynoutria species
P3 – Újonnan létrehozott, őshonos vagy idegenhonos fafajú fiatal erdősítés - New afforestations
RA – Őshonos fajú facsoportok, fasorok, erdősávok - Scattered native trees or narrow tree lines
RB – Őshonos fafajú puhafás jellegtelen vagy pionír erdők - Uncharacteristic or pioneer softwood forests
RC – Őshonos fafajú keményfás jellegtelen erdők - Uncharacteristic hardwood forests and plantations
RDb – Őshonos lombos fafajokkal elegyes idegenhonos lombos és vegyes erdők - Non-native deciduous forests and plantations mixed with native tree species
S1 – Ültetett akácosok - Robinia pseudoacacia plantations
S2 – Nemesnyárasok - Populus × euramericana plantations
S3 – Egyéb tájidegen lombos erdők - Plantations of other non-native deciduous tree species
S4 – Erdei- és feketefenyvesek - Scots and black pine plantations
S6 – Nem őshonos fafajok spontán állományai - Spontaneous stands of non-native tree species
S7 – Nem őshonos fajú facsoportok, erdősávok és fasorok - Scattered trees or narrow tree lines of non-natives tree species
T1 – Egyéves, intenzív szántóföldi kultúrák - Annual intesive arable fields
T10 – Fiatal parlag és ugar - New abandonments of arable lands
T2 – Évelő, intenzív szántóföldi kultúrák - Perennial intesive arable fields
T6 – Extenzív szántók - Extensive arable fields
T8 – Extenzív szőlők és gyümölcsösök - Extensive vineyards and orchards
T9 – Kiskertek - Gardens
U10 – Tanyák, családi gazdaságok - Farms
U11 – Út- és vasúthálózat - Roads and railroads
U2 – Kertvárosok, szabadidős létesítmények - Suburbs and recreation areas
U3 – Falvak, falu jellegű külvárosok - Villages
U4 – Telephelyek, roncsterületek és hulladéklerakók - Yards, wastelands, dumping grounds
U7 – Homok-, agyag-, tőzeg- és kavicsbányák, digó- és kubikgödrök, mesterséges löszfalak - Sand, gravel, clay and peat mines, loess walls
U8 – Folyóvizek - Water streams
U9 – Állóvizek - Standing waters

18.2 NATURA 2000 SITES TO BE FOUND WITHIN THE 10 KM RADIUS OF THE POWER PLANT

Natura 2000 sites to be found within the 10 km radius of the Paks Nuclear Power Plant:

Area of the Tolnai-Duna (HUDD20023) within the 10 km radius:

Dunaszentgyörgy swamp forest (HUDD20072): 328.03 ha

Crocus repiculatus fields at Paks (HUDD20071): 91.16 ha

Meadows at Tengelic (HUDD20070): Area falling within the 10 km radius

Ground-squirrels field at Paks (HUDD20069): 352.14 ha

Loess valleys of Middle Mezőföld (HUDD20020): Few ten hectares area in the southeast within the 10 km radius

Paks II. directly affects a Natura 2000 site, namely Tolnai-Duna. The narrow lane along the river bank which is affected by the planned recuperation water power plant and energy dissipation structure is the flood plain gallery forest strongly affected by water flow and the secondary degraded grassland on the side of the dike. There are no protected or priority plant species on the Natura 2000 site. The crown level of the willow poplar floodplain forest mainly comprises black poplar and white willow. In the shrub level, European dewberry and shrub level false indigo can be found in large quantities. Along the section directly affected by the investment, in addition to *Solidago gigantea*, the grassland level is dominated almost exclusively by nitrofrequent species.

Figure 87: Flood plains willow and poplar forests on the Island in between the channels

18.3 THE IMPACT OF PAKS II ON THE BOTANY

18.3.1 THE IMPACT AND THE IMPACT AREA OF THE CONSTRUCTION

Vegetation affected

Due to works on the construction area, the current uncharacteristic dry, semi-dry grasslands will disappear. These habitats are covered by weeds, degraded and disturbed, their level of natural status hardly exceeds the lowest category, category 1. Biomonitoring did not explore any protected species there. On areas classified into the category of ‘yards, wastelands, dumping grounds’ also directly affected by the investment, no nature conservation value can be found.

Occupation of the area between the cold and warm water channels and the development of the recuperation power plant and the energy dissipation structure on the bank of the Danube entails the partial removal of the current willow, poplar flood plain forest - a narrow riparian zone of which is Natura 2000 site. This forest is not under protection but has a good natural status, a community of fast dynamics with a favourable forecast for regeneration under unchanged water flow conditions.

Major plant associations affected by the implementation of the long distance transmission lines related to the investment: annual intensive arable land cultures, uncharacteristic dry, semi-dry steppes, spontaneous stands of non-native tree species, acacia plantations, scots and black pine plantations, weedy degraded open sand steppes. Location of poles have been designated with attention to nature conservation aspects, therefore, plant associations, valuable for nature conservation must be reckoned with when constructing the poles.

Damage to habitats

On the temporary construction area of Paks II and in the construction zone of the long distance lines, habitats become less favourable due to the compaction of the soil and trampling, and partial damage to the plantation during the construction works must be taken into account. Drainage of compacted soil is less favourable, plants will find it more difficult to cope with e.g., drought.

Figure 88: Grassland with feather grass in the incorporated area of Paks Nuclear Power Plant

Main habitats affected

- Temporary construction area: uncharacteristic dry, semi-dry steppes, open sand steppe grasses, sand steppe meadows, uncharacteristic soft wood or pioneer forests of indigenous tree species, spontaneous stands of non-native tree species, false oat grass meadows.
- Along long distance lines route: annual intensive arable cultures, uncharacteristic dry, semi-dry steppes, spontaneous stands of non-indigenous tree species, acacia plantations, scots and black pine plantations, open sand steppe grasses, uncharacteristic soft wood or pioneer forests of indigenous tree species, tree groups plantations of non-native species, forest belts and lines of trees, sand steppe meadows, road and railway network.

More valuable areas for nature conservation are the open sand steppe grasses and sand steppe meadows. Grasslands have become degraded to a different degree and that determines their ability to regenerate. Patches of more natural status can get better regenerated especially if there is a propagulum source, a patch of a forest nearby (of indigenous tree species). It is more difficult or difficult for more degraded grasslands to get regenerated. In addition to trampling, drought and the proliferation of invasive species is also an impedimental factor.

Affected protected plants

Potential affected species on the habitats of open sand steppe grassland and sand steppe meadows.

- On the site of the power plant: feather grass *(Stipa pennata)*, sand feather grass *(Stipa borysthenica), (Centaurea arenaria), (Silene borysthenica)*
- Along the route of the transmission lines: *(Centaurea arenaria)*, *(Corispermum nitidum),* feather grass *(Stipa pennata),* sand feather grass *(Stipa borysthenica), (Dianthus serotinus)*, *(Silene borysthenica)*

Figure 89: Dianthus serotinus

From the aspect of plant associations and plant species to be protected, the scope of the direct impact area of the construction studied covers the temporary construction area, all the related construction areas (including the Island and the Danube bank), as well as the construction zone of the long distance transmission lines. The scope of the immediate impact area of the processes affecting vegetation covers the temporary construction area for the investment, all the related construction area and its direct environment (including the Island and Danube bank), a couple of hundreds of metres environment of the Paks Nuclear Power Plant (maximum 500 m in the west, and in the direction of south, about 300 m), the construction zone of the route of the long distance transmission lines and its further environment of maximum 100 m. From botany aspect the implementation of the construction of Paks II does not have transboundary environmental impacts.

18.3.2 THE IMPACT AND IMPACT AREA OF OPERATION

During the period of operation, grass plantations in park like environment and secondary degraded grasslands will probably evolve in the densely built-up area of the power plant with facilities. On surfaces regenerated subsequent to the implementation of the investment on the temporary construction area, on areas surrounded by fences and maintained by proper landscape preserving management, natural vegetation - especially open and closed sand grasses - may develop without any disturbance and may be a rescue site for plants under protection. Limitations will be prescribed for the cultivation mode in the safety zone of the transmission lines during the operation of the long distance transmission lines. The impact of the power plant causing water level fluctuations and temperature changes has no demonstrable impact on the flora of the embankment. The indirect impacts of the power plant, such as the deposition of air-polluting substances, are insignificant from a botanical point of view.

The scope of the direct impact area of operation, studied from the aspect of plant associations and plant species to be protected covers the entire area of Paks II (including temporary construction area), the safety zone of the transmission lines, the energy dissipation structure and the environment of the recuperation plant. The indirect impact area of operation, studied from the aspect of plant associations and plant species to be protected practically corresponds to the direct impact area, and the area overlapped by the impact area of air pollution may also be potentially affected. From botany aspect the operation does not have transboundary environmental impacts.

18.3.2.1 The impact and impact area of malfunctions and accidents

Malfunctions, accidents locally occurring on the site will not affect areas covered by vegetation valuable for nature conservation. Among non-radioactive emission emergencies, fire cases will result in the damage to or destruction of the vegetation in proportion to the extension of the area affected. Emergencies related to waters, water system in connection with the Danube may cause damage to plant and plant associations breeding in the riparian zone of the Danube. Emission emergency events of non-radiology aspect have no trans-boundary impact from the aspect of botany.

18.3.3 THE IMPACT AND IMPACT AREA OF ABANDONMENT

In the area of the demolition works, vegetation and habitats regenerated during the operation period will be affected. Dust may settle on plants or polluting materials may be emitted in the air by the construction equipment. The damage caused to habitats by demolition represents a potential source of hazard of the spreading of invasive species. The rate of re-cultivation will determine to what extent biosphere can take possession of the area again. The site of the power plant, however, is quite small in total to cause a significant change in the environment by the abandonment. The route of transmission lines is strongly exposed to weeding and infiltration of invasive species, which are the largest danger for the native sand steppe habitats. Following the abandonment of the power plant, the negative impact detailed above will come to an end.

18.4 THE IMPACT OF PAKS II. ON THE FAUNA

18.4.1 THE IMPACT AND IMPACT AREA OF THE IMPLEMENTATION

The implementation Paks II. has many direct impacts on the fauna. 37% of the aquatic macro invertebrates in the Danube section studied are invasive species. Protected species include: 3 water snails, 4 mussels, 2 dragon flies and 1 may-fly. The thick shelled river mussel *(Unio crassus)*, which is the priority species of the Tolnai-Duna Natura 2000 site and enjoys national level protection as well, is of high community importance. Its presence has been verified several times, however, we know little of the size and dynamics of the population in the area affected. Therefore it would be important to carry out targeted monitoring in the future in order to follow up the development of the thick shelled river mussel population on the section examined. The yellow-legged dragonfly *(Gomphus flavipes)* is an indicator species of the downstream sections of larger rivers. It is a Natura 2000 indicator species and under decrease in all countries of Europe, but has a stable population in the area examined. Of the may-fly, the Danube may-fly (*Ephoron virgo*) is also under protection.

The works to be performed during the extension of the cold and warm channel sections affect water quality and aquatic life, probably including the above-mentioned species as well, but only temporarily. Fishes will probably wander away as a result of the construction works of the cold and the warm water channel, but they may return once the works have been completed. The construction of the new warm water channel may create new, varied habitat conditions for the fish.

It is advisable to examine the fauna of the Danube bank sections to be affected by the technological works in more detail prior to the commencement of the construction works and to monitor it continuously during the operation. (It is to be noted that the new location of the warm water channel will entail the destruction of less dragon fly items, species and habitats than the route planned earlier at the Uszódi Island)

Because of its occupation of the area, the construction of Paks II will have an impact on the insect communities strongly tied to the vegetation there, including the orthoptera, certain butterflies and soil surface arthropoda. From the protected orthoptera species, the slant faced grasshopper *(Acrida ungarica)*, Eurasian pincer grasshopper *(Calliptamus barbarus)* a very rare species nationally, the small sealed grasshopper *(Omocestus minutus)* are particularly affected. We need to note that the two protected species occurring here do not belong to the endangered species nationally, but can be found in high density e.g. in some parts of the Great Hungarian Plain. As for butterflies, the area of the construction and the extension of the cold and warm water channels is characterised by extreme poverty of species before the intervention as well. Items of one protected species those of the large copper butterfly *(Lycaena dispar)* occur on this area, but the population of this species will surely not be adversely affected by the works, therefore there is no need for any intervention in this respect. The populations of the protected species occurring on the Island, i.e. pallas' sailor *(Neptis sappho),* European peacock *(Nymphalis io)*, *N. c-album*, red admiral *(Vanessa atalanta)*, blue underwing *(Catocala fraxini),* and the highly protected Freyer's purple emperor *(Apatura metis)* are not endangered and following disturbance they may fast get resettled to the part remaining. Excavation of fertile soil layer and its disposal will affect the soil fauna and soil surface animals in the area, as well as increased traffic and trampling. There are two protected species occurring in the area: the granulated ground beetle *(Carabus granulatus)* ont he Island and *Geolycosa vultuosa* on the temporary construction area. Neither of them can be considered a rare species, they occur in Hungary on any habitats suitable for them. The decreasing number of insects damages the food base of bats.

If during the works, the vegetation remains on areas adjacent with the habitats affected, there these communities, species may survive the duration of the construction and the pioneer vegetation resistant to disturbance growing in place of the vegetation removed may serve as a temporary habitats for some of the species, although it may be negatively affected by the proliferation of invasive species. If the temporary construction area as a whole is affected as habitat, the estimated populations of these species here will probably continue to live on similar adjacent habitats.

When installing the poles for the long distance lines, vegetation will be removed on a large area. Removal of the fertile soil layer and its transportation off will also have significant impact on the plantation. Along the route of the transmission lines to be constructed, on patches of disturbed sand grasses, communities of the slant face grasshopper *(Acrida ungarica)*, the Eurasian pincer grasshopper *(Calliptamus barbarus)* and the small field grasshopper *(Omocestus minutus*), which is rare nationally, are also probable to occur. Their habitat will disappear during the construction works, similarly to the habitats of southern festoon butterfly *(Zerynthia polyxena)*, European peacock *(Nymphalis io), N. c-*

album, red admiral *(Vanessa atalanta)*, cardinal butterfly *(Argynnis pandora)*, jersey tiger *(Euplagia quadripunctaria), Cucullia balsamitae* and green silver-spangled shark *(Cucullia argentea)* occurring here.

Figure 90: Jersey tiger (Euplagia quadripunctaria)

Attention was paid to the more valuable sand steppe grasslands when designating the location of poles of the long distance transmission lines, by minimizing the damage involved in the installation of the poles on orthoptera, butterflies and soil surface anthropoda. We need to highlight that valuable sandy steppe-like habitats may be created in the long term in the area under the high voltage poles, depending on proper management. Intervention along the route of the lines will allow the extension of grassland areas to the expense of the non-native plantations. It can be expected that on the grasslands resettling in place of the acacia and pine plantations very poor in species and intended to be cleared, the protected species of orthoptera and butterflies will resettle again.

The number of amphibian and reptile species occurring on the site of the Paks Nuclear Power Plant is relatively high because relatively little intervention has been carried out on a certain part of the area (e.g. temporary construction area, island) since the time of its establishment. Amphibians and reptiles are affected during earthworks (particularly if works are performed during their resting period, i.e. from November to March). If landscaping is started during their active period, some of the items may flee from the area and hide in the fringes of the area where they may find an area to live on. The equipment may hit animals. Amphibiants move onto the hot concrete in the dark, where they are exposed to an increased hazard of being hit, as works continue at night as well at the premises of the power plant.

The construction of the blocks of Paks II affects the feeding and hatching sites of the birds species occurring, hatching and feeding in the area. The planned development area and the temporary construction area as well as the Island are currently good feeding sites for a number of bird species of community importance, e.g., the black stork (*Ciconia nigra)*, tawny pipit (*Anthus campestris)*, the European night jar (*Caprimulgus europaeus)*, the black wood packer (*Dryocopus martius)* or the red backed shrike (*Lanius collurio).*

Figure 91: Feeding wheatear (Oenanthe oenanthea) in the construction area

Increased noise load will affect the following bird species of community importance and breeding on the area affected: western marsh harrier *(Circus aeruginosus)*, black wood packer *(Dryocopus martius)*, white backed wood packer *(Dendrocopos medius)*, woodlark *(Lullula arborea)*, collared fly catcher *(Ficedula albicollis)*, European night jar *(Caprimulgus europaeus)*, red backed shrike *(Lanius collurio)*. Increased noise load will affect the following bird species of community importance and feeding on the area affected: black stork *(Ciconia nigra)*, tawny pipit *(Anthus campestris)*, white tailed eagle *(Haliaeetus albicilla).* All generated waste, generated during construction works may be a source of danger for bird species breeding or feeding there (birds tied to water or large body birds which may e.g. easily get entangled in packaging materials that may even lead to their death).

The construction of the block lines will affect the bird species breeding and feeding in the direct or more distant environment of the bases and of the areas under the track of the lines as well, with special regard to *Falconiformes*, *Passeriformes*, *Galliformes* and *Strigiformes*.

The construction of electricity systems will directly affect the following bird species of community importance: red kite *(Milvus milvus)*, black kite *(Milvus migrans)*, western marsh harrier *(Circus aeruginosus)*. In addition, the impact on mound-building mice also needs to be considered.

We cannot expect direct impacts to be significant and separable from natural fluctuation in case of aquatic fauna and butterflies. In connection with the changing structure of the plantation, a less valuable fauna of orthoptera may evolve, and this phenomenon may expand to areas not disturbed as well. The change to the community of anthropoda arising from the change to the plantation may be unfavourable for amphibian and reptiles and may give rise to the reduction of their food basis. In the communities of soil surface anthropoda, invasive and synantrophic species (linked to humans) may also appear and spread. Decrease of the isolated population may lead to their local disappearance or even genetic transformation. The fragmentation of populations presents a potential hazard for amphibian and reptiles and, to a certain extent, though on a larger spatial scale, small birds, birds maintaining a territory, and species hatching in the area as well. The fragmentation of habitats will directly affect mostly the following bird species of community importance and breeding on the area affected: black wood packer *(Dryocopus martius)*, wood lark *(Lullula arborea)*, collared fly catcher *(Ficedula albicollis)*, tawny pipit *(Anthus campestris)*, red backed shrike *(Lanius collurio)* European night jar *(Caprimulgus europaeus)*, corn crake *(Crex crex).*

Due to the noise, dust and air pollution, the majority of the amphibian and reptile species will most certainly look for refuge on further areas. The rising dust will get deposited on the vegetation, which in a direct manner will affect its development and in an indirect manner, the animals including birds living and feeding there. Increase of the noise level will primarily be a problem for frogs, causing disturbance in females finding their way to males in the direction of their calling voice and all this can influence reproduction success. More valuable birds (black stork *(Ciconia nigra)*, tawny pipit *(Anthus campestris)*, white-tailed eagle *(Haliaeetus albicilla)* European night jar *(Caprimulgus europaeus)* avoiding disturbance and higher noise may leave their current habitats and they may be replaced by less valuable bird species which are more tolerant of noise. The block line may disturb the embryonic development of amphibians. Artificial lights applied during night affects frogs, newt, salamander in finding their way, in their strategy for finding food, reproduction and growth as well as development.

The direct and indirect impacts mentioned above will affect the area of Paks Nuclear Power Plant and Paks II as a whole, including the track of the new high voltage transmission line and its one or two hundred metres wide area, transport routes, the Danube section under the outflow of warm water channels, as well as the fauna living there.

The works to be performed during the construction will probably not have any trans-boundary environmental impact on the fauna. No such impact is expected to arise during the operation of Paks Nuclear Power Plant, of Paks II or of their joint operation, either, in case of regular operation.

The interventions affecting Danube are expected to impact a valuable aquatic invertebrate fauna in light of the examinations conducted so far. It is strongly recommended to take into consideration these and carry out the necessary surveys of the fauna prior to the commencement of the construction works. Specific environmental protection proposals may be made depending on the outcome of the surveys.

Figure 92: Scallop and snail shells on the Danube bank in Paks

It can be said in general that when performing works affecting the river bed of the Danube, disturbance of the natural environment and activities affecting the river bed should possibly be limited to the smallest area. Concerning fish, no special environment protection measures need to be done in respect of the construction of Paks II, as most of the fish would wander away from dredging, etc. intervention affecting the banks.

In order to maintain the valuable ortophtera species here, it is necessary to maintain favourable conditions and/or improve these conditions for the populations of the habitats patches remaining in the construction area and its vicinity. This primarily means improving the conditions and impeding the diminishing or maybe increasing the area of the sand steppe habitats in the vicinity of the Paks Nuclear Power Plant, and the suppression of the spread of milk weed and acacia.

The negative impacts caused by the construction of block lines to birds can be mitigated by the proper insulation of poles and transmission lines, which reduces the number of birds suffering electric shock. The restoration of the original sand vegetation under the transmission lines and the related fauna constitutes a realistic task of habitats reconstruction, which requires complex nature conservation management. It would be advisable to sow the safety zone of the electricity lines by seeds collected from the neighbourhood, promoting thereby landscape rehabilitation. These interventions will accelerate the re-settlement of protected insect species as well. The number and area of the breeding and feeding sites of birds may be increased by means of recultivation.

As many items of amphibians, reptiles and bats need to be caught in a professional manner in the area of the planned construction and relocated to nearby undisturbed habitats. As all amphibians and reptiles are protected, attention should be paid to it that earthworks should not be performed during the winter hibernation period, but should be done from spring to autumn when actively moving items can flee from the area; earthworks should not proceed from the edge of the area affected towards the inner part, but the opposite; the generation of standing waters should be avoided and noise should be moderated primarily during the spring time reproduction period of the amphibians and birds. The periods of construction which would be favourable for birds and for amphibians and reptiles are somewhat contrary to each other: for the birds, working from autumn to spring and for amphibian and reptiles, working from spring to autumn would be favourable. This problem cannot be resolved based on professional, ecological or risk assessment aspects, but falls within the scope of risk management.

Figure 93: The rich bird fauna in the environment of the power plant

The negative impact of waste presenting hazard to birds (consumption, mechanical impacts) may be reduced by the proper storage of such waste.

