GEOLOGICAL MEDIUM AND UNDERGROUND WATER ON THE SITE AND IN THE IMMEDIATE VICINITY

TABLE OF CONTENTS

13 GEOLOGICAL MEDIUM AND UNDERGROUND WATER ON THE SITE AND IN THE IMMEDIATE VICINITY 9

13.1 Legal background – Zoning, limits..... 9

13.2 Horizontal and vertical delineation of the audited area 9

13.3 General characteristics of the studied underground aquatic environment 10

13.3.1 Short hydrogeological characterisation..... 10

13.3.2 Classification of underground water bodies..... 10

13.4 Basic condition of the geological medium and underground water on the site and in the immediate vicinity 10

13.4.1 Basic condition of the geological medium in the planned investment area..... 10

13.4.2 Basic condition of the underground water on the site and in the immediate vicinity..... 13

13.4.2.1 Assessment of archive measurement results of the groundwater monitoring system operated on the site and in its surroundings 13

13.4.2.1.1 Period before operation of the nuclear power plant 15

13.4.2.1.2 Groundwater pollution status based on monitoring results 15

13.4.2.2 Evaluation of results measured in wells sampled in 2012 15

13.4.2.3 Components analysed..... 17

13.4.2.4 Description of factors affecting field groundwater measurements..... 18

13.4.2.4.1 Groundwater storage layer..... 18

13.4.2.4.2 Relationship between the Danube and groundwater 18

13.4.2.5 Evaluation of the field measurement results..... 19

13.4.2.6 Joint evaluation of soil and groundwater contamination measured in 2012 21

13.4.3 Hydrological modelling of underground water on the site 22

13.4.3.1 Evaluation of the mutual impact of the groundwater and surface water..... 32

13.4.3.2 Results of modelling the unsaturated zone 33

13.4.3.3 Validation..... 36

13.4.3.4 Evaluation of transport processes between the groundwater and the confined groundwater 37

13.4.3.5 Changes in tritium distribution in groundwater 37

13.4.4 Operational confined groundwater works in Csámpa 39

13.4.4.1 General hydrogeological characterisation 39

13.4.4.2 Basic data..... 39

13.4.4.3 Quality status of the water body 39

13.4.4.4 Quantitative status of the water body 40

13.4.4.5 Hydrogeological model of the water body (impact of increased water extraction on the pressure levels of confined groundwater). 40

13.5 Impact of construction of Paks II on the geological medium beneath the site as well as the underground water..... 50

13.5.1 Impact of construction on underground water beneath the site. 50

13.5.1.1 Direct effects..... 50

13.5.1.1.1 Effects of dewatering the working pit on groundwater..... 50

13.5.1.1.2 Estimate of the tritium quantity of water removed from the working pit..... 60

13.5.1.2 Indirect effects 63

13.5.1.2.1 Impact of draining into the Danube of water removed during dewatering..... 63

13.5.1.2.2 Impact of construction on the geological medium 74

13.5.2 Impact areas of construction..... 75

13.5.2.1 Direct effects..... 75

13.5.2.2 Indirect effects 77

13.5.2.3 Transboundary environmental impacts 78

13.6 Impact of operation of Paks II on the geological medium and underground water of the site..... 79

13.6.1 Normal operation 79

13.6.1.1 Impact areas of operation of Paks II..... 80

13.6.1.1.1 Direct effects 80

13.6.1.1.2 Conceptual design of the groundwater monitoring system 97
13.6.1.1.3 Indirect effects 101
13.6.1.2 Effects of joint operation of Paks II and the Paks Nuclear Power Plant 103
13.6.1.3 Impact areas of joint operation of Paks II and the Paks Nuclear Power Plant 103
13.6.1.3.1 Direct effects 103
13.6.1.3.2 Indirect effects 109
13.6.1.3.3 Transboundary environmental impacts 109
13.6.2 Operating troubles, failure events 110
13.7 Impacts of abandonment of Paks II on the geological medium beneath the site as well as the underground water 110
13.8 references 111

LIST OF FIGURES

Figure 13.4.1-1: Location of boreholes drilled in the proposed power plant area. 11
Figure 13.4.2-1: Regional grouping of monitoring wells 14
Figure 13.4.2-2: Wells involved in monitoring 16
Figure 13.4.3-1: Water levels measured at the cold water canal in the examined period 23
Figure 13.4.3-2: Model space created during the test 24
Figure 13.4.3-3: Layer structure created during the test 25
Figure 13.4.3-4: Cell structure of the grid created during the test 25
Figure 13.4.3-5: Location of boundary conditions (head boundaries) developed during modelling 26
Figure 13.4.3-6: Contour map of the groundwater table on 22/08/2013 in the event of low water level in the Danube (85.14 mBf) 28
Figure 13.4.3-7: Contour map of the groundwater table on 17/02/2013 in the event of medium water level in the Danube (87.56 mBf) 28
Figure 13.4.3-8: Contour map of the groundwater table on 11/06/2013 in the event of high water level in the Danube (94.01 mBf) 29
Figure 13.4.3-9: Developments in the direction of flow on 22/08/2013 in the event of low water level in the Danube (85.14 mBf) 29
Figure 13.4.3-10: Developments in the direction of flow on 17/02/2013 in the event of medium water level in the Danube (87.56 mBf) 30
Figure 13.4.3-11: Developments in the direction of flow on 11/06/2013 in the event of high water level in the Danube (94.01 mBf) 30
Figure 13.4.3-12: Velocity space forming in the vicinity of the main building and the HVCS in case of low water level in the Danube 31
Figure 13.4.3-13: Velocity space forming in the vicinity of the main building and the HVCS in case of high water level in the Danube 31
Figure 13.4.3-14: Path of water particles launched from the assumed sources. 32
Figure 13.4.3-15: Paths of particles located in a saturated/unsaturated zone 34
Figure 13.4.3-16: Vertical image of an unsaturated (three-phase) zone in case of low Danube water level 34
Figure 13.4.3-17: Vertical image of an unsaturated (three-phase) zone in case of medium Danube water level 35
Figure 13.4.3-18: Vertical image of an unsaturated (three-phase) zone in case of high Danube water level 35
Figure 13.4.3-19: Comparison of water levels measured and calculated by the model. 36
Figure 13.4.3-20: Summary of tritium sources assumed under the power plant building. 37
Figure 13.4.3-21: Contour map of tritium lens distribution at the end of the analysis period. 38
Figure 13.4.3-22: Comparison of the tritium activity concentration measured and calculated by the model. 38
Figure 13.4.4-1: 10-year time series of the water level of the I-1 observation well on the 1st site. 40
Figure 13.4.4-2: 8-year time series of the water level of the I-3 observation well on the 1st site. 41
Figure 13.4.4-3: 10-year time series of the water level of the I-7 observation well on the 1st site. 41
Figure 13.4.4-4: 10-year time series of the water level of the II-2 producing well on the 2nd site. 42
Figure 13.4.4-5: 10-year time series of the water level of the II-6 producing well on the 2nd site. 42