It is important with regard to all animal species to preserve as much green area as possible during the construction. The fragmentation of habitats should be avoided, if possible. Connections between the individual habitats must be promoted (ecological corridor). The separation of an area of original surface conditions on the side of the Danube, next to the embankment can improve the survival chances of plant and animal species, which is particularly important for protected species.

The continuous biological monitoring of the area is of prime importance. The examinations made so far provide a proper and correct base-line for the monitoring. With the help of monitoring, problems may be perceived in time and corrected.

18.4.2 THE IMPACT AND IMPACT AREA OF OPERATION

From among the impact factors of ordinary operation, impacts of the warmed up cooling water inflow are of primary importance for **aquatic macroscopic invertebrates** in the Danube riparian region. The several decades of experience of the Paks Nuclear Power Plant shows that the conditions described above could be maintained at times of coincidence of the highest temperature and the lowest water level periods. The impact of the heat trail affects the entire river section under the power plant (primary production, disassimilation, oxygen balance), but the higher temperatures prognosticated on the right bank in the boundary section will most probably have a significant impact on the macroscopic invertebrates in the left-side belt of the embankment. With regard to the uncertainty of temperature change models, the prognosticated water temperatures of Danube must be definitely taken as a warning, but their future impact on macroscopic invertebrates in the embankment zone can be evaluated only in general. Impact of the extra heat calculated compared to the current state which certainly will be difficult to be separated from water temperature increase due to climate change will be less predictable. But while the former occurs only locally on sections under the inflow points, at a distance of 1,000 m up to the medium line of the Danube, the latter will change the structure and community organisation processes of the Danube biosphere fundamentally and in a manner not known yet. For example the larvae of dragonflies are expected to occur on a section further away from the entry point.

Figure 94: Yellow-legged dragonfly (Gomphus flavipes)

The impact of two factors should be considered in particular during the operation of Paks II. One is the increase of the water discharge, which may change the hydrological and river bed morphological conditions of the area and thereby the use of the habitats by fish. The other one is the increase of the water temperature, which may affect the population dynamics and metabolic processes of the fish. These hydrological and river bed morphological changes cannot be considered detrimental for fish. Presence of another inflow point creates varied habitats conditions, which, similarly to the currently operating inflow point, may even result in the increase of the local quantity of fish, at the inflow points and under the inflow and on the section between the breakwater structures on the right bank. Therefore, the operation of Paks II can locally influence the distribution of fish in space, but presumably it will not have significant impact on the dynamics of Danube populations.

The completion of the construction works of Paks II will be followed by landscaping, which means that undisturbed, predominantly dry steppe habitats will gradually evolve there, similar to the one today, their former orthoptera and soil surface anthropoda assemblages from the adjacent remaining habitats patches will be able to get resettled again, thus valuable communities may settle again and survive during the term of operationgy in this area.

Protected butterfly species are not expected to settle here in the future either. The same is true for the open steppe areas to evolve along the route of the long distance lines to be constructed. For all this, however, undisturbed environment of long time, several decades is needed. On the island, no major change can be expected in the nature conservation status of the butterfly fauna. Ordinary operation will not affect the habitats of the ground squirrel fields at Paks and the Dunaszentgyörgyi swamp forest, and the butterfly species living there either.

The operation of Paks II is not expected to cause direct damaging impacts to amphibians and reptiles. Certain species are expected to resettle, which is an important factor, considering that all amphibian and reptile species are protected.

Figure 95: The green lizard (Lacerta viridis) tolerates anthropogenic disturbance well

As for the birds, species similar to those currently present can be expected to arrive. Due to the long-term relative lack of disturbance of the operation area, a number of protected and highly protected birds species found their habitats here (mostly as a feeding site). The increased number of long distance lines and poles holding those can be considered as continuous source of danger during operation, poles, however, will be also be positive for the number of predatory birds as pole tops can also be used by birds for sitting there.

In addition to the increased heat load on the Danube due to the construction of Paks II, climate changes caused by global warming must also be considered, their joint impact must be modelled and they need to be monitored in the future. The findings of research conducted so far suggest that global changes may decrease the adaptability of the current water community structures. It must be taken into consideration that we only have sporadic knowledge about the impact of climate change on macro invertebrate species. Based on the knowledge that we have so far, in general, we can state, that water temperature increase will have its highest impact on species tied to a place (sessile) during their whole life or in certain development phases with preference for cold water and low tolerance ability. Similar significant impact can be expected in case of slowly moving, less mobile species (e.g. molluscs). Mobile species of broader tolerance will be the least affected. As a consequence of the forecast joint impact of climate change and warm water discharge, occurrence of invasive species with preference for warmer waters that have already appeared from the south spreading upstream on the Danube will probably increase both with respect to their number of items and number of species. In summation, the production of the entire system may increase (bacteria, algae, etc.), and through the nutrient network and mass turnover it may affect the operation of the entire system.

Impact of the deposition of air polluting substances emitted by the ordinary operation of the power plant and of the slightly increased noise level will not be detectable with respect to the butterfly fauna. Human presence, disturbance and increased traffic is more favourable for the occurrence and spread of soil surface animals under anthropogenic impact on areas directly not affected by the investment. Polluting substances emitted into the air may get enriched in certain less mobile species along the main transport roads. During the operating time of Paks II, personal and cargo traffic and together with this, noise, dust and air pollution will increase. The majority of amphibian and reptile species avoid such habitats. The new block lines leaving the territory of Paks II may promote the re-settlement of lizard species in time.

The impact of the operation of Paks II is expected on aquatic macroscopic invertebrates (including dragonflies subject to separate examination) to a small extent at the inflow of the cold water channel and at the outflow of the warm water channel as well as on the Danube section below this. Introduction of the warmed up cooling water can presumably influence fish stock structure only locally (along a section of ca. 1 km).

From the aspect of the orthoptera, butterflies, soil surface arthropoda and birds, the direct impact area of ordinary operation will cover the entire area of the power plant (including the temporary construction area) and the safety zone of the transmission lines. For amphibians and reptiles, the impact area of operation will primarily be the environment of Paks II.

No trans-boundary impact can be expected in respect of the fauna.

18.4.2.1 The impact and impact area of malfunctions and accidents

Malfunctions may be manifold and their impact on the fauna alike. It is impossible to provide a comprehensive review of them, therefore we deal with the most probable cases only. In the event the temperature rises due to malfunction, the number of items of populations which are tied to their places will decrease and mobile populations will wander away within the aquatic ecosystem. This may lead to the reduction of the number of items in, or the complete disappearance of, the population protected species, such as the thick shelled river mussel *(Unio crassus)*, the yellow-legged dragonfly *(Gomphus flavipes)* or the Danube may-fly *(Ephoron virgo).* As most of the environment is characterised by dry habitat, they are highly exposed to the risk of extensive fires. In the event of fire in the environment of the power plant, the land animal populations living there may be injured or their communities may disappear from the environment of the power plant. This is especially true for the pine plantations along the route of the transmission lines. With regard to transmission lines, electric discharge may pose fire danger. Most of the gaseous compounds released by fire are toxic (e.g., material of insulations) but the deposited remaining materials (substances in ashes) may also be toxic. Petroleum products spilled on soil surface will on the one hand cause the suffocation of animals living in the soil. The impact of municipal waste water getting into the environment in case of malfunction depends on its composition. These impacts will depend on the concentrations, as may change from time to time.

18.4.3 THE IMPACT AND IMPACT AREA OF ABANDONMENT

We can make only very rough ecological estimations regarding the abandonment of Paks II. Information available are rather poor. The impact of the abandonment will greatly depend on the abandonment technology.

The abandonment of Paks II will presumably have a negative impact on the animals living there during the decommissioning works. The impact of the abandonment of Paks II will greatly depend on the abandonment technology. If the abandonment technology requires a larger temporary construction area, habitats will probably be damaged as a result of the works to be performed there. The damage caused by abandonment, similarly to the damage caused by construction works, can be repaired by rehabilitation, provided that the original or similar status of habitats is restored. However, the technological conditions of abandonment are not yet known, therefore we cannot make any estimations on the merits of the case, either.

19 NON-RADIOACTIVE WASTE

19.1 WASTE TYPES AND QUANTITIES

The following waste types will be produced during the establishment, operation and decommissioning of Paks II., naturally, in different proportions:

- construction-demolition (inert) waste,
- non-hazardous industrial waste,
- hazardous waste,
- municipal waste.

Paks II. construction

The work processes of establishment (construction of nuclear power plant units, establishment of the condenser cooling water system, establishment of the in-site section of the transmission grid) will chiefly generate construction-demolition (inert) wastes, concentrated on the 5 years of establishment of the individual blocks each.

The largest amount of waste is soil produced during the excavation of the working pit; while a lesser amount of waste from construction auxiliary structures and materials is generated.

Paks II. construction phases	Quantity	
	[m^3]	[t]
Construction of nuclear power plant units	820 000	1 476 000
Condenser cooling water system installation	570 000	1 026 000
Transmission grid		
construction of the site section	150	270
construction of the out-of-site section	650	1170
total:	1 390 800*	2 503 440*

Note:
* The quantities of excavated soil include the amounts refilled during the construction works.

Table 55:Estimated soil volume excavated from the construction site during the construction of Paks II.

Paks II. operation

Less non-radioactive wastes will be produced during the operation period of the nuclear power plant compared to the construction period. Waste quantities produced during regular operation are shown in the following table. On top of that, wastes will be generated from time to time as a result of maintenance and transformation works. Most of such activities cannot be planned in advance, therefore, no waste quantity estimate is made.

Wastes generated during the regular operation of Paks II.	Quantity [t/year]
non-hazardous waste	800
hazardous waste	100

Table 56:Estimated quantity of wastes produced during the regular operation of Paks II.

Joint operation of Paks II. and the Paks Nuclear Power Plant

The waste quantities produced in the two nuclear power plants during joint operation will add up during the period of joint operation. The intensity of the aggregate quantities will vary from year to year, partly due to the fluctuation of annual waste production, partly due to the fact that the units of Paks II. will be started and those of the Paks Nuclear Power Plant will be stopped at various point in time, and also varying operating cycle lengths. The most intensive period in terms of waste production will be between 2030-2032, when all units of both nuclear power plants will be in operation. The estimated quantities are shown in Table 57.

	Non-hazardous waste [t/year]	Hazardous waste [t/year]
Paks Nuclear Power Plant	*1434*	*276*
Paks II.	*800*	*100*
total:	*~2240*	*~380*

Table 57:Estimated quantity of waste generated during the joint operation of Paks II. and the Paks Nuclear Power Plant

Paks II. decommissioning

The decommissioning period of the nuclear power plant will generate mostly demolition waste, presumably in large quantities. Approximately 400,000-500,000 tons of inactive concrete waste will be produced during the demolition of the buildings.

19.2 WASTE COLLECTION, STORAGE, RECYCLING, DISPOSAL

Waste collection at Paks II. site must be implemented in each phase of the service life of the nuclear power plant by preventing environmental pollution. Collection of waste by waste types (selective collection) to the greatest possible extent must be endeavoured. An adequate amount and quality of collection vessels must be provided in the work area. Workplace collection points as well as in-plant industrial and hazardous waste storages must be allocated pursuant to the applicable regulations. Actions must be taken to ensure the recycling of waste as much as possible so that as little waste should be dumped in landfills for disposal as possible.

A part of the soil excavated at the construction area during establishment will be refilled during construction.

Possible solutions to deposit the remaining soil volume are as follows:

- terrain correction/landscaping within the site,
- terrain correction/landscaping at an external location,
- removal to landfill for terrain correction or cover.

If the excavated soil cannot be removed immediately for subsequent use, a temporary storage area must be designated at the area.
Waste may be removed from the site for recycling or disposal to the following types of facilities:

- selectively collected municipal, industrial and construction-demolition wastes – waste recycling organisations, processing plants,
- mixed municipal waste – municipal landfill site of the town of Paks,
- construction-demolition waste – in-site or at external locations, inert and perhaps municipal landfills, construction waste processing plants,
- hazardous waste thermal recycling – hazardous waste incinerators,
- hazardous waste disposal by landfilling – hazardous waste landfill site.

Always the organisation with a relevant licence in compliance with statutory regulations must be engaged for the removal, recycling or disposal of various waste types.

19.3 IMPACTS AND IMPACT AREAS

19.3.1 DIRECT IMPACTS

It can be said for all phases of the service life of Paks II. that indirect impacts will show at the locations used for the collection and storage of the in-site wastes of the nuclear power plant, as well as by virtue of spilling or leaking wastes during waste handling within the site. The impact factor may cause alteration in the condition of the geological medium, but will have no impact on surface and underground waters.

The operation of Paks II. as well as the joint operation of Paks II. and the Paks Nuclear Power Plant will have a moderate direct impact by virtue of non-radioactive wastes production.

The establishment of Paks II. will have more intensive impacts due to the large amounts of construction waste generated – primarily the soil excavated at the construction site – and due to the fact that said environmental impact will be concentrated to the 5 years of establishment of each unit. **Nevertheless, the indirect impact will remain acceptable with respect to non-radioactive waste production** in this case as well.

19.3.2 INDIRECT IMPACTS

The removal of waste from the site for recycling or disposal will be considered an indirect impact in all phases of the service life of Paks II. In other words, it will show as an impact factor in the vicinity of the transport routes (the route section stretching between the northern entrance of the power plant and the municipal waste dump of the town of Paks, and the relevant sections of Road No. 6 and M6 Motorway). Waste transport may cause alterations in the condition of the geological medium due to the contaminating effects of potential spillage along the route. Air quality will also be affected along the public roads involved. An increased level of noise load is expected due to all road traffic related activities of the nuclear power plant.

The indirect impact area of non-radioactive waste production will remain within a zone of 50-100 m of the road used for waste transport in all service life phases of Paks II.

19.3.3 TRANSBOUNDARY ENVIRONMENTAL IMPACTS

The environmental impacts of non-radioactive waste produced during the service life of Paks II. remain local, and no transboundary environmental impacts are expected.

20 MANAGEMENT AND DISPOSAL OF RADIOACTIVE WASTES AND SPENT FUEL

The collection, treatment, storage and transportation of radioactive wastes, and the management, temporary storage and final repository of spent fuel assemblies invariably involve technological steps during which the primary objective is the protection of the people within and outside the site and the elements of the environment against potential radioactive radiation, or to suppress such effects to the minimum practicable level.

Based on the legislative background currently in effect, spent fuel is distinguished from radioactive wastes, as the former contain fissile materials suitable for further use or to produce new nuclear fuel. In line with this, the management of spent fuel also departs from the treatment procedures of conventional radioactive wastes.

20.1 DEFINITION OF RADIOACTIVE WASTES

Radioactive wastes are essentially defined based on Section 2, Paragraph 15 of the Act on Nuclear Energy: "*radioactive waste: some radioactive material with no further use which cannot be treated as ordinary waste due to its radiation protection characteristics*".

They can be classified or grouped according to various criteria, based on which their collection and later treatment can be carried out. Such grouping options include the place of release, the state of released matter, or also activity concentration.

Based on the place of generation, the wastes generated by maintenance during normal operation, including typically primary loop related cleaning, decontamination works, the wastes produced during the replacement of irradiated parts and equipment, and controlled or non-controlled leakages of the primary loop coolant are separated.

Based on the actual state of matter, solid state, liquid and gaseous radioactive wastes are distinguished. Due to their accurate delimitation, the collection of solid radioactive wastes is fundamentally simpler than that of liquid wastes. The collection of liquid radioactive wastes usually requires special technological solutions already at the place of release.

Given that only solid waste can be evacuated from the facility site, the solidification of liquid wastes requires additional technological steps.

In terms of radioactive wastes, separation by activity concentration means that a given type of waste must be collected, treated, stored and transported subject to the biological and physical protection demanded by the degree of activity concentration of that waste and/or waste package. Classification is done based on the so-called waste index calculated using the sum of the activity concentration (AC_i) and exemption activity concentration (EAC_i) quotients of the radioactive isotopes contained. Storing **low activity level** wastes does **not require** protective radiation **shielding**, it is sufficient to separate them to a designated and controlled access storage area. The storage equipment of **intermediate activity level** wastes are designed based on radiation protection arguments, but – unlike high-level wastes – **heat generation in waste can be disregarded**. It is sensible to distinguish low and intermediate activity level wastes by the half-lives of the isotopes they contain: the **half-life** of the **dominant isotopes** present in **short lifetime waste** is 30 years or less.

20.2 CHARACTERISTICS OF SPENT FUEL ASSEMBLIES

In accordance with Act CXVI of 1996 on Nuclear Energy, Section 2, Paragraph 14: "*Spent nuclear fuel: nuclear fuel irradiated in a nuclear reactor and permanently removed from the reactor. Spent nuclear fuel cannot be classified as waste because of its ability of being reprocessed or when it is yet classified as waste its final repository has to be ensured*".

The state of fuel used in nuclear power plants is typically characterized by the degree of burnup, which is a measure of how much energy is extracted from fuel containing a unit mass of uranium (or uranium and plutonium) during the time spent in the reactor.

In respect of the final disposal and reuse of spent fuel, the equally important factors are the mass and activity of spent fuel, the heat produced by decay, and finally radiotoxicity measuring biological damage.

Due to the chain reaction taking place, significant activity and consequently heat generation can be observed in fuel assemblies even after removal from the zone. **Heat production** in spent fuel diminishes in parallel to activity. After ten years of storage spent in a decay (cooling) pool, the heat produced in spent fuel drops to a mere 1/10,000th part of the rate during normal operation in the reactor, and 1/500th of the residual heat in the assembly immediately subsequent to reactor shutdown.

The **radiotoxicity** of spent nuclear fuel shows the potential detrimental health-damaging effects of the radioactive isotopes found in it could exert when incorporated in the human body. The radiotoxicity of spent nuclear fuel is ten thousand times higher initially than that of the natural uranium used for production. The radiotoxicity level of natural uranium will be reached by spent fuel after more than a hundred thousand years.

The **quantity** of spent nuclear fuel produced during the operation of a rector is primarily determined by the performance of nuclear power plant units and the type of fuel used. In general, the higher the performance of a nuclear power plant unit, the more spent fuel is produced.

As a by-product of processing spent fuel and producing nuclear fuel, no longer reusable, typically high activity level radioactive waste is generated.

Calculating with UO_2 fuel and a service period of 60 years, according to supplier data roughly 3 135 pcs of spent fuel assemblies will be produced, of which the amount of spent fuel is ca. 1 674 t per unit (see Table 58).

Reactor	Heat performance (MW)	Assembly burnup (MWd/kgU)	Utilization factor (%)	Spent fuel mass (t)
VVER-1200	3 200	47.5	90	1 674

Table 58: Quantity of spent fuel generted suring the entire operating lifetime by unit.

Before any further processing, the spent fuel removed from the decay pool is moved to a facility for temporary (interim) storage several years after the start-up of the new units. The residual heat will have to be removed even after storage in the cooling pool, but at that point less intense methods (using air of natural draft only) may prove to be adequate.

20.3 General Provisions for Radioactive Wastes

Radioactive wastes are inevitable by-products of nuclear power-based electricity generation, therefore their management, temporary and final storage must be addressed and ensured. The definition of radioactive waste fits any material generated as a result of some planned nuclear activity, with no demand or method for further use, containing radioisotopes with concentrations in excess of the limit values to be safety released into the environment (regarded safe) or to be disposed in some repository.

The collection, registration, treatment, qualification, packaging, transportation, temporary storage and final disposal of radioactive wastes can be implemented pursuant to the comprehensive, detailed provisions of Government Decree 118/2011. (VII. 11.) Korm. on the nuclear safety requirements of nuclear facilities and related regulatory activities, not forgetting other domestic legislation and international recommendations.

From the aspect of the entity producing waste, in view of the lifecycle of radioactive waste, the key pillars of the waste management strategy include (quantitative and qualitative) design, generation (and selective collection), treatment, conditioning, internal storage, transport and deposition possibilities. One of the most important steps between generation and treatment/conditioning is the most accurate identification possible of the waste output, qualification and labeling (marking) of the waste packages, in order to ensure traceability. The applicable processing and conditioning technologies are affected by the acceptance requirements of the storage facilities and suitability for disposal.

20.3.1 Low and Intermediate Activity Level Solid Radioactive Wastes

The solid wastes produced in the controlled zone of the new nuclear power plant will be **collected selectively** already on the place of release. The **selection** of waste will be done based on its radiological parameters, taking also into account the subsequent waste treatment types.

Potentially inactive waste will be **cleared** after **radiological classification**, and it will be managed as conventional waste.

The part of low activity level waste of which the isotope content will - according **radiological qualification** – reach the clearance limits within a foreseeable time horizon will be forwarded to **isolated temporary storage**, with the aim of enabling future clearance once the radioisotopes have decayed.

Waste suitable to be compressed will be **compacted**, thereby reducing the volume of waste eligible for final disposal. Following **temporary storage**, the compacted waste is, if necessary, **conditioned** (to form waste packages which can be accepted in the NRWR facility. Conditional wastes find **final disposal** in the NRWR repository.

20.3.2 HIGH ACTIVITY LEVEL SOLID RADIOACTIVE WASTES

High activity level solid wastes produced during maintenance activities must be **packaged.** If the nature of such high activity level solid wastes allows it, their **volume** must be **reduced**.

The **temporary storage** of high activity level waste packages is done until the dismantling of the units or the commissioning of the NRWR facility in a repository built for this purpose.

Following temporary storage, high activity level radioactive wastes will be transferred to a deep geological repository to be constructed in Hungary for **final disposal**.

20.3.3 LIQUID RADOACTIVE WASTES

The drains, air ventings, and controlled leakages containing boric acid are collected, handled and reused separately. This way only a minimum amount of **boric acid** enters the **leachate**, thus again reducing the volume of liquid radioactive wastes.

Ion-exchange resin regenerating, loosening solutions resulting from steam generator cleaning system, the waters from the special laundry and the shower room of the primary loop locker room are **released** from the controlled zone depending on their activity concentration either without treatment or after treatment with selective sorbents.