Figure 13.4.4-6: 10-year time series of the water level of the III-8 producing well on the 3rd site. 43
Figure 13.4.4-7: 10-year time series of the water level of the III-9 producing well on the 3rd site. 43
Figure 13.4.4-8: Geometry of the extended model. 44
Figure 13.4.4-9: Model grid 44
Figure 13.4.4-10: Hydraulic infiltration parameters of relevant layers 45
Figure 13.4.4-11: General map of the model area 46
Figure 13.4.4-12: Flow directions in the vicinity of the wells, 50 years migration paths and depression cones. 47
Figure 13.4.4-13: Flow direction along a W - E section. 47
Figure 13.4.4-14: Validation curve of the current status. 48
Figure 13.4.4-15: Flow directions in the vicinity of the wells, 50 years migration paths and depression cones. 48
Figure 13.4.4-16: Flow direction along a W - E section. 49
Figure 13.4.4-17: Validation curve of the 646 m^3/day increment compared to the current status. 49
Figure 13.5.1-1: Horizontal position of the working pit 50
Figure 13.5.1-2: Vertical position of the working pit 51
Figure 13.5.1-3: Annual water level fluctuations of all on-site monitoring wells. 51
Figure 13.5.1-4: Annual water level fluctuations of monitoring wells in the construction site and the mobilisation area. 52
Figure 13.5.1-5: Extent of the depression cone and the flow field at the beginning of the assessment period. 52
Figure 13.5.1-6: Extent of the depression cone and the flow field on the 50th day of the assessment period. 53
Figure 13.5.1-7: Extent of the depression cone and the flow field on the 100th day of the assessment period. 53
Figure 13.5.1-8: Extent of the depression cone and the flow field on the 200th day of the assessment period. 54
Figure 13.5.1-9: Extent of the depression cone and the flow field on the 365th day of the assessment period. 54
Figure 13.5.1-10: Effluent water quantity needed for draining the working pit and keeping it dry. 55
Figure 13.5.1-11: Horizontal position of the second working pit. 56
Figure 13.5.1-12: Vertical image of the second working pit. 56
Figure 13.5.1-13: Extent of the depression cone and the flow field at the beginning of the assessment period. 57
Figure 13.5.1-14: Extent of the depression cone and the flow field on the 50th day of the assessment period. 57
Figure 13.5.1-15: Extent of the depression cone and the flow field on the 100th day of the assessment period. 58
Figure 13.5.1-16: Extent of the depression cone and the flow field on the 200th day of the assessment period. 58
Figure 13.5.1-17: Extent of the depression cone and the flow field on the 365th day of the assessment period. 59
Figure 13.5.1-18: Effluent water quantity needed for draining the second working pit and keeping it dry 60
Figure 13.5.1-19: A zone defined for estimating the amount of tritium. 61
Figure 13.5.1-20: Annual volume of water passing through the zone 61
Figure 13.5.1-21: Distribution of tritium along the east-west section. 62
Figure 13.5.1-22: Direction of the tritium plume flow in a baseline status. 63
Figure 13.5.1-23: Impact of the depression cone on the flow direction of the tritium plume (1st day) 63
Figure 13.5.1-24: Impact of the depression cone on the flow direction of the tritium plume (50th day) 64
Figure 13.5.1-25: Impact of the depression cone on the flow direction of the tritium plume (100th day) 64
Figure 13.5.1-26: Impact of the depression cone on the flow direction of the tritium plume (200th day) 65
Figure 13.5.1-27: Impact of the depression cone on the flow direction of the tritium plume (365th day) 65
Figure 13.5.1-28: Vertical spread of the tritium plume (1st day). 66
Figure 13.5.1-29: Vertical spread of the tritium plume (50th day). 66
Figure 13.5.1-30: Vertical spread of the tritium plume (100th day). 67
Figure 13.5.1-31: Vertical spread of the tritium plume (200th day). 67
Figure 13.5.1-32: Vertical spread of the tritium plume (365th day). 68
Figure 13.5.1-33: Impact of the depression cone on the flow direction of the tritium plume (1st day). 69
Figure 13.5.1-34: Impact of the depression cone on the flow direction of the tritium plume (50th day) 69
Figure 13.5.1-35: Impact of the depression cone on the flow direction of the tritium plume (100th day) 70
Figure 13.5.1-36: Impact of the depression cone on the flow direction of the tritium plume (200th day) 70
Figure 13.5.1-37: Impact of the depression cone on the flow direction of the tritium plume (365th day) 71
Figure 13.5.1-38: Vertical spread of the tritium plume (1st day). 71
Figure 13.5.1-39: Vertical spread of the tritium plume (50th day). 72
Figure 13.5.1-40: Vertical spread of the tritium plume (100th day). 72

Figure 13.5.1-41: Vertical spread of the tritium plume (200th day) 73
Figure 13.5.1-42: Vertical spread of the tritium plume (365th day) 73
Figure 13.5.2-1: Impact area of dewatering the first working pit 76
Figure 13.5.2-2: Impact area of dewatering the second working pit 76
Figure 13.6.1-1: Site image modified with the new power plant and the hot water canal branch 80
Figure 13.6.1-2: Contour map of the groundwater table and the velocity space in case of low water level in the Danube (85.14 mBf) 81
Figure 13.6.1-3: Vertical image of the groundwater table and the velocity space along a N - S section 81
Figure 13.6.1-4: Vertical image of the groundwater table and the velocity space along a W-E section 82
Figure 13.6.1-5: Water particle path located in the layer under the power plant for low Danube water level 82
Figure 13.6.1-6: Image of the three-phase zone in case of constantly low Danube water level along a N - S section 83
Figure 13.6.1-7: Image of the three-phase zone in case of constantly low Danube water level along a W - E section 83
Figure 13.6.1-8: Distribution of the tritium plume one year after shut down of Units 1-4 of Paks Nuclear Power Plant in case of low Danube water level 84
Figure 13.6.1-9: Distribution of the tritium plume five years after shut down of Units 1-4 of Paks Nuclear Power Plant in case of low Danube water level 84
Figure 13.6.1-10: Distribution of the tritium plume ten years after shut down of Units 1-4 of Paks Nuclear Power Plant in case of low Danube water level 85
Figure 13.6.1-11: Distribution of the tritium plume twenty years after shut down of Units 1-4 of Paks Nuclear Power Plant in case of low Danube water level 85
Figure 13.6.1-12: Contour map of the groundwater table and the velocity space in case of medium water level in the Danube (87.73 mBf) 86
Figure 13.6.1-13: Vertical image of the groundwater table and the velocity space along a N - S section 86
Figure 13.6.1-14: Vertical image of the groundwater table and the velocity space along a W-E section 87
Figure 13.6.1-15: Water particle path located in the layer under the power plant for medium Danube water level 87
Figure 13.6.1-16: Image of the three-phase zone in case of constantly medium Danube water level along a N - S section 88
Figure 13.6.1-17: Image of the three-phase zone in case of constantly medium Danube water level along a W - E section 88
Figure 13.6.1-18: Distribution of the tritium plume one year after shut down of Units 1-4 of Paks Nuclear Power Plant in case of medium Danube water level 89
Figure 13.6.1-19: Distribution of the tritium plume five years after shut down of the Units 1-4 of Paks Nuclear Power Plant in case of medium Danube water level 89
Figure 13.6.1-20: Distribution of the tritium plume ten years after shut down of Units 1-4 of Paks Nuclear Power Plant in case of medium Danube water level 90
Figure 13.6.1-21: Distribution of the tritium plume twenty years after shut down of Units 1-4 of Paks Nuclear Power Plant in case of medium Danube water level 90
Figure 13.6.1-22: Distribution of the tritium plume thirty years after shut down of Units 1-4 of Paks Nuclear Power Plant in case of medium Danube water level 91
Figure 13.6.1-23: Distribution of the tritium plume forty years after shut down of Units 1-4 of Paks Nuclear Power Plant in case of medium Danube water level 91
Figure 13.6.1-24: Contour map of the groundwater table and the velocity space in case of high water level in the Danube (94.01 mBf) 92
Figure 13.6.1-25: Vertical image of the groundwater table and the velocity space along a N - S section 92
Figure 13.6.1-26: Vertical image of the groundwater table and the velocity space along a W-E section 93
Figure 13.6.1-27: Water particle path located in the layer under the power plant for high Danube water level 93
Figure 13.6.1-28: Image of the three-phase zone in case of constantly high Danube water level along a N - S section 94
Figure 13.6.1-29: Image of the three-phase zone in case of constantly high Danube water level along a W - E section 94
Figure 13.6.1-30: Distribution of the tritium plume one year after shut down of Units 1-4 of the Paks Nuclear Power Plant in case of high Danube water level 95
Figure 13.6.1-31: Distribution of the tritium plume five years after shut down of Units 1-4 of the Paks Nuclear Power Plant in case of high Danube water level 95
Figure 13.6.1-32: Distribution of the tritium plume ten years after shut down of Units 1-4 of the Paks Nuclear Power Plant in case of high Danube water level 96
Figure 13.6.1-33: Distribution of the tritium plume twenty years after shut down of Units 1-4 of the Paks Nuclear Power Plant in case of high Danube water level 96