Following **volume reduction,** radioactive leachate is **conditioned** (solidified) such that the end product meets the requirements regarding final disposal.

The condensates produced during the volume reduction of radioactive leachate are either reused or released to the environment as extra (above balance) water.

Conditioned wastes are transferred to the NRWR Facility for **final disposal**.

20.4 GENERAL PROVISIONS FOR SPENT FUEL ASSEMBLIES

This context includes the comprehensive supervision of the new fuel delivered to the site and the spent fuel assemblies removed from the reactor, plus the required treatment steps.

In addition to physical protection, fresh, unused fuel does not require any additional special (radiation protection) treatment, it has no radiation health care relevance.

The treatment of spent fuel is a far more complex task, the applicable legislative provisions and international recommendations require the strictly co-ordinated operation of involved technological and radiation protection procedures.

After being discarded from the reactor, spent fuel assemblies are placed into a **decay pool** where the removal of residual heat is assured until its magnitude decreases to a value which allows its interim dry storage.

Following storage in the decay pool, spent fuel is transferred for temporary storage. There are currently two options available:

- the spent fuel assemblies are transported to the Russian Federation for temporary technological storage or for technological storage and reprocessing. The spent fuel, or in case of reprocessing the nuclear waste, is then stored in the territory of the Russian Federation for the duration of the time period defined in Article 7, Paragraph 1 of the agreement (contract) regarding nuclear fuel supply (20 years). then it will be returned to Hungary,
- the domestic temporary storage of spent fuel.

In the EIS, **domestic temporary storage** possible for several decades is considered for the interim storage of spent fuel assemblies, on the site housing the units or in its immediate vicinity. Temporary storage will continue until the direct final disposal of fuels is ensured.

Thus subsequent to temporary storage, the **direct domestic final disposal** of spent fuel will be assumed.

20.5 EXPECTED IMPACTS OF CONSTRUCTION

During implementation, **no direct impacts** stemming from the generation, collection, treatment and neutralization of radioactive waste are expected. The first load will arrive at the site 1 year prior to the termination of construction.

During implementation, **no direct environmental impact** regarding radioactive wastes are expected, therefore the development of indirect impacts can be neglected as well.

During implementation, the emission of radioactive isotopes from radioactive wastes is not expected, thus the indirect effects, and the notion of impact area are not relevant, **indirect effects** are **not expected** (in the absence of relevant factors).

In the absence of relevant factors (**underlying reasons**), the impact area due to collecting, storing radioactive waste, the **impact area of transboundary environmental impacts** cannot be determined.

20.6 EXPECTED IMPACTS OF OPERATION

20.6.1 RADIOACTIVE WASTES

In respect of radioactive wastes, the expected impacts of the operation of a nuclear power plant is determined by the quality and quantity forecast of such wastes.

During the design of the planned unit type, special attention was paid to enable the generation of a smaller quantity of radioactive waste during operation that it was customary for the earlier technological solutions. Due to the layout of the primary loop systems and the higher degree of compactness of the technology, the amount of low and intermediate activity level wastes will be significantly less than the quantity currently generated in the existing Paks units.

The Paks II systems were designed to be capable of processing the radioactive wastes produced during their lifetime in a way that pins the levels of solid, liquid and gaseous releases to some reasonably practicable minimum. The lessons learned so far were incorporated into design work.

The treatment and temporary storage of radioactive wastes is done in the auxiliary building next to the containment area, according to state of matter and activity concentration features. The on-site storage of selectively collected and pre-treated low and intermediate activity level wastes will be allowed for a period of 10 years. The on-site temporary storage of high activity level wastes will be allowed until the end of the operating lifetime, therefore the selection of their final disposal location and the construction of the required storage capacity will have to be accomplished by the end of the operating lifetime.

After temporary on-site storage, low and intermediate level activity, solid or solidified radioactive waste is transported by road to the NRWR facility to a subsurface repository.

The estimated annual average quantity distribution of low, intermediate and high activity level solid wastes produced during the power generating operation of the reactor units of Paks II to be implemented is shown in Table 59.

Waste	Amount of waste [m^3/year]	Amount of waste after treatment (solidification, cutting, etc.) [m^3/year]	Number of units to be handled / stored
Low activity level solid	70	28	140 barrels
Intermediate activity level solid	11	4	20 barrels
High activity level solid	0,5	-	5 capsules
Bulky, not manageable (generated by maintenance / repair)	5	-	-
Cemented evaporation residue	25	20	100 barrels
Cemented ion-exchange resin	10	8	40 barrels
Cemented sludge / mud	0,6	0,5	3 barrels

Table 59: Estimated annual amount of generated solid radioactive wastes by unit. [40]

In estimating the amount of waste eligible for final disposal, the effect of applying the waste management and conditioning technologies to be implemented with the new units was also included.

20.6.2 SPENT FUEL ASSEMBLIES

Using the available unit data, is it possible to estimate the amount of spent fuel generated during the entire operating lifetime. Calculating with UO_2 fuel and a service period of 60 years, according the given data 1 674 t of spent fuel will be produced in one reactor, calculating with two units this gives 3 348 t.

Spent fuel assemblies are first placed in the decay pool located within the containment.

Regarding the temporary storage of spent fuel removed from the decay pool, there are seceral solutions proposed in the available literature and technological descriptions. Taking into account the specific features of the paks site, and weighing the benefits and drawbacks of implementing various technologies, on-site temporary storage in surface, dry containers appears to be the best choice. In fact, selecting a storage area within the site has several advantages in terms of safety & asset protection, social acceptance, transport / logistics tasks and the monitoring system to be established in relation to the new units. Based on the available information, a ca. 75 × 100 m large, suitably paved surface may be suitable for the temporary storage of spent fuel assemblies egnerated during the entire operating lifetime over several decades.

Figure 96: Dry, cask storage, upright layout. [42]

Figure 97: Filling the cask for dry storage, horizontal layout. [43]

Figure 98: Typical layout of a dry cask storage area. [44]

20.6.3 EXPECTED IMPACTS AND IMPACT AREA OF OPERATION

Radioactive wastes

Low and intermediate activity level radioactive wastes will be collected and treated in the auxiliary building. The impact area of the **direct** radiological **impacts** due to the applied technological steps and potentially affecting the environmental elements above the limit values will be limited to the nuclear power plant site, in particular to the area of the **storage and treatment building**.

The route of transportation of conditioned waste to NRWR is 64 km long. Of this, 49 km goes on Motorway M6, hence, in that section, the radiation exposure of a person assumed standing on the edge of the carriageway does not need to be considered, since pedestrian traffic is prohibited along motorways; furthermore, a person present in the service (rest) areas and the territory of filling stations on the motorway can be only so close to the centre line of the lane where the effect of cargo radiation is negligible. In the first section of the transport route a feeder road between the present northern access road to the Paks Nuclear Power Plant and M6 is included in the master plan of the town of Paks, which extends from the intersection of the northern access road and Road 6 to Paks M6 southbound exit, without traversing populated areas.

It can be concluded that the annual radiation exposure of the population, even with a conservative estimate, is by orders of magnitude below the public dose limit or the dose constraint, hence during **transportation to the final disposal facility**, the **transport route** or, rather, the **edge of the carriageway** can be considered as the **border of the impact area,** assuming that it is always the same person standing on the edge of the road when the transport vehicle passes by.

The technical layout of the packaging allowing delivery to the repository should be such that during the estimated lifetime of said packaging the radioactive matter contained within cannot escape, therefore the **impact area of indirect impacts** can be expected to coincide with the **boundaries of the storage area site**.

The potential radiation exposure due to the storage of high activity level radioactive waste with respect to environmental components is limited to the area of the site, or rather within the impact area identical to the 500 m boundary of the formally not yet officially determined safety zone.

The **impact area** of the **indirect impacts** of high activity level wastes depends on the **management and storage technology** of the wastes mentioned. After their production on-site storage is preferable as long as the proportion of short half-life isotopes and heat generation also decreases. What follows is transportation to the final disposal facility. The Boda Aleurite (Claystone) Formation (BAF), currently investigated with high priority, may serve as a final disposal facility within the borders. The direct and the indirect impacts that may originate from such facilities basically depend on the functioning and the operation of the engineered barriers implemented in accordance with the specifications. Deep geological repositories may retain radioactive isotopes safely for several tens of thousands of years. The typical storage technology is waste packages provided with the engineering protection specified, the repository chambers separated by a thick watertight concrete layer from the natural rock then filling up the chambers full of containers with rock gob and sealing with a concrete layer. From the data of the geophysical monitoring system installed in the repository chamber before filling up and closing, one can infer a leakage, which might occur as a direct impact related to the immediate environment of the deep geological storage area, however, the probability of this is practically negligible.

In the case of compliance with the strict instructions and process descriptions (procedures) during normal operation with respect to the management of radioactive wastes, the environmental impacts originating from the management of radioactive wastes of different levels shall not reach or go beyond national borders. The same applies to spent fuel assemblies.

Spent fuel assemblies

The assemblies (placed in containers) will presumably spend decades in the on-site temporary storage area, when they will be transported to either a reprocessing plant or a final disposal facility without any further manipulation, since the surface storage containers provide adequate protection even during transport operations.

The environmental radiation exposure due to the containers in the surface storage area does not exceed the dose constraint even on the boundary of the impact area identical to the boundary of the safety zone

In the case of transportation to a reprocessing facility, the section of the assigned railway line to the border is taken into account. When planning the route it is also considered that the train passes by the minimum number of populated areas possible based on the existing rail network, it has priority and it is secured, thus, including the planned stops, too, the length of stay is also minimal.

The **determination of the indirect impact area** also depends on the **method of treatment** after **temporary storage**. So far as the fuel is subject to reprocessing and reuse, i.e. the isotopes usable as fissile material are extracted for the purpose of further electricity production, the transport route from the temporary storage area to the reprocessing facility and the environment of the utilizing facility shall be also taken into account. However, during processing, a part of the isotope inventory is transformed to high-level waste, which is adequately conditioned (usually by means of vitrification) in the reprocessing facility. This high-level waste (in accordance with the actual legal environment) is returned to the nuclear power plant, from where it gets to the planned deep geological repository in the way as it has been described for high-level wastes.

20.6.4 IMPACT AND IMPACT AREA OF JOINT PAKS II AND PAKS NPP OPERATION

During joint operation, the reactors of Paks II will be in the first decade of their operation; the on-site placement and temporary storage of the radioactive waste and spent fuel produced during this period will be done in the auxiliary building of the primary loop located next to the containment and in the decay pool; i.e. no dispatch of radioactive wastes from the site and no manipulation of spent fuel assemblies outside the containment are expected in the case of Paks II. Even if there will be dispatch for the purpose of disposal, the amount will be probably smaller compared to the dispatches from the Paks NPP. Regarding radioactive wastes and spent fuels, the impacts expected during joint operation will come forward almost exclusively on the units of the Paks Nuclear Power Plant due to the incidental environmental impacts of such wastes produced during the technical actions required and due at the end of the operation of the units.

Common actions during joint operation will include the dispatch of radioactive waste from the site by road, and spent fuel dispatch by rail. Regarding joint operation, during the preparations for the 20 years of protected preservation, the transportation along the route described above of low- and intermediate-level waste to NRWR with the associated radiology impact is expected from the units of the Paks Nuclear Power Plant closed one after the other. The spent fuel assemblies removed from the closed units of the Paks Nuclear Power Plant will be taken to ISFS. The exact scheduling of the dispatch of spent fuels to the ISFS Facility after the 50 years of cooling is currently not known; however, the delivery times of the wastes from the two facilities as well as the transport routes involved should be aligned in order to avoid additive impacts.

Considering the several decades of on-site temporary storage of low, intermediate and high activity level wastes, no dispatch can be expected from the Paks II area during joint operation in the light of current ideas.

The impact area of radioactive waste emission during normal operation as well as the management and temporary storage of the wastes of the two facilities can be considered to be identical to the boundary of the safety zone.

Transboundary environmental impacts of the joint operation of the Paks Nuclear Power Plant and Paks II can be excluded during normal operation.

20.6.5 IMPACTS OF DESIGN-BASIS EVENTS

The collection and management of those types of radioactive wastes that are produced in the course of design-basis operation events but in off-normal conditions can be performed in the auxiliary building of the primary loop; hence the impact area of the direct environmental impacts of these wastes will be expectedly within the boundary of the safety zone of the site, and therefore analysis of the indirect as well as the transboundary environmental effects is not justified.

20.7 EXPECTED IMPACTS OF DECOMMISSIONING

Irrespective of the immediate dismantling version currently in effect vis-à-vis Paks II, the permanent shut-down of the nuclear power plant and the execution of the corresponding technological steps will take years. Demolition causes effects similar to that of construction with the difference that, contrary to construction, a significant amount of mainly low- and intermediate-level waste is produced, which waste steam must be managed on-site. The disposal of this large waste quantity will require sizeable mining activities and material handling, but the impact area of the effects so engendered will presumably be restricted within the national borders.

21 ENVIRONMENTAL RADIOACTIVITY – RADIATION EXPOSURE OF THE POPULATION LIVING NEAR THE SITE

21.1 ENVIRONMENTAL RADIOACTIVITY OF THE 30 KM RADIUS AREA AROUND THE NUCLEAR POWER PLANT

The monitoring of the environment surrounding the Paks NPP by measuring the radioactivity of different environmental samples has been an on-going program since 1978, from setting the baseline (zero level) to continuous operating measurements. The measurements were and are still made by the staff of the Paks NPP, the authorities and several other institutions as well.

The measured activity concentration results of the following environmental elements were used to characterize the environmental radioactivity of the Paks NPP:

- Dose rate of environmental radiation,
- In-situ gamma spectrometry measurements,
- Atmospheric, soil and grass samples,
- Surface water samples,
- Mud samples,
- Fish samples,
- Groundwater samples,
- Milk samples.

The key inputs forming the basis of evaluation were primarily the PERMS and JERMS (see main document) YR 2001-2011 Annual Reports. The environmental measurement results available for the period between 2001-2011 were split into groups according to location areas. Based on preliminary investigations, the nuclear power plant surroundings were described by 3 distances (< 5 km, between 5-10 km, and between 10-30 km) and 4 directions (North, South, East and West) as indicated hereunder:

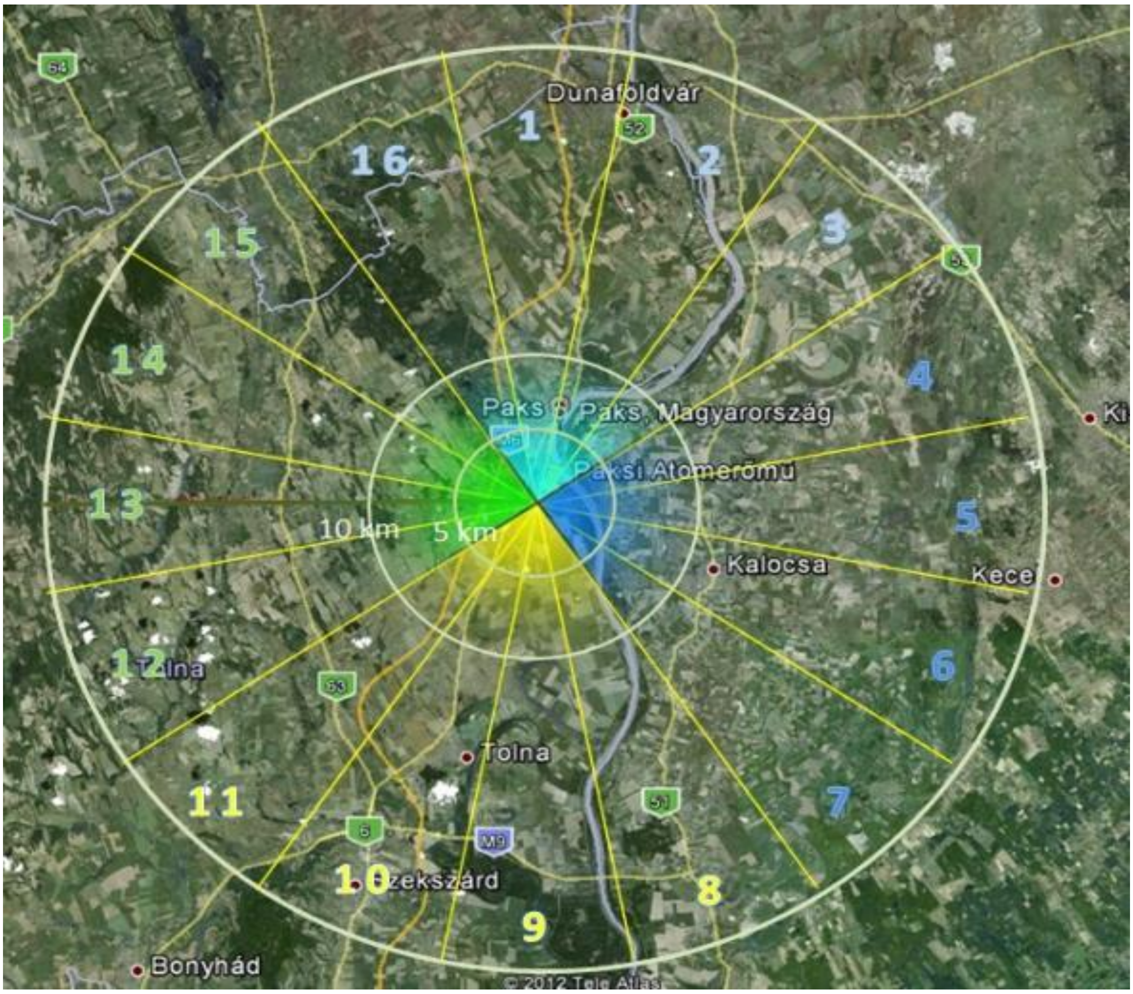


Figure 99: Sector group split for the 30 km area surrounding the nuclear power plant.

Regarding Danube water and mud samples, the Danube was split into upstream and downstream sections at Paks.

The movement and binding of radioactive materials in elements of the environment are a result of complex processes, so e.g. the absorption of radioisotopes by plants is influenced by a number of factors, of which the most important are: soil structure, soil cohesion degree and mechanical composition, the rooting depth of plants, the ratio of plant parts above and below ground surface, length of the vegetation period, the climatic and meteorological conditions.

The effect exerted by one element of the environment upon another, that is, the interactions between them can be described most simply using the IAEA recommendations, namely the so-called interaction matrices. Knowing these interactions also allows the description of the movement of radioactive materials escaped into the environment. Natural habitats, growth areas and their main interactions through which radioactive contaminations may migrate and move from one location to another. The diagonal of the interaction matrix contains the main environmental elements, while the adjacent cells show the interactions between them. Interactions between the diagonal elements are understood to be effective clockwise.

The table below shows natural habitats and growth areas and their main interactions through which radioactive contaminations may propagate and move from one location to another.

	1	2	3	4
1	Forest	Wind (aerosol, vapor) Ground- and surface water (downflow) Soil (mixing) Ash use (manuring) Use of animal dung (manuring) Organic decomposition products Use of wood products	Wind (aerosol, vapor) Ground- and surface water (downflow) Soil (mixing) Ash sedimentation (incineration) Organic decomposition products Animal fodder	Wind (aerosol, vapor) Ground- and surface water (downflow) Soil (mixing) Ash sedimentation (incineration)
2	Wind (aerosol, vapor) Ash sedimentation (incineration)	Cultivated area	Wind (aerosol, vapor) Ground- and surface water (downflow) Soil (mixing) Ash sedimentation (incineration) Organic decomposition products Animal feed	Wind (aerosol, vapor) Ground- and surface water (downflow) Soil (mixing) Ash sedimentation (incineration) Organic decomposition products
3	Wind (aerosol, vapor) Ash sedimentation (incineration) Farm animals, animal dung	Wind (aerosol, vapor) Ash sedimentation (incineration) Use of animal dung	Grassland	Wind (aerosol, vapor) Ground- and surface water (downflow) Soil (mixing) Ash sedimentation (incineration) Organic decomposition products
4	Wind (aerosol, vapor, spray) Water (animal trough) Flood	Wind (aerosol, vapor, spray) Groundwater (inflow) Sediment (excavation) Water (animals drinking) Irrigation Flood	Wind (aerosol, vapor, spray) Groundwater (inflow) Sediment (excavation) Water (animals drinking) Irrigation Flood	River, lake

Table 60: The main interactions between natural habitats and growth areas.

MEASUREMENT RESULTS OF ENVIRONMENTAL ELEMENTS – JERMS DATA

To begin with, it is important to note that global contaminants like ^{134}Cs, ^{137}Cs or ^{90}Sr originate with high probability from nuclear experiments or the Chernobyl catastrophe, and it is also difficult to separate tritium (^{3}H) and radiocarbon (^{14}C) to tell whether their origin is cosmogeneous, or they are global contaminants, or they were generated by the operation of the Paks NPP.

Measurements of **aerosol** activity concentration only supplied appreciable data for the spatial distribution of ^{134}Cs, ^{137}Cs and ^{131}I (for >10 km). ^{131}I was observed 11 times at distances larger than 10 km, which may indicate a hospital use origin, while the YR 2011 data may refer to emissions from the Institute of Isotopes Co. Ltd. (or Fukushima). The time-wise constant radioactivity of **soil** samples also shows (see Table 61) that mostly global origin nuclear materials are found in the proximity of the nuclear power plant, and it is also apparent that the mean values fall short of the national average:

Nuclide	Year	Average [Bq/kg]	Min [Bq/kg]	Max [Bq/kg]	Number	Country average [Bq/kg]	Reference level [Bq/kg]
^{134}Cs	2001-2011	-	0,26	2,6	5	-	**-**
^{137}Cs	2001-2011	9,7	0,5	52	516	17	**9,7**
^{90}Sr	2001-2011	1,8	0,18	56	183	2,3	**1,8**

Table 61: Cumulative data of soil activity concentration.

Turning to the spatial distribution of **soil** activity concentrations, for the most part again global origin radioactive materials occur near the Paks NPP. Moving on to the spatial distribution of **grass** and **animal feed** activity concentration, similar properties were found like for soil radioactivity, with the exception of the occurrence of tritium. The distribution by river km of the **water** sample activity concentrations obtained for the **Danube section upstream** from Paks also shows that radioactive materials are present in the river even upstream from the liquid discharge point of the Paks NPP. The three typical radioactive materials of global origin (^{137}Cs, ^{90}Sr, ^{3}H) could be detected continuously in time, too. The **water** samples taken from the **Danube section downstream** from the Paks NPP showed nearly identical activity concentrations as upstream from the discharge point, in fact sometimes the value measured upstream from the discharge point was higher than its Paks downstream counterpart. In the Danube section upstream from the Paks NPP, **sediments** show uniform ^{137}Cs distribution in time. In **sediments** in the Danube section downstream from the discharge point the ^{137}Cs and ^{90}Sr radionuclides are present uniformly in time, with values not significantly higher than those upstream of the nuclear power plant. Time variation of stagnant water detectable samples is mostly observed for ^{90}Sr, while the ^{3}H value stays below the national average (^{3}H: 4.3 Bq/dm^{3}). The temporal distribution of **stagnant water sediment** activity concentration can be best measured for ^{137}Cs. There are only a couple of meaningful data each concerning the spatial distribution of **stagnant water aquatic animal** activity concentration, it these the average activity concentration of ^{137}Cs was 0.22 Bq/kg. This value does not exceed the national average (0.42 Bq/kg).

Regarding the spatial distribution of activity concentrations measured in **cow milk**, meaningful data were available for the ^{137}Cs and ^{90}Sr radionuclides only.

The time distribution of cow milk activity concentration was uniform (even), falling into the order of magnitude of the national average.

Nuclide	Year	Average [Bq/kg]	Min [Bq/kg]	Max [Bq/kg]	Number	Country average [Bq/kg]	Reference level [Bq/kg]
^{137}Cs	2001-2011	0,040	0,020	0,073	37	0,055	**0,040**
^{90}Sr	2001-2011	0,092	0,024	0,93	47	0,066	**0,092**

Table 62: Cumulative data of cow milk activity concentration.

The spatial distribution of **dose rate** (measured with TLD) shows that in the proximity of the Paks NPP the values tend to fall into the lower range of the values measured in the country (average: 78 nSv/h).

MEASURED VALUES OF ENVIRONMENTAL ELEMENTS – PERMS DATA

The PERMS measurements were essentially performed close to the Type ”A” measuring stations (A1-A9) and the control measurement station (B24), plus the site and its immediate surrounding. Type ”A” stations are located closer to the Paks NPP, where the radionuclides emitted by the nuclear power plant can be detected with higher probability. Here again only artificial radionuclides were considered as a basis.

Based on operational measurements, **air** sample data show that only a few radionuclides generally characteristic of the nuclear power plant (^{54}Mn, ^{58}Co, ^{60}Co) could be detected in the study period between 2001-2011. The ^{137}Cs, ^{14}C and ^{3}H activity concentration values of Type ”A” stations and those of the Type ”B” control station are similar to each other. Based on **fallout**, **soil** and **grass** sample measurements, only the ^{60}Co radionuclide was typical of the Paks NPP, the ^{137}Cs and ^{90}Sr nuclides were at the same time radioactive isotopes of global origin. The ^{131}I radionuclide of air and fallout samples may originate from the Fukushima NPP accident and the emissions of the Institute of Isotopes. In the mud and soil samples taken on-site and its immediate surroundings the occurrence of nuclear power plant (^{54}Mn, ^{58}Co, ^{60}Co, ^{110m}Ag, ^{106}Ru, ^{144}Ce) radionuclides is a result of confluences and thus accumulation, but the results make evident their origin as nuclear power plant emission. Apart from these places of accumulation, nuclear power plant radionuclides cannot be detected with certainty in other environmental elements.

Dose rate values also fall into the bottom region of the measured domestic range.

Station	Dose rate average [nSv/h]	Years
A1	65,5	2001-2011
A2	66,6	2001-2011
A3	73,3	2001-2011
A4	77,0	2001-2011
A5	73,8	2001-2011
A6	68,7	2001-2011
A7	63,8	2001-2011
A8	82,2	2001-2011
A9	66,4	2001-2011
B24	82,1	2001-2011
Reference level based on JERMS	78	2001-2011

Table 63: Average dose rate values.

Groundwater radiology results

On the site of the Paks NPP and in its neighborhood, sampling wells were constructed at several locations, in order to allow the measurement of ^3H and other radioactive isotope activities in groundwater. In samples taken at places within the site perimeter tritium could be detected showing large fluctuations. The averages changed between 2 and 2 326 Bq/dm^3 as a function of season, water level and flow velocity. The following conclusions of general relevance can be drawn:

- Tritium flow is mainly directed N – NE in the close neighborhood of the main building of the Paks NPP. The exposure propagation direction is perturbed by high Danube water levels. High levels turn the flow direction towards N – NW and exposure propagation stops, while its area widens westward, too.
- Apart from tritium, only a small amount of ^{14}C was detectable, no other artificial origin radionuclides were observed in groundwater wells.
- Measurement results suggest that tritium activity concentrations are gradually reducing.

The occurrence of tritium (^3H) and radiocarbon (^{14}C) can be essentially traced back to global origin, too. Unfortunately, the available pertinent national coverage measurement database is of limited scope only, but a certain part of the values appearing around the nuclear power plant can be assigned to it for sure. Their occurrence on-site in subsurface waters is undoubtedly due to the nuclear power plant, but the extent of exposure is restricted to the site boundaries.

YR 2012 study of radioisotope occurrence in the neighborhood of the nuclear power plant

To determine the current status (radioisotope concentrations) of the environs of the nuclear power plant, 5 test locations were selected to perform the following measurements: in-situ gamma spectrometry measurement (50 tests), gamma dose rate measurement (50 tests), soil activity concentration measurement (50 samples), grass, sedge and tree bark activity concentration measurement (50 samples). The tests were performed within the framework of the earlier Paks NPP lifetime extension environmental rationale project, at the following potential accumulation points identified on a morphological basis.

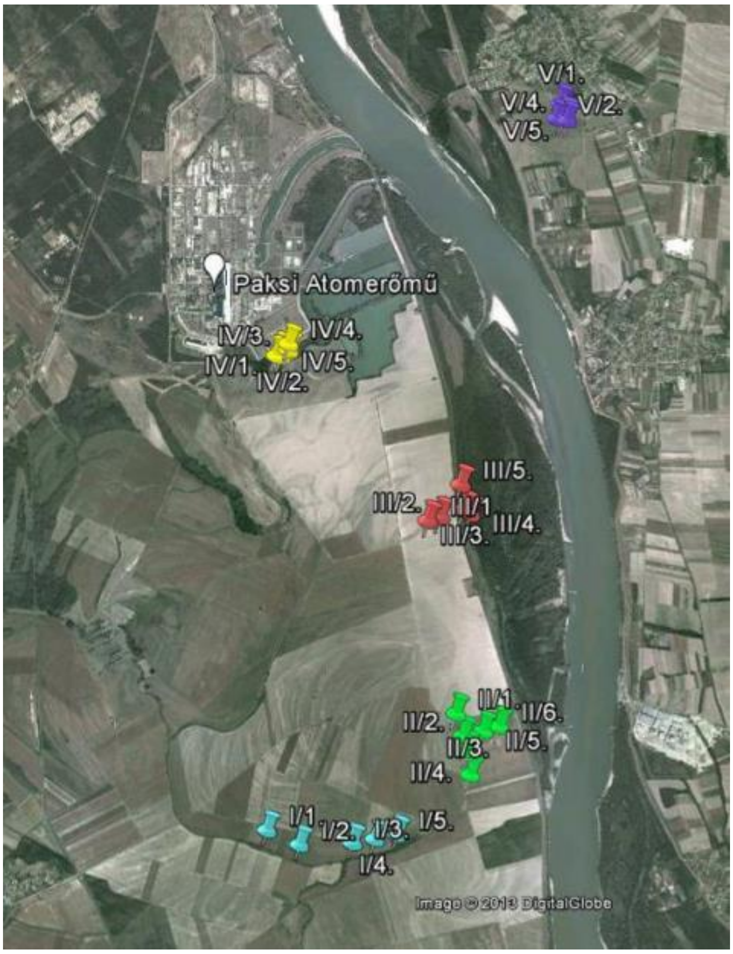


Figure 100: Satellite image of the sampling locations defined in the program.

Using the selected measuring locations, soil and plant samples were taken in two stages of the vegetation cycle (spring-summer and late summer-autumn) in order to determine their radionuclide concentration.

It can be stated in general that the gross-beta activity concentration measured in soil and plant samples originated for the majority of them in 80 – 95 % from their ^{40}K content, thus the two values showed good correlation. The average gross-beta activity concentration of soil samples taken within a 30 km radius area around the Paks NPP was 612 Bq/kg. The measured values varied within the 410 – 788 Bq/kg range. The average gross-beta activity concentration of plant samples was 706 Bq/kg in spring, and 604 Bq/kg in autumn. The measured values varied within a broader range, between 226 – 1236 Bq/kg. It is also clear that the seasonal variations described for the case of the ^{40}K isotope naturally appeared through these values, too.

In the soil samples taken the Paks NPP, the ^{90}Sr and ^{137}Cs activity concentrations (1.0 Bq/kg and 16.1 Bq/kg, respectively on the average) were measured, at test location III (0.4 Bq/kg and 7 Bq/kg respectively on the average). In mud samples, the measured values of both ^{90}Sr and ^{137}Cs isotope concentrations turned out to be lower. In mud samples, the average ^{90}Sr activity concentration was 0.30 Bq/kg, whereas the average ^{137}Cs activity concentration was 5.9 Bq/kg. For the sake of comparison, the average of ^{90}Sr activity concentrations measured in Lake Balaton mud was 0.92 Bq/kg, while that of the ^{137}Cs isotope was 45 Bq/kg on the average. In Lake Velence mud, the average ^{90}Sr activity concentration was 4.39 Bq/kg, and average ^{137}Cs concentration was 31 Bq/kg. The concentration of ^{90}Sr was in samples taken from test location IV was 1.5 Bq/kg. The average activity concentration calculated from the results of all plant samples gives 0.44 Bq/kg for ^{137}Cs, and 1.06 Bq/kg for ^{90}Sr.

Summary of environmental radioactivity

Based on PERMS and JERMS data, the radionuclides typical of the nuclear power plant were appreciable in the detectable range only a few times in air, fallout, mud and soil samples; in fact, mostly ^{54}Mn, ^{60}Co, ^{58}Co and ^{110m}Ag radionuclides were observed. The appearance of radioiodine nuclides was detected in cases like the 2003 operational failure, or when the impact of the Fukushima accident or the emissions of the Institute of isotopes were measured. At points further away from the power plant, the occurrence of radioiodine could be assigned to escape due to medical applications, too. In addition to processing the data measured between 2001-2011, in 2012 in-situ gamma spectroscopy and gamma dose rate measurements were made in the vicinity of the Paks NPP, plus soil and plant samples were taken. The laboratory measurements again only confirmed the ^{90}Sr and ^{137}Cs radionuclides in the different environmental samples. The presence of the ^{60}Co radionuclide in soil could be ascertained only once at one specific place (near the Paks NPP). In the same spirit, the measurements performed at these locations (defined as accumulation points due to morphological and wind direction considerations) in the 1990's could also detect radionuclides – namely ^{110m}Ag - in a couple of cases only.

Based on the above arguments, it can be concluded that it is impossible to attempt to assess the environmental effects of normal nuclear power plant releases by measurements, or to describe their movements and migration through particular environmental elements. Environmental gamma dose rates also support the statement that no places with elevated values can be found in the nuclear power plant area.

21.2 HEALTH STATUS OF THE POPULATION LIVING IN THE STUDIED 30 KM RADIUS AREA

By examining the health status of people living in the vicinity of the site, it is possible to evaluate the incidence (frequency) of diseases potentially related to ionizing radiation among the population living within a 30 km radius around the site.

The study area was defined as a circle of 30 km radius around the center of the Paks NPP.

The regulations do not specifically apply to epidemiology-related assessments. The standards do not fix processing methods either. For evaluation, the primary reference considered was the publication by Lawson A, Biggeri A, Böhning D, Lessafre E, Viel J-F, Bertollini R, titled: Disease Mapping and Risk Assessment in Public Health, Wiley, 1999, resuming the results of the Biomed 2 Project supported by the European Union and the European Office of the WHO.

Only those indicators relating to diseases or disease groups form the basis of the report that have a separate ICD (International Classification of Diseases) code, and which do not arise in the practice of reporting anomalies suggestive of differences in statistical data analysis for the reference population (namely, for which the international benchmarks do not point to a disproportionately large deviation in Hungarian reference data; and for which in the reference population the regional differences and temporal trends do not indicate an incompatible disproportion of the nature of the disease).

Diagnosis of the cause of death

For many years now the Central Statistical Office (CSO) in Hungary has collected death test certificates, on which the doctor (coroner) declaring death records demographic data and the diagnosis of the cause of death. The cause of death diagnosis - compared to a conventional diagnosis - is not a statement of a disease, but a description of the process leading to death in accordance with the relevant rules. We consider the starting point in the disease process as an indicator during health monitoring, as assessments of the potential impacts of potential risk factors associated with the development of the disease are the fundamental objectives of the Project. The annual number of death cases observed in the municipalities for 2001-2010 were made available by CSO in aggregated form.

Social status

Within the study area, the socio-economic status differences between the citizens of the settlements are significant. Since this status influences through shaping many elements of lifestyle the likelihood of diseases, these effects should be controlled through the study as compounding factor, the first step regarding this is the collection of the related data. For data analyses, the source of the most reliable area-specific socio-economic status indicators is the database of the National Census which was last conducted in 2011; this database provides information on a wide range of the socio-economic situations. Thus during the program we analyzed the frequency of diseases for which an exposure of several years is needed for development, the status indicators from the census from 2011 are suitable to meet the aims of the study.

Population Register

The settlement population register was dressed up by various institutions over the past 10 years, always ensuring legal continuity though, the current institution in charge being the Administration and Electronic Public Services Central Office (KEKKH). During the program, calculation of the indicators defined for each year requireed the knowledge of the mid-year resident population demographic data, which could be produced using the data supplied by the KEKKH Office.

Definition of impact area

In the study, we processed aggregated data for the settlements inside the impact area grouped by postal codes. The population register is issued at settlement level. The cause of death diagnosis and incidence of development disorders are also data registered at municipality level, but patient data are registered based on the postal (zip) codes of the patients' domiciles.

The population within the 10 km radius (as potentially first affected), in the 10-20 km zone (as potentially second affected) and in the 20-30 km zone (as control population able to reflect as the best the local conditions) were considered separately for the evaluation. The location of the settlements within the zones and the distance between the settlements and the power plant served as the basis of the spatial arrangement of the risk conditions.

Assessment of mortality risk

Mortality data were processed according to individual causes of death. For each cause of death, the risk of death observed in Paks was evaluated and a statistical analysis of the deviation of the observed number of cases from the expected values was done. Statistical evaluations were made of the observed form of mortality risk and its statistical results obtained from testing the reference level deviation in the settlements of the 30 km zone.

Analysis of disease occurrence risk

The incidence calculated based on the reports of health care institutions were processed according to disease groups. For each disorder group, the risk of morbidity observed in Paks was evaluated and a statistical analysis of the deviation of the observed number of cases from the expected values was done.

By testing the cumulative relative risk and its deviation from the reference level in each zone from 10 km and the local risks corrected by the socio-economic status, and the assessment of the relationship between distances measured from the power plant, the role of the power plant as the potential point source was tested.

In summary, the pathography of the populations living in the impact area was favorable in comparison to the reference value or showed the same health status as the reference population. The theoretical possibility of the increase of the statistical indicators of the risks associated with the nuclear power plant arose in connection with the study results associated with certain patographies.

To overview the tumor risk factors we did not develop an own questionnaire, but we used that from the World Health Organization (WHO) CINDI projects, which was validated and published, so we translated the freely usable questions.

When involving general practitioners, we used a testing approach that allowed, by the correction of the effects of risk factors in the development of cancer, to quantify the risk of cancer only affected by the exposure from the vicinity of the nuclear power plant. Instead the direct measurement of the examined exposition (dose of the ionizing radiation emitted directly to the environment by the Paks NPP), we estimated it based on the distance between the residence of the subjects and the nuclear power plant. The harm caused was the cancer incidence registered by the general practitioner. The controlled other risk factors were: age, sex, education, smoking, occupational radiation exposure, family clustering of cancer, diabetes, hypertension, ischemic heart disease. During the study, the general practitioners collected the data in three counties, in settlements closer than 30 km to the Paks Nuclear Power Plant on the basis of international standard questionnaire. The general practitioner filled out the questionnaire regarding his/her cancer patients diagnosed between January 1st 2010 and December 31st 2012, then filled out another questionnaire based on data of a matching (age, sex, education) control subject. During data processing the risk factors were analyzed according to tumor type.

By taking the section of the analyses of risk factors, results were obtained which matched the nature of the given tumor (smoking increases laryngeal cancer, lung cancer, head and neck cancer and the risk of developing bladder cancer), respectively, and which reflected the effects of sample selection. Since the database was built using matching controls for age, sex and education, in the case of a perfect match the property of these factors to influence the risk factors would not have been visible, despite that fact that they obviously got it.

Regarding each tumor localization effort, rating one usually did not see a positive relationship between the proximity of the Paks Nuclear Power Plant and the incidence of tumors to occur. In the case of breast cancer we observed a statistically significant decrease in incidence in the vicinity of the power plant. Many tumor localization tests took place, thus only the evaluation of the distribution of the odds' ratios made it possible to assess the impact of the power plant. The odds' ratios of tumor types are evenly dispersed around the neutral value.

The joint results of the evaluation of the test above indicate that the risk of tumor diseases observed near the nuclear power plant is not enhanced by the vicinity of the power plant.

In summary, the study did not unveil an increased risk for morbidity caused by cancer among people living in the vicinity of the Paks NPP.

21.3 CURRENT RADIATION EXPOSURE OF THE POPULATION LIVING WITHIN A 30 KM RADIUS AREA AROUND THE SITE

The radiation exposure of the population was developed along the following lines:

- Radioactive emission data of the currently operating nuclear facilities located on-site, direct and scattered radiation dose rates, nuclear environmental monitoring data were used to estimate population radiation exposure.
- To estimate radiation exposure due to other artificial sources, other artificial radiation exposures arising from various activities like radioactive waste evacuation, fresh and spent fuel transportation, movement of radiation sources within the site, and finally industrial radiography tests were also taken into account.

The estimation of radiation exposure was limited to the 30 km area around the site, using measured data collected between 2001-2011, applying internationally accepted, standard methods and programs.

To estimate the radiation exposure of the population, once the site and environmental characteristics determining the propagation of radioactive materials were established, scenarios were developed for the assumed releases. To estimate radiation exposure, other exposures from various sources and activities were also taken into account, including the evacuation of radioactive waste, the transportation of new, unused and spent fuel, the movement of radiation sources within the site, and finally industrial radiographic testing. It should be noted here that the direct and scattered radiation coming from the Paks NPP can be neglected for all practical purposes. Given that the measured dose rate data fall into the background range, it is impossible to calculate population radiation exposure from them with respect to nuclear facilities. Significant direct and scattered radiation can affect the population mainly due to other sources, so the model calculations were performed to evaluate these.

Based on the model scenarios, the potential radiation exposures of the critical group were determined for particular and adequately combined cases. Radiation exposure was estimated applying internationally accepted methods and programs, using them with ICRP and IAEA recommendations and data.

In the light of the calculations, it was assessed whether or not the dose defined in the dose constraint is suitable for the operation of the Paks NPP and the ISFS Facility considering the critical population (hypothetical group including children living in Csámpa and Gerjén). This value was set in 1998 as 100 μSv/yr, of which 90 % can be used by the Paks NPP and 10 % by ISFS.

To describe atmospheric propagation during normal operation, a procedure based on the so-called sector averaged Gaussian plume model taken from international recommendations was used. The description of the contamination of given elements of the terrestrial food chain rests on the so-called concentration factor technique.

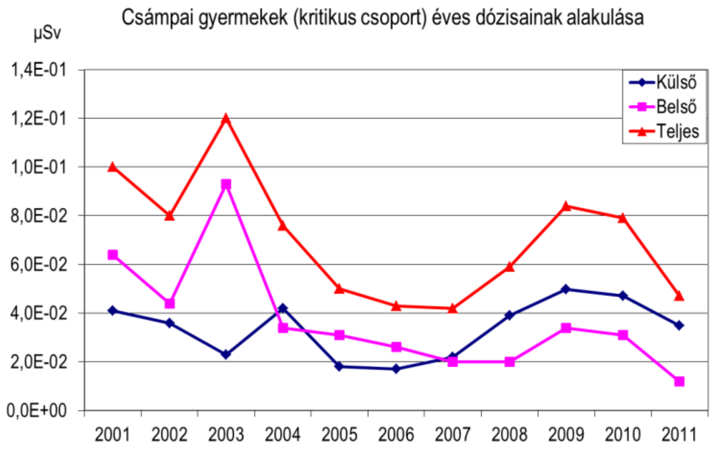
The model describing discharge into the Danube accounts for the fact that lateral (sideways) mixing is only partially achieved – even at large distances from the point of discharge. The hydrological parameters permit the determination of the distance-dependent so-called partial mixing correction factors that specify how many times larger is the concentration of radionuclides on the right bank at some given distance from the point of discharge with respect to complete, uniform mixing.

In this exercise, the radiation exposure of the population was estimated along the individual external irradiation pathways using an international model and then compared with the available measurement data.

Population exposure calculated from airborne releases

Atmospheric propagation due to airborne emission, concentrations in terrestrial food chain elements and radiation exposures originating from particular irradiation paths were mainly determined by the in-house developed "SS57" program package based on the models described in the IAEA Safety Series No. 57 and IAEA Safety Reports Series No. 19 publications. During the calculations, the so-called sector averaged Gaussian plume model based procedure was applied. This procedure is based on international recommendations, unites experience gained in many countries throughout the world, and combines routine practices with ease of use.