Figure 13.6.1-34: Distribution of the tritium plume thirty years after shut down of Units 1-4 the Paks Nuclear Power Plant in case of high Danube water level 97
Figure 13.6.1-1: Installation phases of the monitoring system wells and flow paths 98
Figure 13.6.1-2: Waste disposal sites, storage sites for oily and hazardous materials and locations of monitoring wells 99
Figure 13.6.1-1: Distribution of the tritium plume half a year after dewatering in case of low Danube water level....103
Figure 13.6.1-2: Distribution of the tritium plume one year after dewatering in case of low Danube water level 104
Figure 13.6.1-3: Distribution of the tritium plume five years after dewatering in case of low Danube water level 104
Figure 13.6.1-4: Distribution of the tritium plume half a year after dewatering in case of medium Danube water level 105
Figure 13.6.1-5: Distribution of the tritium plume one year after dewatering in case of medium Danube water level 105
Figure 13.6.1-6: Distribution of the tritium plume five years after dewatering in case of medium Danube water level....106
Figure 13.6.1-7: Distribution of the tritium plume ten years after dewatering in case of medium Danube water level 106
Figure 13.6.1-8: Distribution of the tritium plume seventeen years after dewatering in case of medium Danube water level....107
Figure 13.6.1-9: Distribution of the tritium plume half a year after dewatering in case of high Danube water level 107
Figure 13.6.1-10: Distribution of the tritium plume one year after dewatering in case of high Danube water level 108
Figure 13.6.1-11: Distribution of the tritium plume five years after dewatering in case of high Danube water level....108
Figure 13.6.1-12: Distribution of the tritium plume ten years after dewatering in case of high Danube water level 109

LIST OF TABLES

Table 13.4.1-1: Laboratory analysis summary of the soil samples from the investment area. 12
Table 13.4.1-2: Naphthalene and PAH indications in soil samples of boreholes drilled in the investment area 13
Table 13.4.2-1: Flow regime relationship between the Danube and the monitoring system wells 13
Table 13.4.2-2: Summary of parameters measured in the groundwater monitoring wells 19
Table 13.4.3-1: Monthly precipitation in the site 23
Table 13.4.3-2: X,y, z components of infiltration coefficients applied in the model 27
Table 13.4.3-3: Other hydraulic infiltration parameters....27
Table 13.4.4-1: Parameters of the Csámpa wells....40
Table 13.4.4-2: Tritium activity of the R63 in Paks and the 4 producing wells in Csámpa. 46
Table 13.5.1-1: Effect of dewatering of the working pit in individual monitoring wells. 55
Table 13.5.1-2: Effect of dewatering of the working pit in individual monitoring wells. 59
Table 13.5.2-1: Normal, operating and controlled liquid radioactive emissions of the Paks Nuclear Power Plant in 2013 77
Table 13.5.2-2: Danube discharge rate at Paks as a function of characteristic water levels....77
Table 13.5.2-3: Activity concentration values calculated with the characteristic discharge rates of the Danube in 2013 77
Table 13.6.1-1: Operating periods of the Paks II units and their joint operation with the existing units of the Paks Nuclear Power Plant. 79
Table 13.6.1-1: Storage of oil and chemical compounds in the operating period....100
Table 13.6.1-2: Names and EOV coordinates of monitoring wells 100
Table 13.6.1-1: Normal, operating and controlled liquid radioactive emissions of the Paks Nuclear Power Plant....101
Table 13.6.1-2: Danube discharge rate at Paks as a function of characteristic water levels....102
Table 13.6.1-3: Activity concentration values calculated with the characteristic discharge rates of the Danube. Paks Unit II.1...102
Table 13.6.1-4: Activity concentration values calculated with the characteristic discharge rates of the Danube, Paks Units II 1 and 2 102
Table 13.6.1-1: Total increase of activity concentration in the Danube caused by the emission of alpha, beta and gamma radiating isotopes. 109

LIST OF ABBREVIATIONS

Short name	Full name
KHV	Environmental impact assessment (Környezeti hatásvizsgálat)
KHT	Environmental Impact Assessment Study (Környezeti hatástanulmány)
HVCS	cold water canal (hidegvíz-csatorna)
MVCS	hot water canal (melegvíz-csatorna)
mBf	Height above mean water level of the Baltic Sea (Balti-tenger közepes vízszintje feletti magasság)
KV	low water (kisvíz)
KÖV	medium water (középvíz)
NV	high water (nagyvíz)
VGT	Hungarian Basin Management Plan (Magyarország vízgyűjtő-gazdálkodási terve)
VKI	Water Framework Directive, WFD (Víz Keretirányelv)
PAH	Polycyclic aromatic hydrocarbons (policiklusos aromás szénhidrogének)
BTEX	Benzene and alkylbenzenes (Benzol és alkilbenzolok)
TPH	Total amount of hydrocarbon-type contaminants with C6-C40 carbon atoms in environmental samples (környezeti minták C6-C40 szénatom;számú szénhidrogén típusú szennyezőanyagainak együttes mennyisége)
KKÁT	Spent Fuel Interim Storage (Kiégett Kazetták Átmeneti Tárolója)
GHB	General head boundary (általános peremfeltétel)
CHB	Constant head boundary (konstant peremfeltétel)
WHO	World Health Organisation (Egészségügyi Világszervezet)

13 GEOLOGICAL MEDIUM AND UNDERGROUND WATER ON THE SITE AND IN THE IMMEDIATE VICINITY

13.1 LEGAL BACKGROUND – ZONING, LIMITS

Legal documents by the European Union (Decision, Directive)

Directive 2000/60/EC of the European Parliament and the Council on establishing a framework for Community action in the field of water policy

Acts

Act LIII of 1995 on the General Rules of Environmental Protection

Government decrees

Government Decree 314/2005 (XII.25.) on Environmental Impact Assessment and the Integrated Environmental Permit.
Government Decree 219/2004 (VII. 21.) on the Protection of Ground waters.

Government Decree 123/1997 (VII. 18.) on the protection of water resources, future water resources and the water facilities producing potable water

Government decision

Government Decision 1042/2012 (II. 23.) on the River Basin Management Plan of Hungary

Ministerial decrees

Ministerial Decree 14/2005 (VI. 28.) KvVM on the rules concerning the screening surveys of remedial site investigations.

Joint Decree 6/2009. (IV. 14.) KvVM–EüM–FVM of the Ministries of Environmental Protection, Health and Agriculture on pollution limits required for the protection of the geological media and the underground water against pollution and the measurement of pollutions

Ministerial Decree 101/2007 (XII. 23) KvVM on professional requirements for intervention in underground water resources and water well drilling

Ministerial Decree 15/2001 (VI. 6.) KöM on Radioactive Emissions to the Atmosphere and into Waters in the Course of Using Nuclear Energy and their Monitoring.

13.2 HORIZONTAL AND VERTICAL DELINEATION OF THE AUDITED AREA

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.

The characterisation of the underground water environment extends to the groundwater, bank filtrated water 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 is 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.

13.3 GENERAL CHARACTERISTICS OF THE STUDIED UNDERGROUND AQUATIC ENVIRONMENT

13.3.1 SHORT HYDROGEOLOGICAL CHARACTERISATION

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 filled up. Currently, it 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 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.

Typically, the wells produce a discharge rate of 200 l/min from the latter, but there are significant differences between the discharge rates of individual wells.