The radiation exposures originating from the airborne emissions of the Paks NPP and ISFS were calculated for each year between 2001-2011. These calculations for Paks NPP airborne emissions for the Csámpa children (critical group) age group are shown in the figure below. Apart from 2003 (failure year), between 2001 and 2007 the total radiation exposure showed continuous decrease, which was followed by a period of increase till 2009 (the 2010-11 values again showed decrease).



Csámpai gyermekek (kritikus csoport) éves dózisainak alakulása - Evolution of annual doses for Csámpa children (critical group), Külső - external, Belső - internal, Teljes - total.

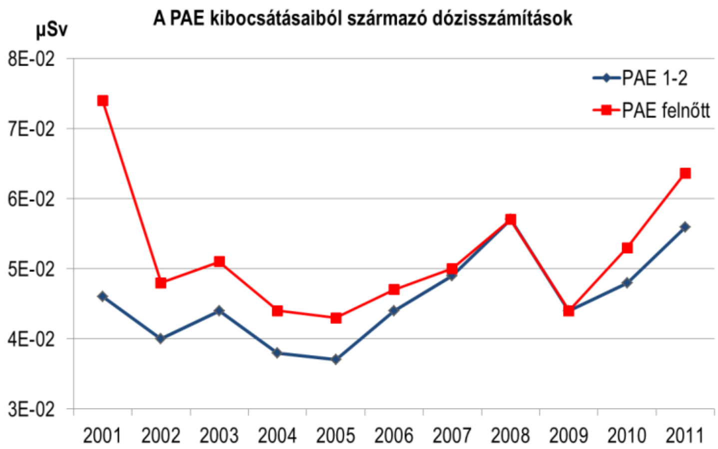
Figure 101: Evolution of annual doses for Csámpa children (critical group) due to power plant chimney emisisons.

Radiation exposure due to water discharges

Liquid discharges from the nuclear power plant eventually reach the Danube as receptor mass of water. Using a conservative approach, here the dilution, sedimentation processes of the interim section – collection tanks, hot water canal – will be neglected (actually radioactive decay can be also disregarded for propagation with the Danube, it only counts for deposited radionuclides).

The simplest model applicable to describe dilution and propagation in running waters assumes complete mixing. This condition is necessarily violated close enough to the point of discharge, thus in the plume higher concentrations can be expected than those predicted by complete mixing. The degree of this departure is difficult to calculate accurately, as it depends on a large number of parameters (discharged and recipient water volumes, temperatures, flow velocities, etc.), and incidentally the mathematical treatment of the problem is also quite involved.

The calculation of external and internal radiation exposures due to liquids discharged from the Paks NPP and the ISFS Facility were carried out in respect of the Gerjen children (1-2 years old) age group, the results are shown in the figure below.



A PAE kibocsátásaiból származó dózisszámítások - Dose calculations from Paks NPP discharges, PAE 1-2 - Paks NPP 1-2, PAE felnőtt - Paks NPP adult.

Figure 102: Radiation exposures due to liquid discharge from the Paks NPP of the Gerjen children (1-2 years old) age group

Radiation exposure arising from other sources

Some **radioactive waste** transportation routes run next to inhabited areas, so citizens may actually come close to the transport trucks. Then a person staying (5 minutes) near the roadside may be just 5 m away, so s/he may be subject to radiation exposure up to 23.04 μSv, provided the barrels in question carry average NPP activity. This is an absolutely conservative estimate, as it assumes that someone is just there close to the truck during all deliveries.

For the transportation of **fresh fuel elements**, two cases were considered. In the first: the train has to stop for some reason (traffic blocked), then the people waiting for connections may stay near the train for some time (1/2 hour), relatively close, 5 m away, say. In this case, the radiation exposure due to fuel in one railway wagon is: 0.66 μSv. In the second: the train crosses the station without stopping with 30 km/h velocity, then the critical person, also present there at the station waiting for another train is 5 m away, and when the block train passes receives 1.17 nSv radiation exposure.

The neutron and gamma radiation exposure of the population was calculated for the transfer of **spent fuel** elements within the site using C-30 type transportation containers to ISFS, at different distances from the site boundary, also including the critical Csámpa population. In the calculations, average burnup degree (40.9 GWday/tU) spent fuel elements with 3 year decay time were used. From this, the radiation exposure of the critical population (1300 m from the external container wall) was obtained by assuming a transfer trip time of 1 hour, and 480 pcs of transferred spent fuel elements each year, which can be seen as a maximum value. The corresponding radiation exposure turned out to be 0.0235 nSv.

Radiation exposure at different distances was also investigated for the case when **equipment with radionuclides on their surface** is moved within the site. For ^{60}Co at 500 m a 5.33E-09 μSv/h dose rate was calculated. This means that roughly 21 years would be required to pass for equipment with radioactive materials on its surface to produce 1 nSv radiation exposure.

To perform **industrial radiographic tests**, high activity radiation sources are used in different applications, and these sources typically occupy two possible places: the radiation source is in its own shielded holder case, or is out in the environment without protection during the radiographic test. The calculations applicable to radiographic testing were performed for different distances with 2 TBq initial activity ^{192}Ir and 5 TBq initial activity ^{75}Se radiation sources and assuming about 2,200 tests performed annually, whence it follows that the resulting radiation exposure is 0.67 μSv at 1 300 m and 5.62 μSv at 500 m

Summary of population radiation exposure

The annual levels of population radiation exposure determined via modeling were invariably several orders of magnitude smaller than the dose limitation (1 mSv) or the dose constraint level (100 μSv) imposed on the Paks NPP + ISFS facilities) even applying such conservative assumptions that can only be true in reality with very small probability. The radiation exposure values calculated from emissions and discharges fell into the nSv/yr range, while the effects due to additional sources (fresh or spent fuel, transportation of radioactive waste, radiographic tests) can in principle exceed this, but only during short periods, so taking a worst case approach the radiation exposure of individuals of the population is expected to be of the order of μSv/yr, which is several orders of magnitude smaller than the limit defined in the regulations.

Changes of this magnitude in annual radiation exposure cannot be verified in practice by measurements, therefore in what follows one will have to rely on model calculations and the like.

21.4 Impact of Paks II Construction on the Radiation Exposure of the Population near the Site

During implementation, the radiation exposure of the population may primarily originate from radiography testing. Knowing the number of radiographic tests it is possible to determine the annual radiation exposure of the population. The values can be expected to be of the same order of magnitude as the results mentioned before. Radiation exposure due to radiographic tests is seen as a direct impact, no indirect impacts can be interpreted in the construction phase.

21.5 Impact of Paks II Operation on the Radiation Exposure of the Population near the Site

Radiation exposure due to airborne emission

During normal operation, emissions take place at 100 m (chimney) and at 40 m (turbine building) heights. Starting from the pre-defined 100 m chimney height and taking the similar features of the Paks NPP as basis a 120 m effective emission height and the data of a 120 m meteorology tower were used. Instead of the given 40 m emission height a little more elevated, 50 m effective height was taken, adapted to the 50 m data of the meteorology tower.

For emission by nuclide, the normal operating values supplied by MVM Paks II Zrt (data of Russian party) [40] were taken as starting point.

Radionuclide	Emission through chimney Emission I	Emission above turbine bdg roof Emission II
	Bq/yr	**Bq/yr**
^{3}H	7,80E+12	2,40E+09
^{14}C (CO_2)	3,00E+10	-
^{14}C (organic)	5,70E+11	-
^{83m}Kr	1,34E+12	5,40E+10
^{85m}Kr	4,56E+12	1,22E+10
^{85}Kr	7,12E+11	1,32E+08
^{87}Kr	2,76E+12	1,28E+11
^{88}Kr	1,01E+13	3,00E+11
^{131m}Xe	4,98E+11	3,20E+09
^{133}Xe	5,62E+13	9,40E+11
^{135}Xe	1,51E+13	6,60E+11
^{138}Xe	5,72E+11	6,20E+10
^{131}I (aerosol)	4,85E+07	2,48E+05
^{132}I (aerosol)	6,46E+07	8,00E+05
^{133}I (aerosol)	9,20E+07	7,44E+05
^{134}I (aerosol)	4,40E+07	2,24E+05
^{135}I (aerosol)	7,53E+07	5,68E+05
^{131}I (elemental)	4,85E+07	2,48E+06
^{132}I (elemental)	6,46E+07	8,00E+06
^{133}I (elemental)	9,20E+07	7,44E+06
^{134}I (elemental)	4,40E+07	2,24E+06
^{135}I (elemental)	7,53E+07	5,68E+06
^{131}I (organic)	4,85E+07	3,47E+06
^{132}I (organic)	6,46E+07	1,12E+07
^{133}I (organic)	9,20E+07	1,04E+07
^{134}I (organic)	4,40E+07	3,14E+06
^{135}I (organic)	7,53E+07	7,95E+06
^{51}Cr	1,57E+05	3,00E+02
^{54}Mn	9,66E+03	4,20E+02
^{60}Co	6,20E+04	4,80E+03
^{89}Sr	6,50E+05	2,80E+04
^{90}Sr	1,19E+03	8,80E+01
^{134}Cs	4,00E+07	2,00E+06
^{137}Cs	6,06E+07	2,60E+06

Source: MIR.1200 Preliminary data and information for safety and environmental licensing, Appendix 3.

Table 64: Emission during normal operation for the two units (Bq/yr).

The following supplementary considerations were made for the emitted radionuclides:

- Tritium was considered as 100 % vapor
- Radiocarbon was considered as 5 % CO_2 and 95 % organic, based on multi-annual Paks NPP emission data
- Radioiodines were considered 4 % aerosol, 40 % elemental and 56 % organic, based on averaged Paks NPP emission data tabulated for the past few years
- Noble gases were identified as elemental gas, the rest of radionuclides not specified above as aerosol

For calculation purposes here again the ”SS57” codename model was used, and from the concentrations obtained the following doses were derived:

- External radiation exposure
    - Immersion gamma dose
    - Ground surface gamma dose
    - Gamma dose due to resuspension
    - Immersion beta dose (skin dose)
- Internal radiation exposure
    - Inhalation dose
    - Inhalation dose due to resuspension
    - Ingestion dose due to food consumption

Based on 2009 meteorological data, the calculations were performed for the age groups of children aged 1-2 and adults using the sector split hereunder:

Sector-Group	Sector	Ring	Distance [km]
4-7	4,5,6,7	< 1 km	0,5
8-11	8,9,10,11	1-5 km	3
12-15	12,13,14,15	5-10 km	7,5
16-3	16,1,2,3	10-30 km	20
Csámpa	12	Csámpa	1,5

Table 65: Sector split of release calculations.

From the next two tables it is clear that the results are essentially similar to the values calculated for the previous units, while the total dose figures obtained for the Csámpa small children fall short of the past multi-annual maxima. This is due, in part, to the fact that Csámpa is located further away from and in a slightly different direction with respect to the new chimneys, and to the – obviously different – average emission values supplied.

Streamlined with emissions the proportion of each nuclide departs from the case of the former units, nevertheless the external dose due to noble gases (^{88}Kr ruling) and ingestion due to radiocarbons prevail as dominant. Apart from these, tritium, (elemental) ^{131}I and Cs isotopes possess significant dose contributions. The dose affecting 1-2 years old children appears slightly higher than that for adults, and in both cases external doses dominate.

Given that the calculated effective doses do not exceed the 90 μSv value anywhere in the study area, actually the highest calculated values (even the 220 nSv obtained for small children at 500 m) are two and a half order of magnitude smaller than this threshold, it is fair to conclude that the normal operation of the nuclear power plant will not introduce any additional risk (on top of the neutral 90 μSv baseline) beyond the safety zone.

Distance	<1 km				1-5 km				5-10 km				10-30 km				1,5 km
Route/Sector	**4-7**	**8-11**	**12-15**	**16-3**	**4-7**	**8-11**	**12-15**	**16-3**	**4-7**	**8-11**	**12-15**	**16-3**	**4-7**	**8-11**	**12-15**	**16-3**	**12**
Immersion gamma	1,1E-07	1,3E-07	8,4E-08	7,2E-08	1,5E-08	2,2E-08	9,2E-09	1,4E-08	3,3E-09	5,0E-09	1,8E-09	3,2E-09	5,0E-10	7,7E-10	2,5E-10	5,1E-10	4,0E-08
Surface gamma	1,7E-09	2,1E-09	1,4E-09	1,2E-09	3,2E-10	4,8E-10	2,1E-10	3,0E-10	8,8E-11	1,4E-10	5,2E-11	8,7E-11	1,6E-11	2,5E-11	8,3E-12	1,7E-11	7,7E-10
Resusp. gamma	1,9E-13	2,3E-13	1,5E-13	1,3E-13	2,6E-14	3,8E-14	1,6E-14	2,4E-14	5,9E-15	8,8E-15	3,3E-15	5,7E-15	1,1E-15	1,6E-15	5,5E-16	1,1E-15	6,8E-14
Immersion beta*	7,8E-08	9,7E-08	6,2E-08	5,3E-08	1,3E-08	2,0E-08	8,6E-09	1,3E-08	3,5E-09	5,4E-09	2,0E-09	3,5E-09	6,1E-10	9,4E-10	3,1E-10	6,3E-10	3,4E-08
Total external	**1,1E-07**	**1,3E-07**	**8,6E-08**	**7,4E-08**	**1,6E-08**	**2,3E-08**	**9,5E-09**	**1,4E-08**	**3,4E-09**	**5,2E-09**	**1,9E-09**	**3,3E-09**	**5,2E-10**	**8,0E-10**	**2,6E-10**	**5,3E-10**	**4,1E-08**
Inhalation	6,4E-09	7,5E-09	5,0E-09	3,8E-09	1,2E-09	1,8E-09	7,4E-10	1,1E-09	3,1E-10	4,7E-10	1,8E-10	3,0E-10	6,3E-11	9,3E-11	3,2E-11	6,1E-11	2,8E-09
Resusp. Inhalation	2,2E-12	2,7E-12	1,7E-12	1,5E-12	3,0E-13	4,4E-13	1,8E-13	2,7E-13	6,5E-14	9,7E-14	3,6E-14	6,2E-14	1,1E-14	1,7E-14	5,8E-15	1,1E-14	7,8E-13
Ingestion	6,7E-08	7,9E-08	5,1E-08	4,2E-08	9,6E-09	1,4E-08	5,8E-09	8,6E-09	2,2E-09	3,2E-09	1,2E-09	2,0E-09	4,0E-10	5,9E-10	2,1E-10	3,9E-10	2,5E-08
Total internal	**7,4E-08**	**8,7E-08**	**5,6E-08**	**4,5E-08**	**1,1E-08**	**1,6E-08**	**6,5E-09**	**9,8E-09**	**2,5E-09**	**3,7E-09**	**1,4E-09**	**2,3E-09**	**4,7E-10**	**6,9E-10**	**2,4E-10**	**4,5E-10**	**2,8E-08**
Total	**1,8E-07**	**2,2E-07**	**1,4E-07**	**1,2E-07**	**2,6E-08**	**3,9E-08**	**1,6E-08**	**2,4E-08**	**5,8E-09**	**9,0E-09**	**3,3E-09**	**5,7E-09**	**9,9E-10**	**1,5E-09**	**5,0E-10**	**9,7E-10**	**6,9E-08**

* 1% of the immersion beta dose (skin dose) value is included in the external and total (effective) doses.

Table 66: Doses relevant to 1-2 years old children in different areas based on 2009 meteorological data, by irradiation pathway (I+II, Sv).

Distance	<1 km				1-5 km				5-10 km				10-30 km				1,5 km
Route/Sector	**4-7**	**8-11**	**12-15**	**16-3**	**4-7**	**8-11**	**12-15**	**16-3**	**4-7**	**8-11**	**12-15**	**16-3**	**4-7**	**8-11**	**12-15**	**16-3**	**12**
Immersion gamma	1,0E-07	1,3E-07	8,0E-08	6,8E-08	1,4E-08	2,1E-08	8,7E-09	1,3E-08	3,1E-09	4,7E-09	1,7E-09	3,0E-09	4,7E-10	7,2E-10	2,4E-10	4,8E-10	3,8E-08
Surface gamma	1,4E-09	1,8E-09	1,2E-09	1,0E-09	2,8E-10	4,3E-10	1,8E-10	2,7E-10	7,8E-11	1,2E-10	4,6E-11	7,8E-11	1,4E-11	2,2E-11	7,4E-12	1,5E-11	6,7E-10
Resusp. gamma	1,6E-13	2,1E-13	1,3E-13	1,2E-13	2,3E-14	3,4E-14	1,4E-14	2,1E-14	5,2E-15	7,7E-15	2,9E-15	5,0E-15	9,5E-16	1,4E-15	4,9E-16	9,3E-16	6,0E-14
Immersion beta*	7,8E-08	9,7E-08	6,2E-08	5,3E-08	1,3E-08	2,0E-08	8,6E-09	1,3E-08	3,5E-09	5,4E-09	2,0E-09	3,5E-09	6,1E-10	9,4E-10	3,1E-10	6,3E-10	3,4E-08
Total external	**1,0E-07**	**1,3E-07**	**8,2E-08**	**7,0E-08**	**1,5E-08**	**2,2E-08**	**8,9E-09**	**1,3E-08**	**3,2E-09**	**4,8E-09**	**1,8E-09**	**3,1E-09**	**4,9E-10**	**7,5E-10**	**2,5E-10**	**5,0E-10**	**3,9E-08**
Inhalation	9,3E-09	1,1E-08	7,1E-09	5,4E-09	1,6E-09	2,3E-09	9,5E-10	1,4E-09	3,9E-10	5,8E-10	2,2E-10	3,6E-10	7,9E-11	1,1E-10	4,0E-11	7,5E-11	3,8E-09
Resusp. Inhalation	6,1E-12	7,6E-12	4,8E-12	4,3E-12	8,5E-13	1,3E-12	5,2E-13	7,8E-13	1,9E-13	2,9E-13	1,1E-13	1,8E-13	3,5E-14	5,1E-14	1,8E-14	3,4E-14	2,2E-12
Ingestion	4,1E-08	4,9E-08	3,2E-08	2,6E-08	6,0E-09	8,8E-09	3,6E-09	5,4E-09	1,4E-09	2,1E-09	7,7E-10	1,3E-09	2,7E-10	3,9E-10	1,4E-10	2,6E-10	1,5E-08
Total internal	**5,0E-08**	**6,0E-08**	**3,9E-08**	**3,1E-08**	**7,5E-09**	**1,1E-08**	**4,6E-09**	**6,8E-09**	**1,8E-09**	**2,6E-09**	**1,0E-09**	**1,7E-09**	**3,5E-10**	**5,0E-10**	**1,7E-10**	**3,3E-10**	**2,0E-08**
Total	**1,5E-07**	**1,9E-07**	**1,2E-07**	**1,0E-07**	**2,2E-08**	**3,3E-08**	**1,3E-08**	**2,0E-08**	**5,0E-09**	**7,5E-09**	**2,8E-09**	**4,8E-09**	**8,4E-10**	**1,3E-09**	**4,2E-10**	**8,2E-10**	**5,9E-08**

* 1% of the immersion beta dose (skin dose) value is included in the external and total (effective) doses.

Table 67: Doses relevant to adults in different areas based on 2009 meteorological data, by irradiation pathway (I+II, Sv).

Design-basis failure radiation exposure

To investigate TA4 (Design Basis 4) design-basis failures, the data made available for the DBC4 (Design Basis Category 4 Conditions) case included in the Russian data supply [41] were used. Regarding the TA4 / DBC4 event, emissions through the 100 m high chimney were translated to 120 m effective height, while for "surface" emissions the 35 m height of building rooftop fans was indicative. For calculation purposes here again the "SS57" codename model was used. Early (10 days emission-based) and late (30 days emission-based) doses were distinguished as two separate cases. In both cases, the doses were calculated for a single meteorological status quo for the age groups of 1-2 years old small children and adults. Summer emissions were assumed, all other parameters were the same as those for normal conditions. Common meteorological conditions, low precipitation level:

Stability (Pasquill) category: D

Wind velocity: 5 m/s (18 km/h)

Precipitation: 2.8E-7 m/s (1 mm/h)

To define the impact area, first the distance where the doses are maximal was approximated. In the framework of the assumed scenarios, the calculations were performed for the following distances: 300 m, 400 m (distance of maximum dose), 600 m, 800 m, 3 km, 10 km, 20 km, 30 km.

Early doses: Using the 10-day "surface" and chimney emissions first the doses below originating from the cloud and the ground surface were calculated, then their sum was shown:

- Immersion gamma dose
- Immersion beta dose (represented by 1 % in sum)
- Ground surface gamma dose
- Dose due to inhalation
- Doses due to resuspension

Nuclide	10-day chimney emission	10-day "surface" emission
^{131}I (elemental)	2,90E+08	2,10E+09
^{132}I (elemental)	1,50E+07	1,00E+08
^{133}I (elemental)	5,80E+07	4,00E+08
^{134}I (elemental)	3,20E+06	2,30E+07
^{135}I (elemental)	1,00E+07	7,10E+07
^{131}I (organic)	8,70E+09	6,10E+09
^{132}I (organic)	1,70E+08	1,20E+08
^{133}I (organic)	1,40E+09	9,80E+08
^{134}I (organic)	2,00E+07	1,40E+07
^{135}I (organic)	1,90E+08	1,30E+08
^{85m}Kr	9,60E+10	6,70E+08
^{87}Kr	4,40E+10	3,10E+08
^{88}Kr	1,80E+11	1,20E+09
^{133}Xe	9,70E+13	6,80E+11
^{135}Xe	3,30E+11	2,30E+09
^{138}Xe	7,00E+09	4,90E+07
^{134}Cs	6,20E+05	4,30E+07
^{137}Cs	2,20E+05	1,60E+07

Table 68: Early dose emissions (Bq).

Late doses: Using the 30-day ”surface” and chimney emissions first the doses below originating from the cloud and the ground surface were calculated, then their sum was and shown:

- Immersion gamma dose
- Immersion beta dose (represented by 1 % in sum)
- Ground surface gamma dose
- Dose due to inhalation
- Doses due to resuspension
- Dose due to ingestion

Nuclide	30-day chimney emission	30-day "surface" emission
^{131}I (elemental)	4,30E+08	3,00E+09
^{132}I (elemental)	1,50E+07	1,00E+08
^{133}I (elemental)	5,80E+07	4,00E+08
134I (elemental)	3,20E+06	2,30E+07
^{135}I (elemental)	1,00E+07	7,10E+07
^{131}I (organic)	1,40E+10	9,80E+09
^{132}I (organic)	1,70E+08	1,20E+08
^{133}I (organic)	1,40E+09	9,80E+08
^{134}I (organic)	2,00E+07	1,40E+07
^{135}I (organic)	1,90E+08	1,30E+08
^{85m}Kr	9,60E+10	6,70E+08
^{87}Kr	4,40E+10	3,10E+08
^{88}Kr	1,80E+11	1,20E+09
^{133}Xe	1,30E+14	9,20E+11
^{135}Xe	3,30E+11	2,30E+09
^{138}Xe	7,00E+09	4,90E+07
^{134}Cs	6,20E+05	4,30E+07
^{137}Cs	2,20E+05	1,60E+07

Table 69: Late dose emissions (Bq).

The calculations were a carried out for both the adult and 1-2 years old children age groups, with the late doses due to ground surface deposition integrated for 50 and 70 years, respectively, while for internal doses always committed dose factors were used. As an additional conservative constraint permanent presence and the exclusive consumption of locally produced food were assumed, and no potential protective measures were considered.

From the table below, it can be clearly seen that the calculated dose never exceeded the neutral (effective dose <90 μSv/yr) effect (highest value: 21 μSv – late dose of small children at 400 m), thus it can be concluded that beyond the safety zone (an in fact within it too) only neutral impact can be expected.

Case/Distance	300m	400m	600m	800m	3km	10km	20km	30km
Small child early	9,00E-07	**1,10E-06**	9,02E-07	6,56E-07	1,17E-07	1,59E-08	4,78E-09	2,38E-09
Adult early	5,30E-07	**6,53E-07**	5,22E-07	3,95E-07	8,40E-08	1,20E-08	3,65E-09	1,85E-09
Small child late	1,70E-05	**2,10E-05**	1,61E-05	1,12E-05	8,30E-07	5,30E-08	1,07E-08	4,34E-09
Adult late	1,60E-05	**2,00E-05**	1,51E-05	1,01E-05	7,75E-07	4,60E-08	8,80E-09	3,46E-09

Table 70: Cumulative total doses for design-basis failure (Sv).

In respect of early doses, it can be stated that at close distances (e.g., also for the 400 m maximum) the largest part of the dose comes from "surface emitted" ^{131}I (mainly via inhalation), at larger distances noble gases, in particular the immersion gamma dose of ^{133}Xe originating from chimney emission becomes prominent (but of course remains smaller than the dose calculated at maximum by orders of magnitude). In this scenario, adult doses are markedly smaller (roughly half at close distances) than doses of small children.

At close (near) distances, the better part of late doses originates from the ”surface” emission of the two Cs isotopes (and to a smaller extent ^{131}I) (mainly via ground surface gamma and ingestion), whereas at larger distances here also the immersion gamma dose of ^{133}Xe due to chimney emission becomes dominant. In this case, adult doses are again smaller than child doses but only by a little at close distances (as the larger ground surface gamma dose of children is almost compensated by the higher ingestion dose of adults).

Radiation exposure due to liquid discharges

Along the liquid discharge pathways of the Paks NPP (hot water canal) the liquid radioactive wastes entering the Danube undergo mixing and dilution, then reach the water takeout and other utilization points. Thus by virtue of making use of the Danube radioactive contaminations get into direct or indirect (through the aquatic food chain) contact with people, potentially resulting in external or internal radiation exposure. The model used to calculate radiation exposure is based on IAEA recommendations. The planned liquid discharges of the Russian VVER 1200 MW type unit refer to a single unit and are based on the data communicated by the Russian supplier:

Radionuclide	^{3}**H**	^{14}**C**	^{131}**I**	^{132}**I**	^{133}**I**	^{134}**I**	^{135}**I**	^{89}**Sr**
Discharge/Block	9,1E+12	1,05E+09*	3,5E+07	2,3E+06	1,2E+07	1,4E+06	3,9E+06	8,1E+05
Radionuclide	^{90}**Sr**	^{134}**Cs**	^{137}**Cs**	^{51}**Cr**	^{54}**Mn**	^{60}**Co**	^{58}**Co**	
Discharge/Block	2,3E+03	8,0E+07	1,2E+08	5,5E+05	6,1E+05	2,5E+06	5,6E+05	

* Value estimated by Isotoptech Zrt.

Table 71: Planned liquid discharges of the Russian VVER 1200 MW type unit (Bq/yr). [30]

The annual radiation exposure of the children aged 1-2 and adult age groups of the Gerjen population – at the same time representing the reference (critical) population group of the planned new units with respect to liquid releases – is recapitulated in the table below. As shown by the results, the dose of the adult population – subject to the given annual releases, assumed consumption data and lifestyle characteristics – exceeds that of children aged 1-2. In practice for both groups it is internal radiation exposure that is 100% dominating, in particular the contributions of ^{3}H and ^{14}C are the most significant (for children. For adults the contributions of ^{134}Cs and ^{137}Cs can also be labeled considerable). All things considered, however, these radiation exposures – in spite of the heavily conservatively biased approximations – are small, and even taken for two units only amount to 2-3 parts in one thousand of the dose constraint.

Radionuclide	1-2 years old children			Adult		
	external	internal	external	internal	external	internal
^{58}Co	4,2E-04	1,2E-03	1,7E-03	4,3E-04	5,8E-04	1,0E-03
^{60}Co	1,8E-02	5,2E-02	7,0E-02	1,8E-02	1,6E-02	3,4E-02
^{51}Cr	9,0E-06	6,8E-05	7,7E-05	9,2E-06	4,2E-05	5,1E-05
^{134}Cs	9,5E-02	2,6E+00	2,7E+00	9,6E-02	1,9E+01	1,9E+01
^{137}Cs	1,4E-01	3,4E+00	3,5E+00	1,4E-01	2,0E+01	2,1E+01
^{3}H (HTO)	0,0E+00	5,1E+01	5,1E+01	0,0E+00	5,1E+01	5,1E+01
^{14}C	0	3,9E+01	3,9E+01	0	3,9E+01	3,9E+01
^{131}I	2,2E-04	9,3E-01	9,3E-01	3,5E-04	2,1E-01	2,2E-01
^{132}I	7,6E-05	2,0E-04	2,7E-04	1,3E-04	7,9E-05	2,1E-04
^{133}I	1,1E-04	2,5E-02	2,6E-02	1,8E-04	6,9E-03	7,0E-03
^{134}I	5,3E-05	3,7E-05	9,1E-05	9,2E-05	1,8E-05	1,1E-04
^{135}I	9,2E-05	1,3E-03	1,4E-03	1,6E-04	4,4E-04	5,9E-04
^{54}Mn	2,7E-04	5,9E-04	8,6E-04	2,8E-04	6,2E-04	9,0E-04
^{89}Sr	8,1E-06	3,8E-03	3,8E-03	8,2E-06	1,4E-03	1,4E-03
^{90}Sr	5,1E-07	1,7E-04	1,7E-04	5,1E-07	1,5E-04	1,5E-04
Total	**2,5E-01**	**9,7E+01**	**9,7E+01**	**2,6E-01**	**1,3E+02**	**1,3E+02**

Table 72: Doses of the 1-2 years old children and adult age groups of the Gerjen population from the annual liquid discharges by Russian VVER 1200 MW type unit (nSv/yr).

Detection study of environmental activity concentrations and potential accumulations due to Paks II airborne and liquid releases

The objective was to investigate whether or not the effect of the airborne emissions of the 2 pcs of Russian VVER-1200 type units is measurable in individual environmental elements and potential accumulations. A conservative approach was used in the sense that the highest activity concentrations were compared with the detection limits of the environmental monitoring program routinely executed by the nuclear power plant.

For the activity concentrations (air, surface, meat, cereal, vegetable, milk) determined for given distances (<1; 1-5 km, 5-10 km, 10-30 km) the different directional maxima were taken, together with the value obtained for 1.5 km, and these were expressed in proportions of the detection limits. The results proved that show that in the first group (comprising feasible measurements) enable the detection of only a few radionuclides, primarily in regard to tritium and radiocarbon. It should be noted that these are also global pollutants at the same time which makes it rather difficult to identify the added load originating from the nuclear power plant. The second group (comprising measurements that take more of an effort to carry out) in addition to a few radionuclides of the ambient air concentration some of the elements of ground surface activity could be measured in theory, such as elemental iodine, radiocesium (which is, on the other hand, present irrespective of the presence of the nuclear power plant, in a concentration higher than the level referred to herein), but those could be detected rather within shorter distances from the Paks Nuclear Power Plant. Calculations show that all of the other radionuclides fall in the non-measurable category.

For liquid discharge, The activity concentrations were calculated for the aquatic food chain for the Danube water, sediment and fish plus the soil, leafy vegetables, livestock feed, cow's milk and beef (each affected through irrigation) environmental elements using the technique described for airborne emissions In the first group – this includes only the tritium and radiocarbon content of Danube water and the ^{137}Cs activity concentration expected to be found in fish – a targeted monitoring taking not significantly more resources than the routine monitoring program would, in theory, be likely to make it possible to detect the impacts of the new units. In the second group the measurement of the impact would take many times as great an effort (very large number of samples, extremely sensitive measuring instruments, very long measuring times). (The impacts of the residual ^{137}Cs contamination from the Chernobyl catastrophe could, in this case again, interfere with the measurements.) It is believed that in the case of the third group there is no realistic chance at all for detecting the power plant's environmental impact.

On the whole, it is concluded that in the case of normal operation the radiological impact of atmospheric and aquatic releases has very low value, many orders of magnitude smaller than the dose constraint (90 µSv/year).

Impact areas of Paks II operation

Radiological impacts are categorized as follows:

Category	Radiological impact (E=effective dose)
neutral	E < 90 µSv/year
tolerable	90 µSv/year < E < 1 mSv/year
burdensome	1 mSv/year < E < 10 mSv/2 days or 10 mSv/incident*
damaging	10 mSv/2 days or 10 mSv/incident < E < 1 Sv/incident**
eliminating	1 Sv/lifetime < E

* without food chain effect

** for the entire lifetime (50 years for adults, 70 years for children), without food chain effect

where

90 µSv/year effective dose is the dose constraint level prescribed by the ÁNTSZ-OTH office.
1 mSv/year effective dose is the population dose limit
10 mSv avoidable effective dose in cases other than the normal operation
1 Sv/lifetime is the emergency intervention level pertaining to permanent resettlement

The cumulative radiological impacts (direct, indirect) remain – within a 500 m radius – below the dose constraint (neutral impact) in the case of normal operation since this requirement is met even at the boundary of the safety zone, therefore ***in the case of normal operation*** the boundary of the safety zone is to be regarded as the boundary of the impact area.

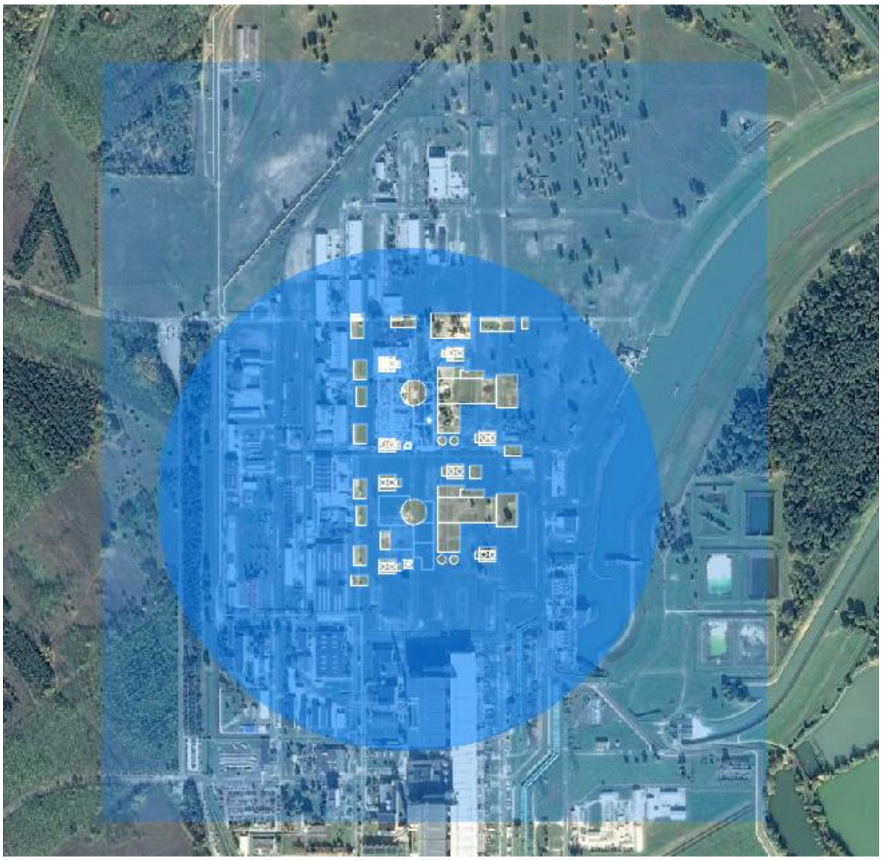


Figure 103: Impact area of Paks II normal operations: 500 m radius circle within the 500 m safety zone.

(The impact area was determined and is displayed on the basis of the respective central points of both chimneys and the impact is indicated in a circle around these central points (a circle of a diameter of 500 m). Clearly, this area is within the 500 m safety zone.)

Combined impact of Paks II, Paks NPP and ISFS Facility operations

The cumulated maximum total doses of the three entities (Paks II., Paks NPP and ISFS) operating in the area are shown in the tables below for the two age groups and the individual distances. It can be seen that the cumulative dose is two orders of magnitude smaller than the neutral limit.

Plant/Area	**Csámpa**	**<5km**	**5-10km**	**10-30km**
Paks NPP (2009)	8,40E-08	4,00E-08	6,50E-09	1,00E-09
Paks II (2009)	6,90E-08	3,90E-08	9,00E-09	1,50E-09
ISFS (2011)	1,40E-09	4,00E-10	6,60E-11	1,00E-11
Total	**1,54E-07**	**7,94E-08**	**1,56E-08**	**2,51E-09**

Table 73: Total doses of Paks II, Paks NPP and ISFS from peak year for children aged 1-2 years, Sv.

Plant/Area	**Csámpa**	**<5km**	**5-10km**	**10-30km**
Paks NPP (2009)	6,00E-08	2,90E-08	4,70E-09	7,30E-10
Paks II (2009)	5,90E-08	3,30E-08	7,50E-09	1,30E-09
ISFS (2011)	7,00E-10	2,10E-10	3,40E-11	6,60E-12
Total	**1,20E-07**	**6,22E-08**	**1,22E-08**	**2,04E-09**

Table 74: Total doses of Paks II, Paks NPP and ISFS from peak year for adults, Sv.

Children aged 1-2 (nSv/yr)	**Adult (nSv/yr)**
1,54E+02	2,04E+02

Table 75: Maximum combined impact of liquid discharges on annual level in Gerjen.

For the case of radiation exposures due to normal operation, the impact area will be the perimeter of the combined safety zones of Paks II, the Paks NPP and the ISFS Facility.

Proposed radiation protection monitoring system

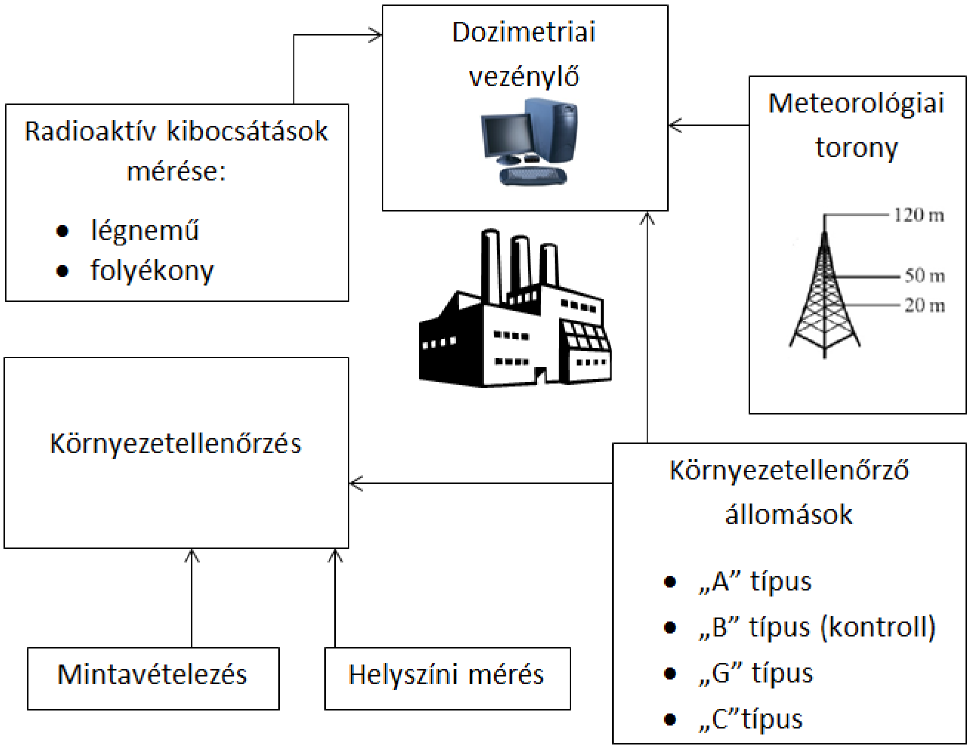
The currently operating environmental radiation protection system can be regarded as comprehensive, it meets al applicable international standards. Liquid and airborne releases are measured with a two-tier control system: continuous measurements by remote measuring systems, and sampling.

The remote measuring system includes remote measuring stations: Type A (9 pcs), G (11 pcs), C (15 pcs) and B (1 pc, control) stations. The Paks II units will globally be placed within the current environmental monitoring system, with a few exceptions:

- Thus the extension of the currently operating environmental radiation protection monitoring system of the Paks NPP is proposed to surround the area around the Paks II site.
- The number of type ”A” and ”G” measuring stations should be augmented.
- The expansion of type ”V” stations can be justified as function of the applied release technology.
- It is proposed to extend the sampling and measuring of the Environmental Monitoring Laboratory to encompass the Paks II site for the current environmental elements, which is important to ensure continuity and comparability (reference level), too.
- New groundwater monitoring wells must be constructed, as it was described in detail in Chapter on Geological formations and groundwater in the Danube Valley.

- In order to establish the two-tier monitoring system of airborne and liquid releases of the Paks II units, in the new chimneys and at the points of liquid discharge continuously operating radiation detectors similar to the current ones must be installed.

For laboratory measurements, it is recommended to priorities selective isotope measurements and to procure instruments with lower detection limits. The conceptual structure of the proposed Paks II radiation protection monitoring system is sketched in the figure below.



Legend: Dosimetry control, Measuring radioactive releases: - airborne – liquid, Meteorological tower, Environmental monitoring, Sampling, On-site measurement, Environmental monitoring stations – Type "A", Type "B" (control), Type "G, Type "C"

Figure 104: Conceptual structure of the proposed Paks II radiation protection system.

Impact of Paks II decommissioning on the radiation exposure of the population living near the site

In respect of decommissioning, based on international experience it is safe to conclude that no increased impact can be expected as compared to normal operation, the impact will be similar to the ones already presented, only the release points and the amount of waste may vary.

22 RADIATION EXPOSURE OF ANIMALS AND PLANTS

This chapter in the environmental impact study assessing the installation of the new nuclear power plant units in Paks focused on the radiation exposure of animals and plants, originating from the new source. This kind of assessment of animals and plants represents a relatively new area in radiation protection. Actually, there are no legal regulations in effect expressly related to this issue. However, some international scientific organizations made a proposal a few years ago to regulate the area at the decision-makers' level. Consequently, legal regulations are expected to be adopted sooner or later to apply restrictions for protecting the species and ecosystems of animals and plants against ionizing radiation created by mankind.

So this issue seemed reasonable to become one of the focal points as early as during the installation of the new nuclear power plant units. That is, to specify the current base level, given that each additional potential increment in radiation exposure will add to this base level, on the one hand, and to make estimations and assess how much the planned units would increase, compared to the current level, the radiation exposure of nearby terrestrial and aquatic animals and plants, on the other hand. Since no limit, fixed to a specific numerical value, is set with regard to the radiation impact of a new activity on animals and plants, the dose rate originating from the natural background radiation of certain animals and plants can provide a reasonable benchmark for assessing the impact. So, if the incremental dose rate potentially connected with human activity is just a fraction of the natural rate, it will certainly have no influence on the operation of the environmental systems.

Since our knowledge about this background dose rate related to animals and plants is rather scarce, we had to assess the natural radiation exposure of the biota, prevailing regardless of any human activity, in the environment of Paks. This decisively originates from the radioactive isotopes with mass number 40 of uranium, thorium and potassium, all existing in the crust ever since the development of the Earth, and animals and plants (inc. humans) have always been exposed to this effect. The measurement data from radiation protection measurements collected for this location and our own experimental tests, carried out to make up for and complete the missing information, could provide a duly detailed picture about radiation doses affecting terrestrial and aquatic animals and plants. In summary, as regards the background radiation exposure of terrestrial animals and plants living in the environment of the Power Plant, the size of this exposure is below 0.5 µGy/h in the majority of the species. Creatures accumulating lime and mosses have a considerably higher value that can even exceed the reference level currently recommended for animal and plant species. Moreover, the radiation exposure of the specific species might in many cases be underestimated by a factor of two or three if we do not use location-specific concentration ratios to calculate internal radiation exposure. The natural base level is within a broader range in the case of aquatic animals and plants: those living their life wholly in the water body or partly on its surface and in the air can be characterized with a dose rate near that for terrestrial plants and animals, still, those mainly staying at the bottom of the bed and those living in a typical solid protection cover (shellfish, snail) have approx. ten-fold bigger radiation dose.