13.3.2 CLASSIFICATION OF UNDERGROUND WATER BODIES

According to Hungary's River Basin Management Plan (VGT) - Government Decision 1042/2012 (II. 23.) on Hungary's river basin management plan - the environment of the Paks Nuclear Power Plant belongs to the 1-11 Sió river basin planning subunit and it is located on its eastern edge.

According to Point 2 c) of Annex 2 of Government Decree 219/2004 (VII. 21.) on the protection of underground water, the environment of the Paks Nuclear Power Plant is regarded as a sensitive area in terms of the condition of the underground water, because the top of the main porous aquifer formation is located within 100 m below the surface.

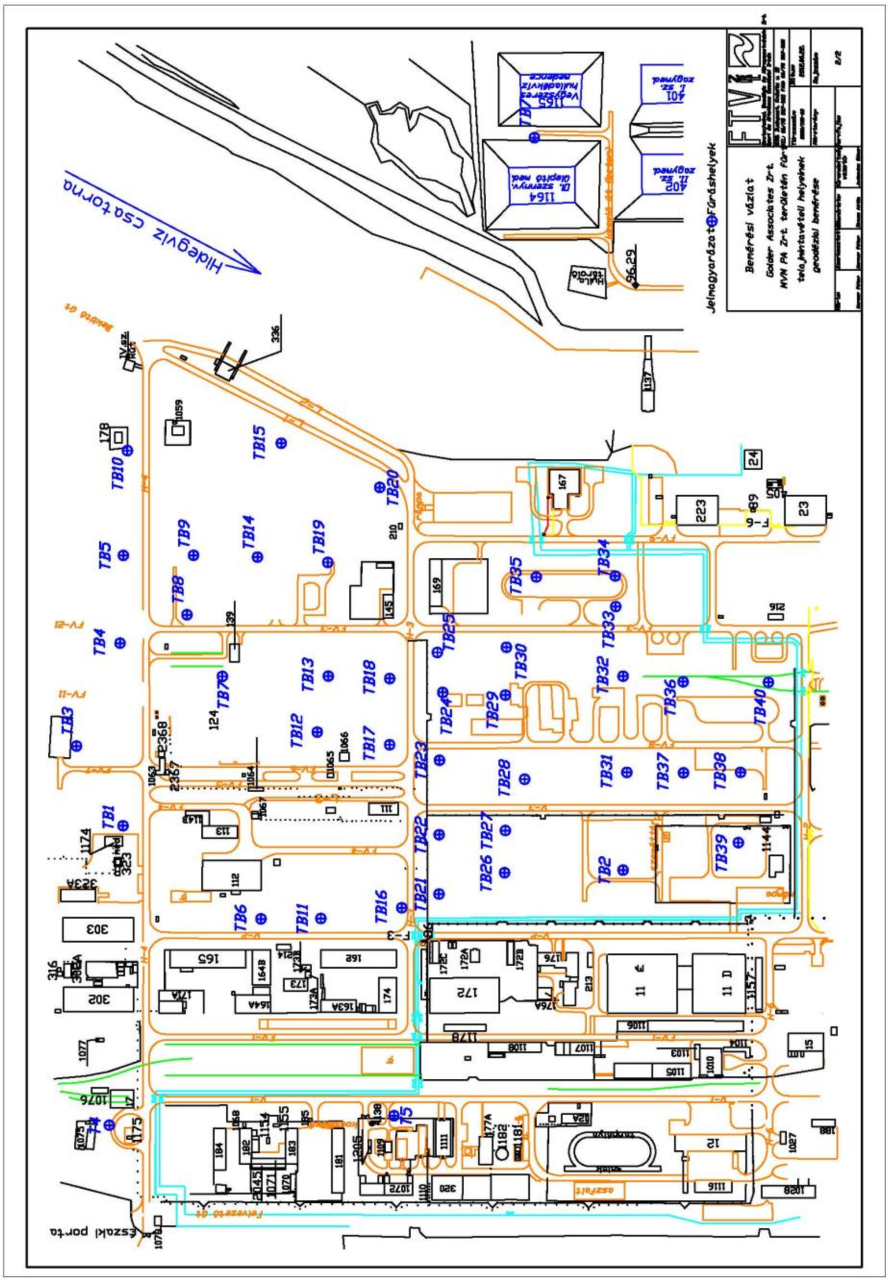
In addition, according to Point 1. a) of Annex 2 of the Decree, the interior, exterior and hydrogeological protection areas of the operating and future drinking water bases are regarded as highly sensitive areas in terms of the underground water condition. As regards the Paks II development, this affects the Csámpa water base providing communal water supply for the power plant.

13.4 BASIC CONDITION OF THE GEOLOGICAL MEDIUM AND UNDERGROUND WATER ON THE SITE AND IN THE IMMEDIATE VICINITY

13.4.1 BASIC CONDITION OF THE GEOLOGICAL MEDIUM IN THE PLANNED INVESTMENT AREA

The environmental status of the geological medium has been determined and characterised according to on-site assessments performed in 2012.

In the proposed power plant area, 40 exploratory wells were drilled at a depth of 10 m (marked TB-1 – TB-40), using direct push technology and continuous core sampling, with a 47 mm bore diameter. The location of drilled boreholes is shown in Figure 13.4.1-1.



Bemérési vázlat - Sketch
Golder Associates Zrt. MVM PA Zrt. területén fúrt talajmintavételi helyeinek geodéziai bemérése - Geodesic survey of the bored soil sampling locations of Golder Associates Zrt. in the area of MVM PA Zrt.
Jelmagyarázat ⊕ fúrás helyek - Legend ⊕ drilling locations
Hidegvíz csatorna - Cold water canal
1164 Szennyv. ülepítő med .- 1164 Sewage basin
1165 Vegyszeres hulladékvíz medence - 1165 Chemical waste water basin
401 I. sz. zagy med. - 401 sludge basin No. I
402 II. sz. zagy med. - 402 sludge basin No. II
bekötő út - service road
aszfalt - asphalt
felvezető út - access road
északi porta - northern gatehouse

Figure 13.4.1-1: Location of boreholes drilled in the proposed power plant area.

We have collected point samples from the soil at depth ranges of 0–1 m, 1–3 m, 4–7 m and 8–10 m for the purpose of chemical laboratory tests (a total of 200 samples).

The soil samples from the near-surface (0-1 m) and capillary range (4-7 or 8-10 m) were subjected to chemical analysis of the organic compounds defined in Annex 2 of KvVM Decree 14/2005 (VI. 28) for the PAH-BTEX-TPH components.

If during the analysis of the sample from the near-surface or the capillary range, the concentration of a certain component exceeded the "B" contamination limit (according to Annex 1 of Joint Decree 6/2009 (IV. 14) of the Ministries for Environment, Health and Agriculture, respectively (KvVM EüM, TVM), we have also performed determination of a limited number of organic components (PAH, BTEX, TPH) of other samples obtained from the drilling.

We have used the point samples obtained from the drilling to perform a chemical analysis of all inorganic compounds (metals, semi-metals, pH, conductivity) specified in Annex 2 of KvVM Decree 14/2005 (VI. 28.)

In Table 13.4.1-1, we have summarised the analysis results of 40 drill core samples from various points of the investment area, by showing the maximum, minimum and average concentration by component.