The 10 µGy/h reference level proposed for a specific habitat in relation to radiation exposure caused by human activity applies to all the anthropogenic sources there, so the effect of a planned new source should be assessed together with the existing ones. This concludes that the residual radioactive pollution level originating from nuclear weapon tests (global fall-out) near Paks and the current effect of the Chernobyl fall-out on the environment of Paks had to be assessed. The four nuclear power plant units operating for nearly 30 years now also add, due to their atmospheric and aquatic emissions, to the human radiation exposure of animals and plants. These three sources jointly produce the current artificial radiation exposure of animals and plants.

The results from our model calculations covering the above components in terrestrial environment conclude that the increment of the Power Plant (max. $\sim 10^{-4}$ µGy/h) is practically negligible versus global and Chernobyl radiation exposure ($\sim 10^{-3}$ µGy/h).

However, the global increment which makes up the majority of artificial radiation exposure will have a decreasing tendency in time because the half-time of the ^{137}Cs and ^{90}Sr isotopes (that determine its value) is comparable with the lifecycle of the reactor units. By the launch of the first new unit planned by 2025, the dose rates estimated now will fall by 25%, so the prevailing base level of the individual groups of species will be ¾ of the current.

The summation of external and internal dose rates modelled for the planned Power Plant will be the total radiation exposure of the individual terrestrial reference animals and plants, due to the long-term operation of the two units of Paks II. The size of this exposure evidently depends on distance from the air chimneys that emit the radioactive material into the atmosphere. The expected maximum value will be reached by far within the site of the Nuclear Power Plant and its size will be around 0.5 nGy/h in most of the species. The values in the nearest environment outside the site (approx. 1.5 km from the emission points) refer to the appearance of rather minor radiation exposure that does not even approximate the current base level for, practically speaking, all the reference animals and plants. The estimated radiation exposure should reasonably be compared mainly with the increment, added to the base level, of the Nuclear Power Plant in operation for nearly 30 years now. The latter means the dose rates defined for the environment of Station A4, i.e. the test station which is the closest to the area the most exposed to potential Paks II impact. So, as regards impact, the planned Power Plant does not significantly differ from the one already in operation. Even by 2025, the planned starting time, the two Power Plants would add less than 1-2% increment to then still existing global radiation exposure.

As regards the base value of artificial sources, we should also note that it can be considered the valid value for the entire area around the Power Plant, i.e. between main road 6 and the Danube, given that the results of relevant measurements did not refer to any significant differences in soil activity concentrations underlying the estimation. Additionally, we also need to note that the radiation exposure values (with no major differences and just approx. 1% added to the natural background) for the individual groups of species mean there is none among the species requiring special attention due to exposure.

Three aquatic habitats may be of interest in the environment of Paks Nuclear Power Plant, due to emissions from the Power Plant. Primarily the collector of outflows, the river Danube, including especially its some 100 m long section after the Hot Water Canal. Although the Canal itself is an industrial facility, the animals and plants have, even if in limited diversity, long occupied it, or at least its bank. Additionally, Lake Kondor which is an ox-bow ancient dead branch but can have periodical connection with the Hot Water Canal through the artificial fish ponds can also be considered a separated habitat. From among these three habitats, we primarily focused on the Danube as it is the collector of fluid radioactive outflows from the existing and the planned Power Plant.

The result of our model calculations with the supplied emission/outflow data evidences that the cooling water is expected to reach a mere tenth or hundredth percentage of natural background radiation exposure on aquatic animals and plants even in the section where this water flows directly in the Danube. Evidently, smaller exposure is presumed downstream, due to dilution. In standard operating radiation exposure, prognosticated to fall between 20 pGy/h and 1 nGy/h, the internal is determinative.

organism	**total dose rate, µGy/h**				**Paks II increment to total power plant value, %**	**Paks II increment to total artificial, %**
	Paks II	**Paks Nuclear Power Plant**	**global**	**total**		
amphibian	$9.96 \cdot 10^{-05}$	$5.18 \cdot 10^{-04}$	$5.65 \cdot 10^{-04}$	$\mathbf{1.18 \cdot 10^{-03}}$	16.1	8.4
benthic fish	$5.13 \cdot 10^{-04}$	$1.89 \cdot 10^{-03}$	$2.59 \cdot 10^{-03}$	$\mathbf{5.00 \cdot 10^{-03}}$	21.3	10.3
bird	$6.10 \cdot 10^{-05}$	$5.49 \cdot 10^{-04}$	$2.36 \cdot 10^{-04}$	$\mathbf{8.45 \cdot 10^{-04}}$	10.0	7.2
shellfish	$4.90 \cdot 10^{-04}$	$1.61 \cdot 10^{-03}$	$2.48 \cdot 10^{-03}$	$\mathbf{4.57 \cdot 10^{-03}}$	23.4	10.7
crab	$5.89 \cdot 10^{-04}$	$2.04 \cdot 10^{-03}$	$3.27 \cdot 10^{-03}$	$\mathbf{5.90 \cdot 10^{-03}}$	22.4	10.0
snail	$5.26 \cdot 10^{-04}$	$2.32 \cdot 10^{-03}$	$2.75 \cdot 10^{-03}$	$\mathbf{5.60 \cdot 10^{-03}}$	18.5	9.4
insect larva	$1.10 \cdot 10^{-03}$	$4.87 \cdot 10^{-03}$	$6.12 \cdot 10^{-03}$	$\mathbf{1.21 \cdot 10^{-02}}$	18.5	9.1
mammal	$1.49 \cdot 10^{-04}$	$1.09 \cdot 10^{-03}$	$7.89 \cdot 10^{-04}$	$\mathbf{2.02 \cdot 10^{-03}}$	12.1	7.4
pelagic fish	$1.00 \cdot 10^{-04}$	$7.05 \cdot 10^{-04}$	$5.19 \cdot 10^{-04}$	$\mathbf{1.32 \cdot 10^{-03}}$	12.4	7.6
phytoplankton	$8.58 \cdot 10^{-05}$	$4.91 \cdot 10^{-04}$	$2.37 \cdot 10^{-04}$	$\mathbf{8.13 \cdot 10^{-04}}$	14.9	10.6
vascular plant	$3.89 \cdot 10^{-04}$	$1.61 \cdot 10^{-03}$	$2.08 \cdot 10^{-03}$	$\mathbf{4.07 \cdot 10^{-03}}$	19.5	9.6
zooplankton	$3.16 \cdot 10^{-05}$	$1.72 \cdot 10^{-04}$	$5.38 \cdot 10^{-05}$	$\mathbf{2.58 \cdot 10^{-04}}$	15.5	12.3

Table 76: Increments from Paks II and existing artificial sources to the radiation exposure of aquatic animals and plants in the Danube, in 2025.

Although the design, construction and operation of high-performance nuclear power plants intended for energetics purposes is all characterized by outstanding security, one should not in theory exclude certain situations that derive from material defect, natural disaster, perhaps human mistake or error and situations when the immense volume of energy released in the reactor vessel cannot be duly led away in ordinary operation. Although the chance of such incidents to occur is rather scarce, most of the potential defects and their consequences are already taken into consideration in the design phase, so the technologies supporting their management are built in in the course of power plant investment.

Today a security analysis, conducted according to an internationally approved protocol and done by the Russian designer in accordance with the so-called EUR recommendations, is an inevitable requirement for installation, so the probability of occurrence and the related radioactive emission inventory of any potential major defect is known. The data supplied by the Russian party contained several such cases in detail, including a specific scenario of so-called TA4-category design breakdowns (frequency: 10^{-4}-10^{-6}/year) that we estimated the impact of, on animals and plants. One of the characteristics of this tested *very small frequency design breakdown* is that it implies atmospheric emission only, moreover, in controlled circumstances. This can happen in two places: the 100 m high chimney functionally used for ordinary operating atmospheric emissions, on the one hand, and in the place of the 4 security blow-offs that belong to the secondary circuit, which means emission at 35 m height, on the other.

The comparison among the emission speeds of the tested operating incident in some individual time periods concluded that short half-time isotopes ($t_{1/2}$ ~a few hours) are practically emitted in the environment on the first day only. The other conclusion was that the installed and presumably automatically starting failure event management technology is rather efficient in keeping back relatively long half-time iodine isotopes in their elementary condition, as well as e.g. Cs isotopes. 99.5% of atmospheric emission comes from the rare gas ^{133}Xe, the majority whereof gets in the environment through the 100 m high air chimney. Caesium isotopes, with considerably longer half-time than for the rare gas, are 99% emitted at 35 m, and based on the data this is limited to the first day of the incident only. As regards emitted activity, it is ten billionth of that of xenon and is nearly identical with the caesium activity emitted over a 1-year period of ordinary operation. The significance of all this lies in that soil pollution due to fall-out is restricted to a relatively narrow zone (adjusted to the actually prevailing wind direction), due to typically constant wind direction for over half a day/one day. The wind most frequently blows from NW in the environment of Paks, so the area SE of the Power Plant mainly used for agriculture can be affected upon the actual occurrence of such an incident.

To estimate the impact on terrestrial animals and plants, we modelled the route of the radioactive cloud leaving through the emission points, its volume and the fall-out from it, for the environment of Paks, for the weather conditions used in similar analyses on the currently operating units. This means Pasquill D category condition (height of inversion layer: 560 m); 5 m/s wind at 120 m height; rainy weather all through the incident. This latter condition adds significant conservatism to the model because the leaching effect of precipitation considerably exceeds dry fall-out (settlement), so the incremental dose rate of the soil from fresh radioactivity will be overestimated.

For the sake of assessing early impact, the radioactive material emitted in the first 10 days was separately managed and the wind was calculated to be constantly blowing in a single direction. The radioactive concentrations (air, soil) around the emission point and the dose rate from the radioactive cloud were modelled in altogether 20 various distances between the place of emission and 20 km distance, using a program suitable for simulating atmospheric dispersion. The results showed that the maximum of concentrations of materials leaving the 35 m high chimneys is by far within the site, whereas it will be within 1000 m (which, even with the most probable wind direction, is still within the site) with the 100 m high air chimney.

isotope	average activity concentration from 100 m emission point			average activity concentration from 35 m emission point		
	100 m	500 m	1500 m	100 m	500 m	1500 m
	air, Bq/m^3					
^{85m}Kr	$3.74\cdot10^{-40}$	$3.50\cdot10^{-03}$	$1.46\cdot10^{-01}$	$3.30\cdot10^{-03}$	$2.66\cdot10^{-02}$	$5.62\cdot10^{-03}$
^{87}Kr	$1.72\cdot10^{-40}$	$1.60\cdot10^{-03}$	$6.62\cdot10^{-02}$	$1.52\cdot10^{-03}$	$1.21\cdot10^{-02}$	$2.49\cdot10^{-03}$
^{88}Kr	$7.06\cdot10^{-40}$	$6.79\cdot10^{-03}$	$3.02\cdot10^{-01}$	$5.98\cdot10^{-03}$	$5.10\cdot10^{-02}$	$1.21\cdot10^{-02}$
^{131}I	$3.50\cdot10^{-41}$	$3.29\cdot10^{-04}$	$1.37\cdot10^{-02}$	$4.03\cdot10^{-02}$	$3.24\cdot10^{-01}$	$6.79\cdot10^{-02}$
^{132}I	$7.20\cdot10^{-43}$	$6.73\cdot10^{-06}$	$2.79\cdot10^{-04}$	$1.08\cdot10^{-03}$	$8.58\cdot10^{-03}$	$1.75\cdot10^{-03}$
^{133}I	$5.69\cdot10^{-42}$	$5.31\cdot10^{-05}$	$2.22\cdot10^{-03}$	$6.78\cdot10^{-03}$	$5.45\cdot10^{-02}$	$1.14\cdot10^{-02}$
^{133}Xe	$3.78\cdot10^{-37}$	$3.55\cdot10^{00}$	$1.49\cdot10^{02}$	$3.34\cdot10^{00}$	$2.71\cdot10^{01}$	$5.77\cdot10^{00}$
^{134}Cs	$2.41\cdot10^{-45}$	$2.26\cdot10^{-08}$	$9.44\cdot10^{-07}$	$2.11\cdot10^{-04}$	$1.70\cdot10^{-03}$	$3.58\cdot10^{-04}$
^{134}I	$9.02\cdot10^{-44}$	$8.35\cdot10^{-07}$	$3.41\cdot10^{-05}$	$1.80\cdot10^{-04}$	$1.42\cdot10^{-03}$	$2.79\cdot10^{-04}$
^{135}I	$7.80\cdot10^{-43}$	$7.28\cdot10^{-06}$	$3.03\cdot10^{-04}$	$9.87\cdot10^{-04}$	$7.90\cdot10^{-03}$	$1.64\cdot10^{-03}$
^{135}Xe	$1.28\cdot10^{-39}$	$1.20\cdot10^{-02}$	$5.04\cdot10^{-01}$	$1.13\cdot10^{-02}$	$9.17\cdot10^{-02}$	$1.95\cdot10^{-02}$
^{137}Cs	$8.99\cdot10^{-46}$	$9.80\cdot10^{-09}$	$5.13\cdot10^{-07}$	$8.69\cdot10^{-05}$	$9.03\cdot10^{-04}$	$2.41\cdot10^{-04}$
^{138}Xe	$2.82\cdot10^{-41}$	$2.59\cdot10^{-04}$	$1.03\cdot10^{-02}$	$2.38\cdot10^{-04}$	$1.85\cdot10^{-03}$	$3.53\cdot10^{-04}$
	soil, Bq/kg					
^{131}I	$3.41\cdot10^{01}$	$6.80\cdot10^{00}$	$2.29\cdot10^{00}$	$6.98\cdot10^{01}$	$2.31\cdot10^{01}$	$6.33\cdot10^{00}$
^{132}I	$1.45\cdot10^{-02}$	$2.87\cdot10^{-03}$	$9.89\cdot10^{-04}$	$3.90\cdot10^{-02}$	$1.67\cdot10^{-02}$	$4.19\cdot10^{-03}$
^{133}I	$1.03\cdot10^{00}$	$2.05\cdot10^{-01}$	$6.92\cdot10^{-02}$	$2.19\cdot10^{00}$	$7.62\cdot10^{-01}$	$2.06\cdot10^{-01}$
^{134}Cs	$3.49\cdot10^{-03}$	$6.95\cdot10^{-04}$	$2.43\cdot10^{-04}$	$5.37\cdot10^{-01}$	$1.29\cdot10^{-01}$	$3.92\cdot10^{-02}$
^{134}I	$6.89\cdot10^{-04}$	$1.36\cdot10^{-04}$	$4.78\cdot10^{-05}$	$2.51\cdot10^{-03}$	$1.27\cdot10^{-03}$	$2.96\cdot10^{-04}$
^{135}I	$4.51\cdot10^{-02}$	$8.94\cdot10^{-03}$	$3.03\cdot10^{-03}$	$1.02\cdot10^{-01}$	$3.87\cdot10^{-02}$	$1.02\cdot10^{-02}$
^{137}Cs	$1.30\cdot10^{-03}$	$3.02\cdot10^{-04}$	$1.32\cdot10^{-04}$	$2.21\cdot10^{-01}$	$6.88\cdot10^{-02}$	$2.66\cdot10^{-02}$

Table 77: Surface and near-surface activity concentrations from 10-day emission, in the function of distance.

The dose rate estimated on the basis of radioactive concentrations for the individual animals and plants is typically some nGy/h directly outside the site, i.e. hardly 1% of the value typical for natural radiation exposure. If the emission dynamics of the early phase is also taken into consideration in model calculation (practically, short half-time isotopes get in the environment on the first day only), the dose rate for the first day will be higher for each animal and plant (5-10% of natural background radiation exposure), still, the dose rate on the 9 subsequent days will be dominated by external radiation exposure from the radioactive material that had earlier been emitted onto the soil (caesium and iodine isotopes). The numerical results conclude that the TA4 category operational incident at issue has neutral impact on nearby animals and plants, even under unfavourable meteorological conditions. This also means that emission due to breakdown does not lead to the creation of an impact area as an early consequence.

The late impacts of the tested breakdown were assessed on the basis of the 30-day emission data, under the meteorological conditions mentioned earlier. So the wind still blows in the direction observed at the start of the breakdown and it is invariably raining. These conditions lead to a rather conservative estimation because the total emitted radioactive material moves into a specific direction and is expected to have an impact in a narrow zone only.

isotope	average activity concentration from 100 m emission point			average activity concentration from 35 m emission point		
	100 m	500 m	1500 m	100 m	500 m	1500 m
	air, Bq/m^3					
^{85m}Kr	$1.25·10^{-40}$	$1.17·10^{-03}$	$4.89·10^{-02}$	$1.10·10^{-03}$	$8.85·10^{-03}$	$1.87·10^{-03}$
^{87}Kr	$5.70·10^{-41}$	$5.31·10^{-04}$	$2.20·10^{-02}$	$5.06·10^{-04}$	$4.04·10^{-03}$	$8.30·10^{-04}$
^{88}Kr	$2.36·10^{-40}$	$2.27·10^{-03}$	$1.01·10^{-01}$	$1.99·10^{-03}$	$1.70·10^{-02}$	$4.03·10^{-03}$
^{131}I	$1.87·10^{-41}$	$1.75·10^{-04}$	$7.32·10^{-03}$	$2.09·10^{-02}$	$1.68·10^{-01}$	$3.52·10^{-02}$
^{132}I	$2.41·10^{-43}$	$2.24·10^{-06}$	$9.28·10^{-05}$	$3.60·10^{-04}$	$2.87·10^{-03}$	$5.85·10^{-04}$
^{133}I	$1.89·10^{-42}$	$1.77·10^{-05}$	$7.38·10^{-04}$	$2.26·10^{-03}$	$1.81·10^{-02}$	$3.78·10^{-03}$
^{133}Xe	$1.69·10^{-37}$	$1.58·10^{+00}$	$6.65·10^{01}$	$1.51·10^{00}$	$1.22·10^{01}$	$2.61·10^{00}$
^{134}Cs	$8.05·10^{-46}$	$7.53·10^{-09}$	$3.15·10^{-07}$	$7.04·10^{-05}$	$5.67·10^{-04}$	$1.19·10^{-04}$
^{134}I	$3.00·10^{-44}$	$2.78·10^{-07}$	$1.14·10^{-05}$	$6.03·10^{-05}$	$4.73·10^{-04}$	$9.28·10^{-05}$
^{135}I	$2.60·10^{-43}$	$2.42·10^{-06}$	$1.01·10^{-04}$	$3.28·10^{-04}$	$2.64·10^{-03}$	$5.46·10^{-04}$
^{135}Xe	$4.29·10^{-40}$	$4.02·10^{-03}$	$1.69·10^{-01}$	$3.77·10^{-03}$	$3.06·10^{-02}$	$6.52·10^{-03}$
^{137}Cs	$3.00·10^{-46}$	$3.28·10^{-09}$	$1.71·10^{-07}$	$2.90·10^{-05}$	$3.01·10^{-04}$	$8.06·10^{-05}$
^{138}Xe	$9.06·10^{-42}$	$8.33·10^{-05}$	$3.32·10^{-03}$	$7.94·10^{-05}$	$6.16·10^{-04}$	$1.18·10^{-04}$
	soil, Bq/kg					
^{131}I	$2.90·10^{01}$	$5.81·10^{00}$	$1.95·10^{00}$	$5.78·10^{01}$	$1.85·10^{01}$	$5.13·10^{00}$
^{132}I	$4.81·10^{-03}$	$9.57·10^{-04}$	$3.30·10^{-04}$	$1.30·10^{-02}$	$5.58·10^{-03}$	$1.40·10^{-03}$
^{133}I	$3.42·10^{-01}$	$6.82·10^{-02}$	$2.31·10^{-02}$	$7.30·10^{-01}$	$2.54·10^{-01}$	$6.87·10^{-02}$
^{134}Cs	$3.46·10^{-03}$	$6.90·10^{-04}$	$2.40·10^{-04}$	$5.32·10^{-01}$	$1.28·10^{-01}$	$3.88·10^{-02}$
^{134}I	$2.29·10^{-04}$	$4.52·10^{-05}$	$1.60·10^{-05}$	$8.38·10^{-04}$	$4.21·10^{-04}$	$9.87·10^{-05}$
^{135}I	$1.50·10^{-02}$	$2.98·10^{-03}$	$1.01·10^{-03}$	$3.40·10^{-02}$	$1.29·10^{-02}$	$3.38·10^{-03}$
^{137}Cs	$1.31·10^{-03}$	$3.03·10^{-04}$	$1.32·10^{-04}$	$2.22·10^{-01}$	$6.89·10^{-02}$	$2.66·10^{-02}$

Table 78: Surface and near-surface activity concentrations from 30-day emission, in the function of distance.

According to the result of the model calculation, the dose rate from the radioactive material getting on the soil will be determinative outside the site and the majority of the increment comes from the fall-out from 35 m emission. The estimated dose rate values are typically small in this case again: they fail to reach 10% of relevant natural background radiation exposure in the environment of the Power Plant, with regard to any of the animals and plants.

So, regarding late impact, we can similarly conclude that the tested TA4 category operational incident has neutral impact on nearby animals and plants. Here we should particularly emphasize that the weather conditions, which were considered to be invariable all through the incident, resulted in the by far biggest impact from emissions, since total emitted radioactivity was restricted to a relatively narrow zone. If this conservatism is further reinforced by considering the sum of the dose rates (estimated as the impact of the two emission points) as load on animals and plants, the expected impact will be doubled with some creatures at the most, still, this is by far within 10% of the natural level. This means that emission due to breakdown does not result in evincible impact and, consequently, any impact area.

23 ACTIONS TO PROTECT ACCIDENTS WITH AN ENVIRONMENTAL IMPACT AND, UPON THEIR OCCURRENCE, TO MITIGATE THEIR ENVIRONMENTAL CONSEQUENCES

The Comprehensive Emergency Management and Action Plan, a plan that will have to be developed in a later phase during licensing and that is compliant with the current practice of Paks Nuclear Power Plant will comprise actions to prevent general emergency situations and accidents with environmental impacts and, upon their occurrence, actions to mitigate their environmental consequences. The actions relevant to the management of emergency situations affecting or potentially affecting the new units (emergency situation in the nuclear facility, radiological emergency situations, natural and industrial catastrophes, fire, other abnormalities) will be detailed in this Plan, offering a complex plan for the staff involved in clearing and the cooperating partners working in the national system, with regard to preventing the occurrence of accidents, clearing the actual incident and mitigating the impacts.

In conformity with the current practice of Paks Nuclear Power Plant, the Licensee will apply a Nuclear Accident Prevention and Action Plan (NAPAP) during the operation of the new units to clear the environmental impacts of accidents accompanied by the emission of radioactive materials, to manage and liquidate the actual accidents and to mitigate their environmental impacts. NAPAP will offer guidance and define actions to manage, clear and liquidate nuclear facility-based and radiological extraordinary incidents and emergency situations affecting the area of the new units, warranting the availability for the clearing staff of a plan that can manage the actual situation in all its aspects. For the cause of the nuclear facility-based and radiological extraordinary incident and emergency situation, the Plan will consider all incidents assigned to both internal and external reasons. The radiation protection and technological actions under NAPAP help prevent the environmental expansion of radiological impacts, and as such are the most efficient means for mitigating health-related, economic and other impacts. These actions are carried out in the system currently used in Paks Nuclear Power Plant and regularly audited by the nuclear authority, so the Licensee will basically consider this as its own system during the construction and operation of the new units. In accordance with its role in preventing accidents, in managing actual environmental situations and mitigating impacts, the potential system will perform protection and clearing functions, adapted to the National Action Plan for Nuclear Accident Prevention.

24 SUMMARY

On January 14, 2014 the Government of Hungary agree with the Government of the Russian Federation on the renewal of the Nuclear Cooperation Agreement which was concluded between the two governments several decades earlier. The agreement of the two governments were ratified by the National Assembly of Hungary in Act II of 2014 on the Promulgation of the Convention on the cooperation between the Government of Hungary agree with the Government of the Russian Federation on the peaceful use of nuclear energy. Based on the Agreement, two additional 1,200 MW units will be built in the area of the Paks Nuclear Power Plant, with the involvement of the relevant Russian Authorities, as general contractor.

The purpose of the investment is to build up-to-date, third generation pressurized water nuclear power plant units for public power generation purposes with at sixty years of operation, in compliance with the schedule as set out in the National Energy Strategy, with commencement of live operation from between 2025 and 2030.

The Consolidated Environmental Impact Assessment (KHT) study prepared to conduct the complex environmental impact assessment of Paks II. Nuclear Power Plant has studied the Russian nuclear technology selected from the possible solutions contemplated by the Preliminary Consultative Documentation (EKD), including its main relationships, such as cooling water intake and the hot water outlet into the Danube, as well as the transmission cables used for the offtake of the electric energy generated in the power plant, with regard to environmental impacts.

The assessment has studies the base load of the environmental elements and systems and the current condition of the environment, followed by the assessment of the base condition for evaluation purposes. The study covers the areas of the implementation of the new nuclear power plant units and the entire previously estimated impact area, based on the examinations, and analyses conducted after March 1, 2012, mainly in the course of the same year, 2012, and in certain cases in 2013.

The environmental impact analysis of Paks II. Nuclear Power Plant took several months. The study was based on the technical conditions and implementation site plan prepared in March 2014.

We need to note that we determined the impact factors and calculated and modelled their impacts by taking the factors evoking the largest environmental impact into consideration, with regard to the principle of conservative approach of NBSZ as well besides environmental protection aspects.

The environmental impact assessment study of Paks II. covered the following aspects:

- Detailed introduction of the planned investment of the nuclear power plant, presentation of the base data,
  - the volume of the project, time frame of the implementation and the commencement of the operation,
  - description of the implementation of the planned technology,
  - list and location of the facilities required for starting the project,
  - ensuring water supply,
  - treatment of the waste material and wastewater generated in the course of the implementation project,
  - main data of the utilization of materials,
  - volume of the car and truck traffic related to the project,
- the presentation of the selected construction site, including its closer and wider environment, the place of the project and its area requirements, followed by the presentation of the site plan of the project
- definition and calculation of the environmental effects of the nuclear technology on certain elements of the environment and its subsystems,

- delineation of the impact area of the planned investment,
- cross border effects.

We evaluated the impacts by following the logical process of impact factors → impact processes → those impacted (affected by the impact), with regard to the current baseline load on the environmental elements/systems concerned and the changes which are expected to occur to the current environmental and natural conditions during the total lifetime of the project Paks II (e.g. climate change).

We examined the impact factors of the new nuclear power plant blocks and the adjacent facilities in chronological order (establishing-construction/assembly, operation and abandonment), with regard to the areas to be used:

We examined the individual phases by classifying them based on the most typical groups of impact factors. Among the various impact factors, we distinguished between traditional, non-radioactive and radioactive wastes and emissions with consideration to the nature of the facility.

- the use of environmental elements
- emissions and wastes
    - *the generation and management of traditional, non-radioactive emissions and wastes*
    - *The generation and management of radioactive emissions and wastes*
- spent fuel cassettes
    - *The treatment and storage of fuel cassettes removed from the reactor zone*

We carried out the examinations with regard to normal operation and abnormal operational conditions (operating troubles, emergency and events comprised in the design basis) alike.

The environmental baseline conditions, which have been determined in the environmental impact study with detailed measurements and calculations, describe and constitute part of the environmental impacts of the operation of the already operating Paks Nuclear Power Plant.

In summary, we also indicated the cumulated impact area of the direct impacts on the map, which we derived by cumulating the impact areas of the individual specialist areas and indicating the outermost contour lines of the individual impact areas.

In accordance with the detailed analyses of the environmental impact assessement study, the implementation of Paks II. affects the settlemetns of Dunaszentbenedek and Paks települések, while the operation of Paks II. will affect Dunaszentbenedek, Paks and Uszód settlements.

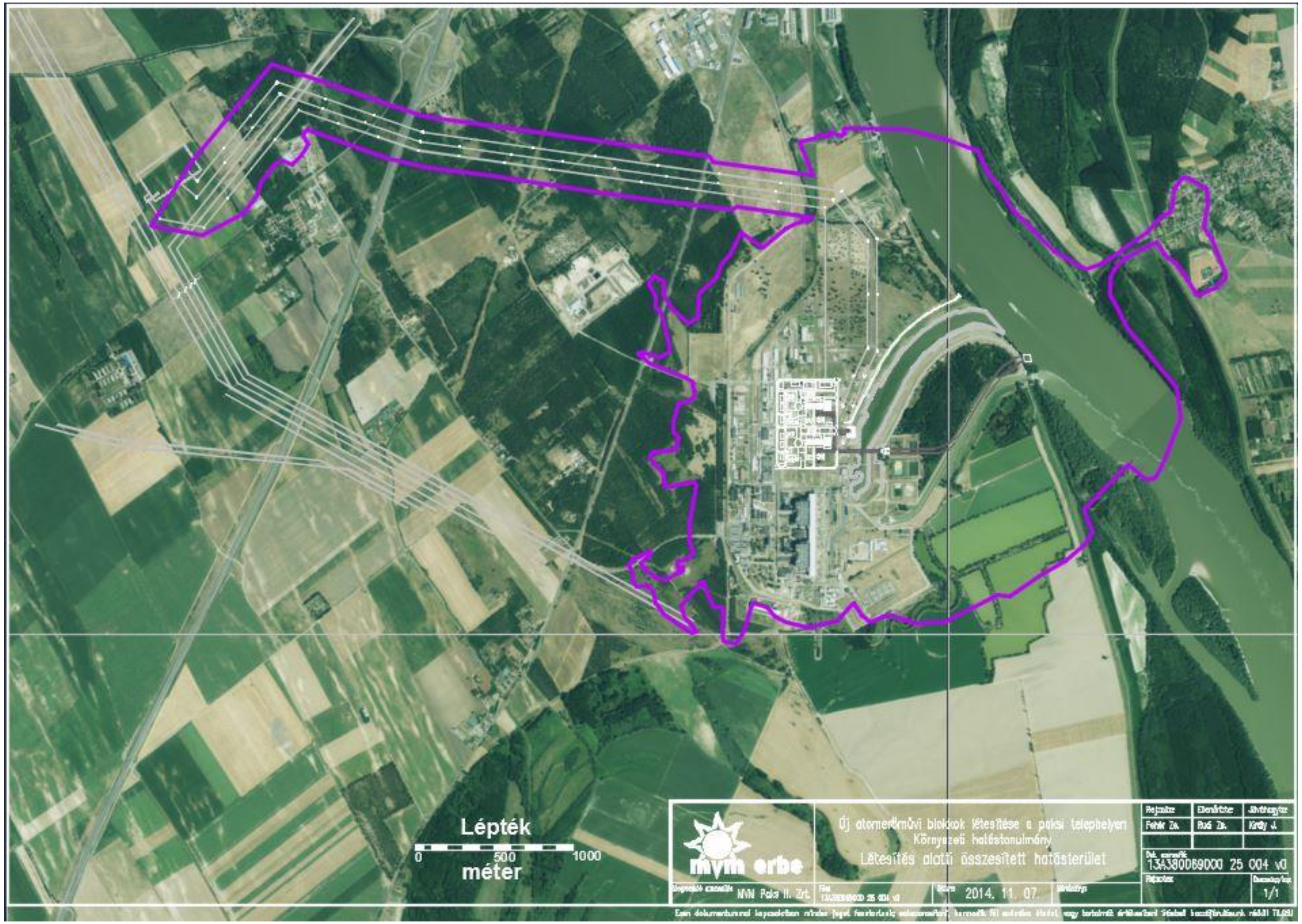
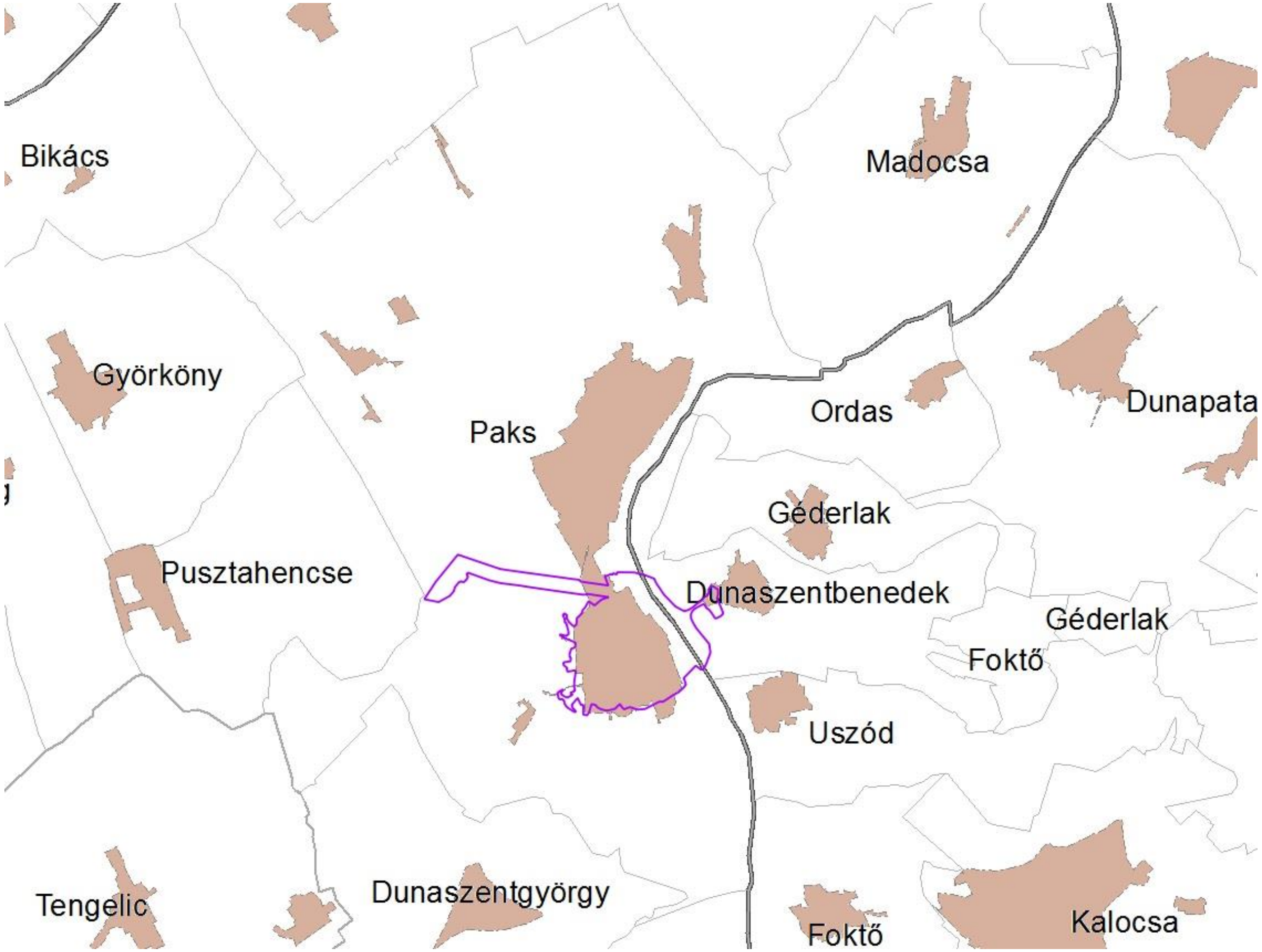


Figure 105: Consolidated impact area of the implementation of Paks II



Forrás: http://gis.teir.hu/arcgis/services/TeIR_GIS/teirgis_kozigazgatas/MapServer/WMSServer

Figure 106: Consolidated impact area of the implementation of Paks II with administrative borders

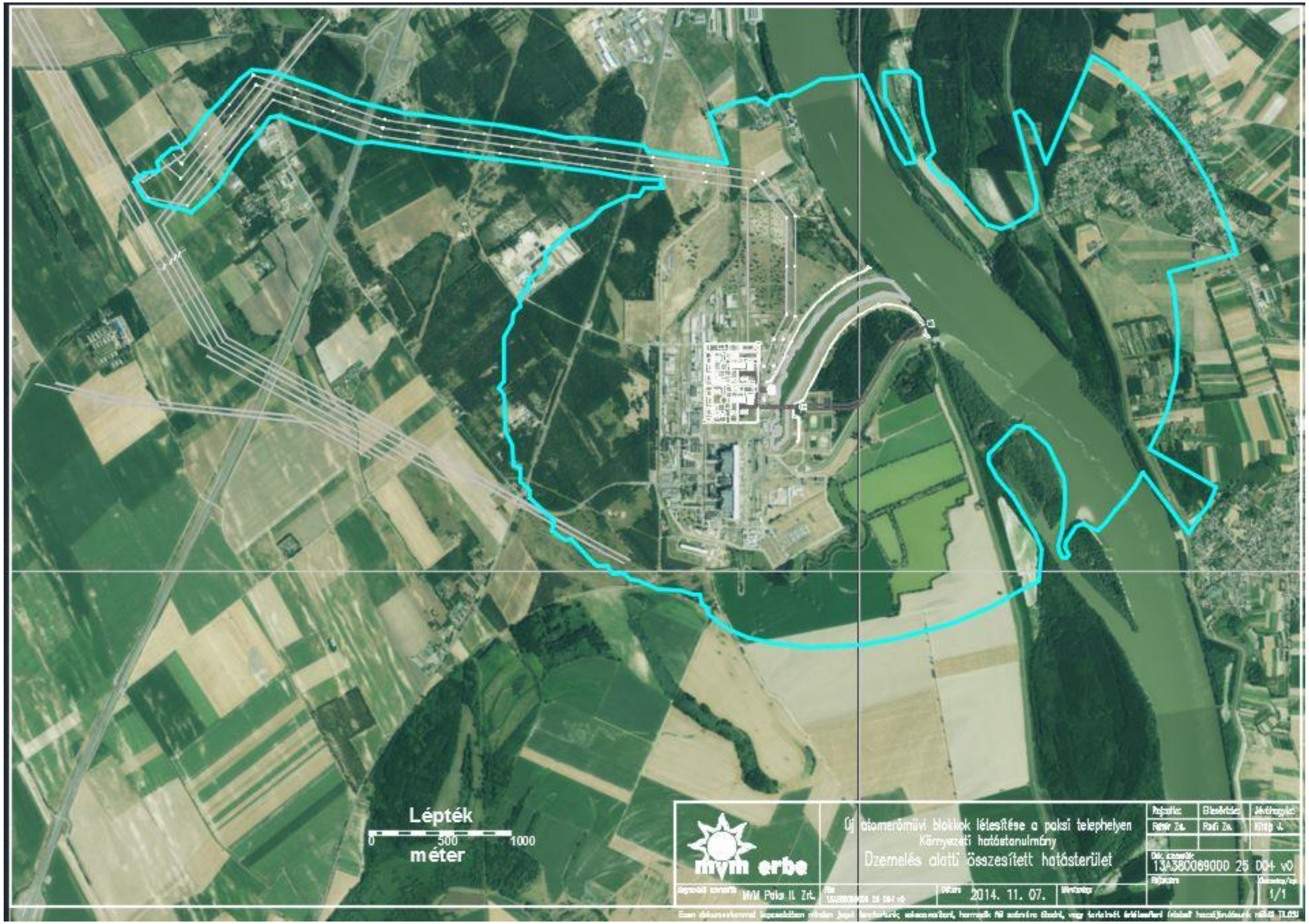
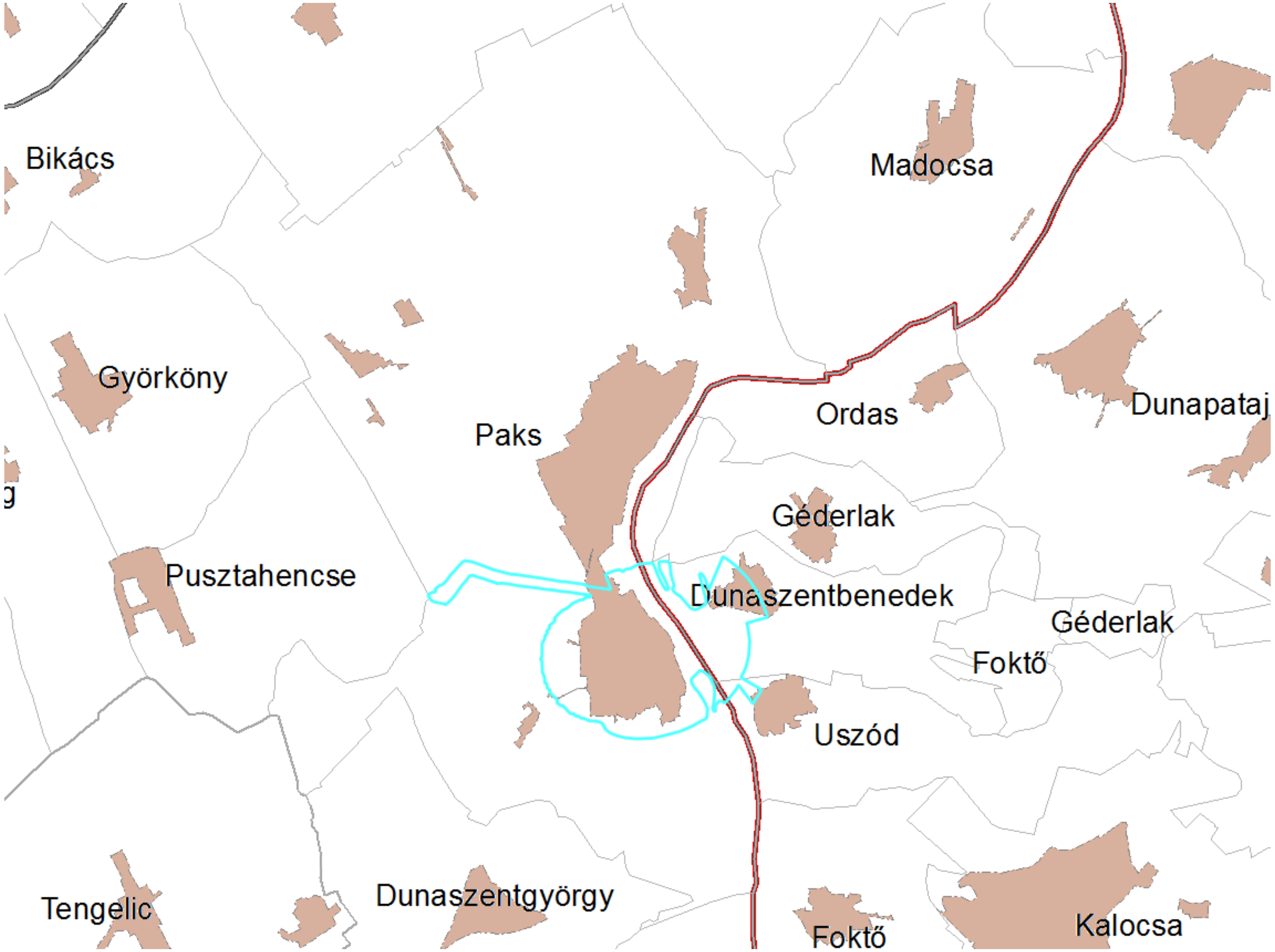


Figure 107: Consolidated impact area of the implementation of Paks II



Source: http://gis.teir.hu/arcgis/services/TeIR_GIS/teirgis_kozigazgatas/MapServer/WMSServer

Figure 108: Consolidated impact area of the implementation of Paks II with administrative borders

The operation of Paks II. affects the areas of Dunaszentbenedek, Paks and Uszód settlements.

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