Components	Measuring unit	"B" contamination limit values	Maximum values	Minimum values	Average
pH		-	9,5	7,3	8,5
Conductivity	μS/cm	2500	620	36	75
Chrome	mg/kg	75	104	4	17.4
Cobalt		30	13	1	3.8
Nickel		40	44	3	12
Copper		75	63	2	8.6
Zinc		200	58	7	20.1
Molybdenium		7	<1	<1	<1
Selenium		1	0.4	<0.3	<0.3
Cadmium		1	<0.3	<0.3	<0.3
Tin		30	3	<1	<1
Barium		250	157	4	31.3
Lead		100	22	1	5.5
Argent		2	<0.9	<0.9	<0.9
Arsenium		15	11	1	3.3
Mercury		0.5	0.08	<0.02	<0.02
Benzene	mg/kg	0.2	<0.05	<0.05	<0.05
Toluene		0.5	<0.05	<0.05	<0.05
Ethylbenzene		0.5	<0.05	<0.05	<0.05
Xylenes in total		0.5	<0.1	<0.1	<0.1
Σ Other alkylbenzenes		0.5	<0.5	<0.5	<0.5
TPH /C5-C40/		100	<50	<50	<50
Total Naphtalenes	mg/kg		0.53	-	-
Total PAH	mg/kg	1	0.56	-	-

Table 13.4.1-1: Laboratory analysis summary of the soil samples from the investment area.

Compared to the other samples, the specific conductivity of the 0.45 m sample from the TB-19 drilling (muddy fillup) was exceptionally high: 620 μS/cm. This means that the soluble mineral salt content of the soil is higher compared to the other audited areas.

In the soil sample taken from a depth of 8.35 m during the TB-19 drilling, we have measured a chromium concentration of 104 mg/kg ("B" = 75 mg/kg) and a nickel concentration of 44 mg/kg ("B" = 40 mg/kg). The sample analysed was medium-grained fluvial sand. These metal contaminants are insignificant, and because of the greater depth, only natural accumulation is likely to be involved. In the other samples, we have not experienced any concentration exceeding the "B" limit for any component.

Out of the hydrocarbon components, BTEX and TPH could not be detected in any of the soil samples analysed, not even in the form of indication. Measurement results regularly remained under the detection limit of the analytical method applied.

We have not detected any soil contamination in naphtalenes and PAHs, either, but smaller indications occurred in a few places as shown by Table 13.4.1-2:

Soil sample mark	Naphtalenes (mg/kg)	Total PAH (mg/kg)
TB-33. F. – 0.4 m	0.07	0.07
TB-34. F. – 8.4 m	0.53	0.56
TB-35. F. – 0.45 m	-	0.11

Table 13.4.1-2: Naphthalene and PAH indications in soil samples of boreholes drilled in the investment area

In summary, it can be established that the geological medium opened up in the investment area to a depth of 10 metres may be considered uncontaminated in respect of the surveyed components, the only exception from this is the TB-19 drilling.

The chrome and nickel contaminations identified in the 8.35 m sample of the TB-19 drilling are insignificant and most probably of natural origin.

13.4.2 BASIC CONDITION OF THE UNDERGROUND WATER ON THE SITE AND IN THE IMMEDIATE VICINITY

The hydrogeological condition survey was based on and framed by gathering the information available, arranging it in a database which was followed by the assessment.

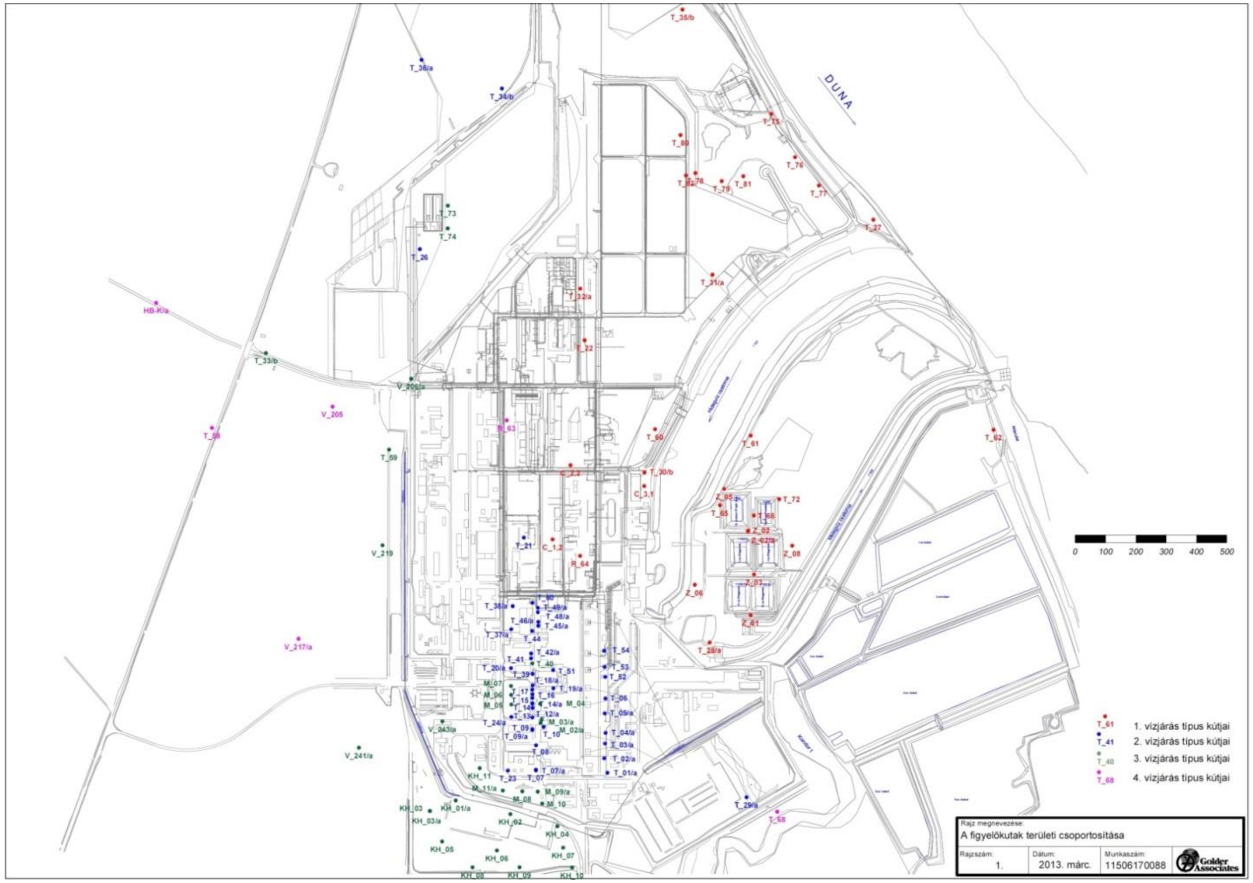
13.4.2.1 Assessment of archive measurement results of the groundwater monitoring system operated on the site and in its surroundings

By processing archive water level measurement data, we have briefly characterized the flow regime of soil and shallow confined groundwater aquifers detected with the monitoring system operated by PA Zrt.

Figure 13.4.2-1 shows the locations of those groups of wells, which can be characterized by similar flow regimes on the basis of the 14-year data set analysed. The simplified relationship between the water levels measured on watermark posts set up next to the Danube and the cold water canal and the flow regime of wells is presented very succinctly in Table 13.4.2-1.

Measured parameter	Group of wells			
	I.	II.	III.	IV.
Measured max. water level (mBf)	93.54	91.15	91.28	Those wells for which no relationship can be shown between their flow regimes and the Danube water levels. It is predominantly determined from the distance from the Danube or the cold water canal or the type of aquifer.
Measured min. water level (mBf)	84.61	84.48	88.25	
Max. flow regime (m)	8.93	6.67	3.03	
Average flow regime (m)	5.4	2.52	1.95	
Danube impact	direct (2-4 days)	close (5-8 days)	shifted in time (9-45 days)	can not be identified

Table 13.4.2-1: Flow regime relationship between the Danube and the monitoring system wells



Rajz megnevezése-Name of drawing
A figyelő kutak területi csoportosítása-Regional grouping of monitoring wells
Rajzszám 1-Drawing number 1
Dátum 2013. márc.-Date: March 2013
Munkaszám 11506170088-Job number 11506170088

T_61 1. vízjárás típus kútjai-Type wells of flow regime T_61 1.
T_41 2. vízjárás típus kútjai-Type wells of flow regime T_41 2.
T_40 3. vízjárás típus kútjai
T_68 4. vízjárás típus kútjai-Type wells of flow regime T_40 3.
Type wells of flow regime T_68 4.

Duna- River Danube
Hidegvíz csatorna-Cold water canal
Kondor tó-Lake Kondor

Figure 13.4.2-1: Regional grouping of monitoring wells

13.4.2.1.1 Period before operation of the nuclear power plant

The groundwater characteristics of the nuclear power plant and its surroundings are know from water samples collected in the period preceding construction of the nuclear power plant during the extensive soil mechanics exploration and from analysis of monitoring wells specifically created for groundwater monitoring. During construction, numerous other water samples arising from geotechnical exploration were quality tested.

Following the instructions of the then existing technical standards, the majority of studies covered the determination of calcium, magnesium, sodium, potassium, ammonium, nitrate, alkalinity, bicarbonate, chloride, sulphate, pH, as well as the free carbon dioxide and the dissolved oxygen content.

The quality of confined groundwater was known from the analysis of the wells at the Csámpa Waterworks. These wells obtain their water from the sandy layers of the Upper Pannonian formations at a depth interval of 50–200 m.

13.4.2.1.2 Groundwater pollution status based on monitoring results

We have analysed the contamination status of the groundwater on the basis of the available data sets. These data sets cover the period from January 2005 to December 2010; as regards the nitrate content we have data from November 2003.

The area distribution of regularly audited monitoring wells is not even, these wells were established primarily in or adjacent to the areas of potentially polluting plant sections or structures.

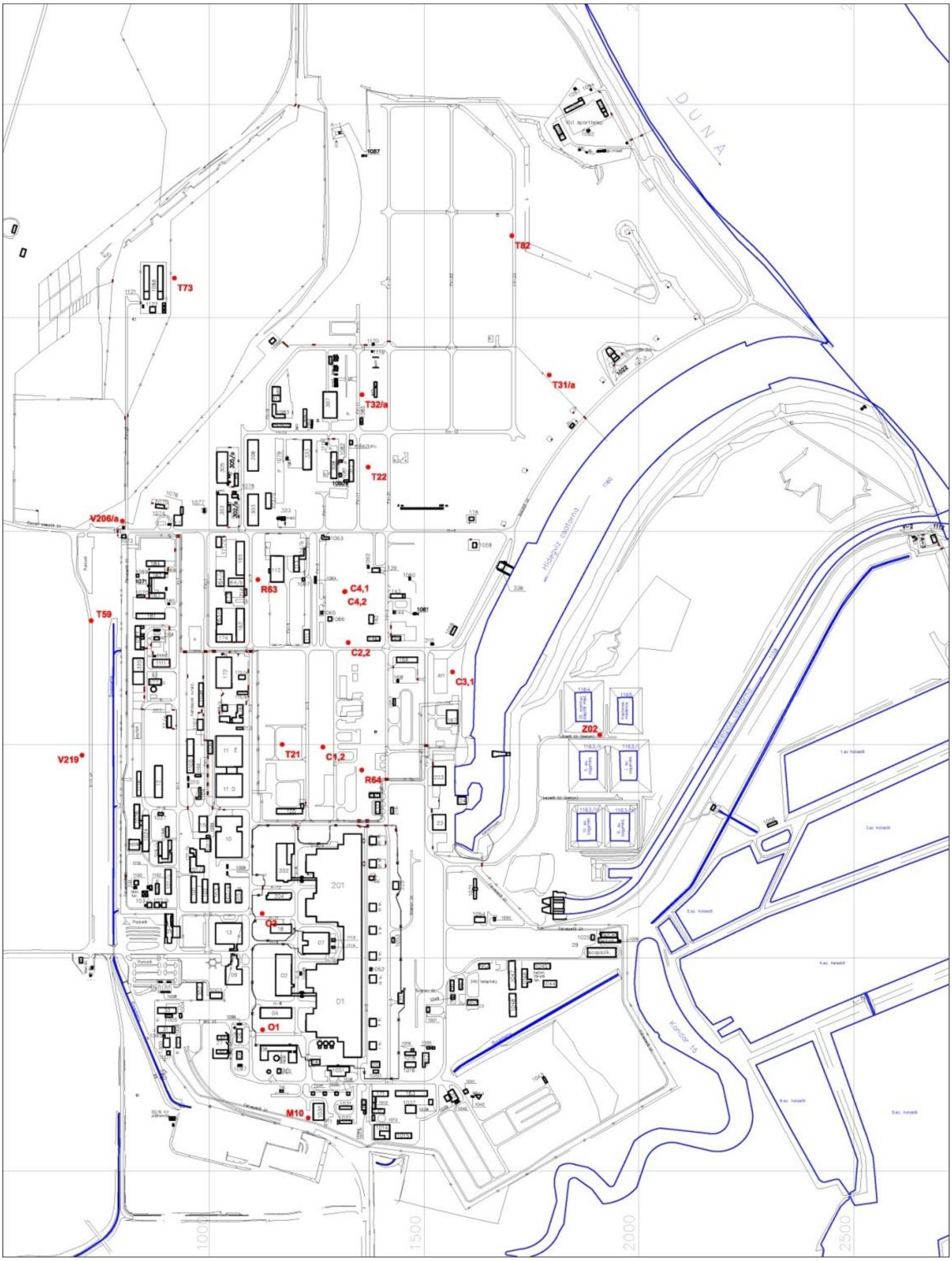
- monitoring wells of the industrial sludge area: Z01, Z02, Z02/a, Z05, T65, T66, T72;
- monitoring wells installed around the gas oil tanks: O1, O2, O3, O4, O5, O6, O7, O8;
- monitoring wells of the hazardous waste collection site: T73, T74, KG03
- monitoring wells of the faecal sewer system of the courtyard T7/a, T20/a, T23, T24/a, M05, M06, M07;
- monitoring wells of the KKÁT sewage drainage channel M08, M09, M10, M11;
- monitoring wells of the KKÁT area: KH01, KH02, KH06, KH08;
- monitoring wells of the makeup water preparation plant: T7/a, T13, T23, T24/a, O1, O2, O5, M09;
- monitoring wells in the immediate environment of the power plant units in the courtyard: M04, M07, T15, T16, T17, T24, T37/a, T39/a, T45/a, T53, T55.

13.4.2.2 Evaluation of results measured in wells sampled in 2012

In order to make the baseline survey of underground waters we have used only the existing and formerly installed monitoring wells which are currently in operation on the site. We have had a consultation with the Client on the wells selected for sampling and upon designation of individual wells, we have strived to analyse those screened at different depths. We have checked the suitability of the pre-selected wells for smapling during our local site visit.

Based on the afore mentioned selection principles we have conducted the quarterly monitoring tests of the wells according to Figure 13.4.2-2 in 2012:

- Contaminant monitoring in already known contaminated areas: O1, O3, Z02, T73, M10;
- Baseline survey: R63, R64, C1.2., C2.2., C3.1., C4.1., C4.2., T21, T22, T31A, T32A, T59, T82, V206a, V219.



Duna-River Danube
Vízi sporttelep-Water sports ground
Hideg víz csatorna-Cold water canal
Meleg víz csatorna-Hot water canal
1. sz. halastó-Fish pond No. 1
2. sz. halastó-Fish pond No.2
3. sz. halastó-Fish pond No.3
4. sz. halastó-Fish pond No.4
parkoló-Car park
Felvezető út-Access road

Figure 13.4.2-2: Wells involved in monitoring

13.4.2.3 Components analysed

Wessling Hungary Kft. (1047 Budapest, Fóti u. 56.) conducting the analyses is an accredited test laboratory registered under number NAT-1-1398/2012. The process of chemical analyses has met the requirements included in the “Quality Management Manual” used by the test laboratory and the specifications of the relevant MSZ EN ISO/IEC 17025 standard.

In the range of studies in the 1st quarter we have conducted our tests for the components included in Annex No.1 of Ministerial Decree 14/2005. (VI. 28.) KvVM on the rules concerning the screening analysis of the cleanup fact finding, according to the monitoring plan:

Inorganic components: pH, specific electric conductivity, fluorid, chloride, nitrite, nitrate, sulfate, phosphate, ammonia, total Cr, Co, Ni, Cu, Zn, Mo, Se, Cd, Sn, Ba, Pb, Ag, As, Hg;

Organic components:

Volatile organic compounds:

- aliphatic hydrocarbons TPH (C5-C9);
- benzene, toluene, ethylbenzene, xylenes and other alkylbenzenes (BTEX);
- halogenated aromatic hydrocarbons (chlorobenzene, dichlorbenzene, trichlorobenzene, bromobenzene, chloronaphtalenes);
- halogenated aromatic hydrocarbons (except: vinyl chloride);
- in the range of other compounds: isopropyl-alcohol, glycols, pyridine, tetrahydrofuran, tetrahydrothiophene;

Non-volatile organic compounds:

- aliphatic hydrocarbons TPH (C10-C40);
- phenols;
- policyclic aromatic hydrocarbons (PAH except: benzo(e)pyrene);
- chlorinated aromatic hydrocarbons (tetra, penta, hexa), chlorophenols
- Pesticides measurable by GC (phenoxyacetic acids, carbamates, triazines)

In case of the additional studies, based on the results in the 1st quarter we have only arranged the analyses for components according to Annex 1 of the KvVM Decree 14/2005 (VI. 28.) on rules relating to the screening of fact finding related to clean up only for inorganic components. In case of organic components, analyses have only been performed for components over the measurement range in the 1st quarter:

Volatile organic compounds:

- aliphatic hydrocarbons TPH (C5-C9);
- benzene, toluene, ethylbenzene, xylenes and other alkylbenzenes (BTEX)-

Non-volatile organic compounds:

- aliphatic hydrocarbons TPH (C10-C40);
- policyclic aromatic hydrocarbons (PAH except: benzo(e)pyrene).

In the samples of the series of tests none of the components’ concentration exceeded the relevant “B” contamination limit (according to Annexes No.2 and 3 of Joint Ministerial Decree 6/2009 [IV. 14.] KvVM–EüM–FVM).

13.4.2.4 Description of factors affecting field groundwater measurements

13.4.2.4.1 Groundwater storage layer

In the Paks Nuclear Power Plant region, groundwater moves in the Upper Pleistocene sediment formations (sand, gravelly sand, sandy gravel) and forms a part of the bank-filtered water resources in the strip along the Danube. The total thickness of the aquifer formations can be estimated at 20-23 meters, the bottom, 7-11 meter thick section is gravelly, but sand dominates in the sedimentary layer above, where the grain size becomes increasingly refined upon moving up. This upper sandy layer is in direct contact with the Danube bed.

The lower gravelly level determines the main conditions of groundwater movement and water storage, the latter's regional average infiltration coefficient is $k = 4 \times 10^{-4}$ m/s.

The regional average infiltration coefficient of top well-graded casting sand is $k = 1{,}5 \times 10^{-4}$ m/s.

The bedrock of the groundwater storage layer consists of an erosional surface of the Zagyva Formation characterized by Upper Pannonian age and fluvial facies. The bedrock is largely made up of pelite-based sediments characterized by poor water conductivity, but sandy interim settlements may also occur locally. In this case, there is a hydraulic connection between the two water types, so we cannot speak of a single aquitard bedrock.

13.4.2.4.2 Relationship between the Danube and groundwater

Within the area, the groundwater forms a contiguous system, the average groundwater level is located in the upper sandy 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. At the time of monitoring works, the Danube water level was 197 cm on March 12th, 300 cm on June 11th, 164 cm on September 19th and 101 cm on October 1st at the Paks watermark post, the water level had dropped by the March, September and October measurements, but had flooded by the June measurement. On December 10th, 2012, the Danube level dropped at Paks, with a water level of 52 cm.

In 2012, the average water level was 176 cm, with a maximum water level of 485 and a minimum of 14 cm. The major flood waves passed down the river in late January and mid-June (when the maximum water level was measured) as well as the very end of December. The lowest water levels were measured in mid-February, in the last third of August, at the end of November and in mid-December. In 2012, the river was characterised in rapid and short periods of water level changes.

In regional terms, it can be said that under average and low water levels, groundwater flows towards the SE with a drop of 2-3 ‰- towards the river bed. In this case, water is replenished from the background, from rainwater infiltrating on the loess plateaus of Mezőföld and vicinity.

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.

13.4.2.5 Evaluation of the field measurement results

During the first measurement campaign, the groundwater level could be measured at a distance of 5.66–10.73 meters from the pipe flanges of the wells, corresponding to an absolute altitude of 89.78–87.45 mBf. In the second measurement series, water levels were located 5.51–10.27 metres under the pipe flange. During measurements in the 3rd quarter, water levels were situated 5.42–10.92 meters from the pipe flange. In the 4th quarter, the groundwater level was at a depth of 5.94–11.58 m from the pipe flange.

The intense water level fluctuation of the Z02 well can be explained on the basis of the small number of measurements (four) and closeness to the Danube by the Danube flow regime and water level fluctuation.

The highest groundwater levels in the wells could be measured during the 2nd quarter, whereas the lowest ones were obtained during the December observations. As a function of distance from the Danube bed, groundwater fluctuation ranged between 0.38–3.89 m.

The flow regime of the R64 confined groundwater well was aligned to that of the groundwater wells, the highest water levels were measured in the 2nd, and the lowest in the 4th quarter. The absolute fluctuation level was 1.15 m.

Even the field test results of the relevant physico-chemical parameters point to the fact - supported even by the monitoring system operating for more than a decade - that the quality of groundwater in the study area is identical to that observed in the average areas. Out of measured water chemistry parameters, the pH value (a water body between pH values of 6.5 to 9.0 is regarded as non-contaminated groundwater) and conductivity ("B"=2500 µS/cm) regulated by relevant limits do not exceed the contamination limit in any of the wells.

		Q1	Q2	Q3	Q4
measured value of groundwater from the pipe flange of wells	m	5.66–10.73	5.51–10.27	5.42–10.92	5.94–11.58
chemical reaction of underground water (pH)		6.8–7.5	7.1–8.0	7.4–8.6	7.8–8.2
transport capacity	µS/cm	<600	<500	500 - 800**	515–1597
dissolved oxygene concentration of groundwater	mg/l	<5	<4*	<4	1.43–5.86l
redox potential values	mV	100	-90 and 150	-60 and 100	-28 and -78

Note:
* except the T21A well, where the dissolved oxygene concentration is 8 mg/l
** (the 1000 µS/cm value is exceeded in the case of some wells: well V219: 1255 µS/cm, well T82: 1156 µS/cm, well C4.1: 1172 µS/cm, well R63: 1217 µS/cm, well Z02: 1401 µS/cm

Table 13.4.2-2: Summary of parameters measured in the groundwater monitoring wells

The highest groundwater levels in the wells could be measured during the 2nd quarter, whereas the lowest ones were obtained during the December observations. As a function of distance from the Danube bed, groundwater fluctuation ranged between 0.38–3.89 m.

The flow regime of the R64 confined groundwater well was aligned to that of the groundwater wells, the highest water levels were measured in the 2nd, and the lowest in the 4th quarter. The absolute fluctuation level was 1.15 m.

We have compared the chemical laboratory test results with the “B” contamination limits specified in Annexes 2 and 2b of Joint Ministerial Decree 6/2009 (IV. 14.) KvVM-EüM-FVM.

Summarising the laboratory test results in the first quarter of 2012, the following statements can be made:

- TPH, BTEX and PAH contamination could not be detected in any of the soil samples analysed
- no halogenised aliphatic and halogenised aromatic hydrocarbons could be detected,
- no fenols, chlorine fenols could be identified in the samples,
- no organic dissolvents and other organic compounds could be detected,
- no pesticide derivatives could be identified in the groundwater,
- Out of metals and semi-metals, cobalt, nickel, copper, zinc, lead and arsenic can be detected in a number of well samples over the "B" limit (in wells Z02, T31, M10, R64)

- Among the general water chemistry parameters assessed the concentration of nitrate and ammonia exceeded in some wells the "B" limit (Points O3, T21, V219, Z02, M10). The maximum concentration overshoot barely exceeded twice the contamination limit.

In view of the results of the analysis made in the second quarter of 2012, including also the results of the first quarter, the following conclusions can be drawn:

- BTEX contamination in the wells was still not measurable,
- Slight amount of PAH impurity can be detected, (wells T31, M10, V219), but the limits were exceeded in minimum extents
- Slight amounts of TPH impurity can be detected in the samples of the R64, T21 and T31 wells (106–155 μg/l), this has raised the possibility of a sampling error
- Out of metals and semi-metals, cobalt, nickel, copper, zinc, lead can be detected in some well samples over the "B" limit (Z02, T73, T31, T82)
- In the Z02 well, the concentrations of cobalt, nickel, lead and copper are multiples of the "B" value exceeding the threshold, moreover, the latter has increased significantly in comparison with the first measurement (twice the limit);
- Among the general water chemistry parameters assessed the concentration of nitrate and ammonia exceeded in some wells the "B" limit (Points O3, T21, Z02, M10, C4.2);
- In the M10 well, the measured value of ammonium concentration is above the relevant limit in both measurement, the measured value in the second measurement was the triple of the first value. This may indicate the presence of contaminating sources (e. g. defective sewer);

In view of the results of the analysis made in the third quarter of 2012, including also the results of the previous quarters, the following conclusions can be drawn:

- TPH, BTEX, PAH contamination could not be detected in the water samples of the wells;
- Out of metals and semi-metals, cobalt, nickel, copper, zinc, lead can be detected in some well samples over the "B" limit (Z02, C1.2, T31);
- In the Z02 well the concentrations of cobalt, nickel, lead and copper are multiples of the "B" value exceeding the threshold;
- In the C1.2 well copper appeared as a new element compared to the previous measurements, moreover, it is rather high (five times the limit);
- In the M10 well, the ammonium level was well above the limit in all three measurements, which suggests the presence of a constant source of pollution close to the sampling point. Similarly to the M10 well, the reasons for high and rising levels ammonium contamination detected in the C4.2 well in the second and third measurement will have to be researched and explored after the fourth measurement.

In view of the results of the water sample analysis made in the fourth quarter of 2012, including also the results of the previous quarters, the following conclusions can be drawn:

- In the water samples in some wells (T21, M10, V219), PAH components could be again detected in concentrations exceeding the "B" contamination limits. Limit overshoots may even be at a 4- or 5-fold extent. TPH and BTEX contaminants could still not be detected;
- Except for molybdenum, toxic metal impurities (cobalt, nickel, copper, lead) could be only detected in the water samples of the Z02 well in the 4th quarter, but the concentration of contaminants has decreased to a certain degree. This metal contamination is most likely caused by the sludge basin.
- The high copper concentration measured in the 3rd quarter had disappeared in the C1.2 well, the measured value was below the detection limit (<0,5 μg/l).
- In the sample from the R64 confined groundwater well, a minor molybdenum contamination could be detected.
- In the M10 well, the ammonium concentration was high throughout the year (2012), about four times the "B" contamination limit. This proves the presence of a permanent contamination source in the vicinity of the sampling point. No ammonium contamination could be detected in the C4.2 well.

- In the 4th quarter, the nitrate concentration exceeded the contamination limit at the O1, O3 and Z02 points. However, the exceedances were not too high.

During monitoring studies, contaminations exceeding the relevant "B" contamination limits could be detected in water samples of a total of 15 wells. There were altogether 3 wells (O3, Z02, M10) where upon each sample collection, at least one assessed component's concentration exceeded the respective "B" contamination limit. Water contamination was caused by general water chemistry components (nitrate ion, ammonium ion), toxic metals and semi-metals (cobalt, nickel, copper, zinc lead, arsenic, molybdenum) as well as certain PAH components (phenantrene, benzo[a]pyrene indenol[1,2,3-cd]pyrene, benzo[a]anthracene, chrysene, benzo[b]fluranthene.

Upon review of the study results it can be concluded in general, that organic components in underground water could only be detected in small concentrations for some PAH components in uneven regional distributions (T21, T31, M10, V219 wells). The temporal distribution of PAH concentrations is highly variable, so we believe, no permanent contaminating source should be anticipated in the vicinity of wells.

In the 2nd quarter, the minimal TPH contamination detected in the R64, T21 and T31 wells (106–155 μg/l) could be presumably caused by a sampling/analytical error because concentrations less than the detection limit (50 μg/l) of the analytical method applied before and after that data were measured. No such technology or structure can be found in the vicinity of these wells from which hydrocarbon contamination could be considered likely.

Permanent toxic metal impurities in higher concentrations could only be detected in the vicinity of the sludge ponds (Z02 well). In the samples of the T31 well, the concentrations of copper and zinc were high in the first three quarters, no contaminants could be detected in the 4th quarter.

In the groundwater samples of the O3 and the Z02 wells, high nitrate concentrations were found in the whole study period. I the groundwater of the M10 well, high ammonium ion concentrations were measured throughout, this may also indicate a failure of the nearby sewer.

Based on the results of sampling and chemical analysis carried out in 2012, it can be concluded that in the sampling points, no such level of contamination can be detected on the basis of which any other intervention would be warranted in the area apart from monitoring activities currently conducted. Contamination detected is most certainly spot-based, limited to the immediate vicinity of the wells in question, but the stratum origin of this measured contamination cannot be ruled out, either (e. g. arsenic). The ammonium and nitrate contamination detected among inorganic contaminants can be most certainly associated with the wastewater utilities in the area and their related leaks.

13.4.2.6 Joint evaluation of soil and groundwater contamination measured in 2012

We could perform the joint evaluation of soil and groundwater contamination in those places where soil sampling points were relatively close to a tested monitoring well.

These sites were in the investment area as follows:

- groundwater wells C4.1, C4.2 and drilling TB-12;
- groundwater well T21 and drilling TB-2;
- groundwater well C1.2 and drilling TB-31;
- confined groundwater well R64 and drilling TB-36;
- confined groundwater well R63 and drilling TB-6;
- groundwater well C2.2 and drilling TB-17.

At the above locations in the investment area, no contaminations could be detected in the soil exploration drillings with respect to the components studied. In the water samples of the C4.2 well, the ammonium concentration in groundwater was slightly high in the 2nd and 3rd quarter of 2012. At the T21 point, slightly high nitrate and PAH (phenanthrene) concentration occurred in the groundwater periodically. In the water wells of the C1.2 well, an exceptionally high copper content was measured once (3rd quarter) where in the other cases, copper in the groundwater was barely detectable. The anomaly was probably caused by a sampling problem. In the sample of the R64 confined groundwater well, negligible levels of molybdenum contamination were detected in the 4th quarter. No contaminations could be detected at any time from the samples of the R63 confined groundwater well and the C2.2 groundwater well.

No correlations between the soil and groundwater contamination status could be established in the investment area.

Comparisons can only be made in just two sites outside the investment area, these are the hazardous waste collection site and the sludge pond basins (northern foreground).

- T-2 and T-3 exploration wells (vicinity of hazardous waste collection site);
- Z02 groundwater well and T-7 exploration well (sludge pond areas).

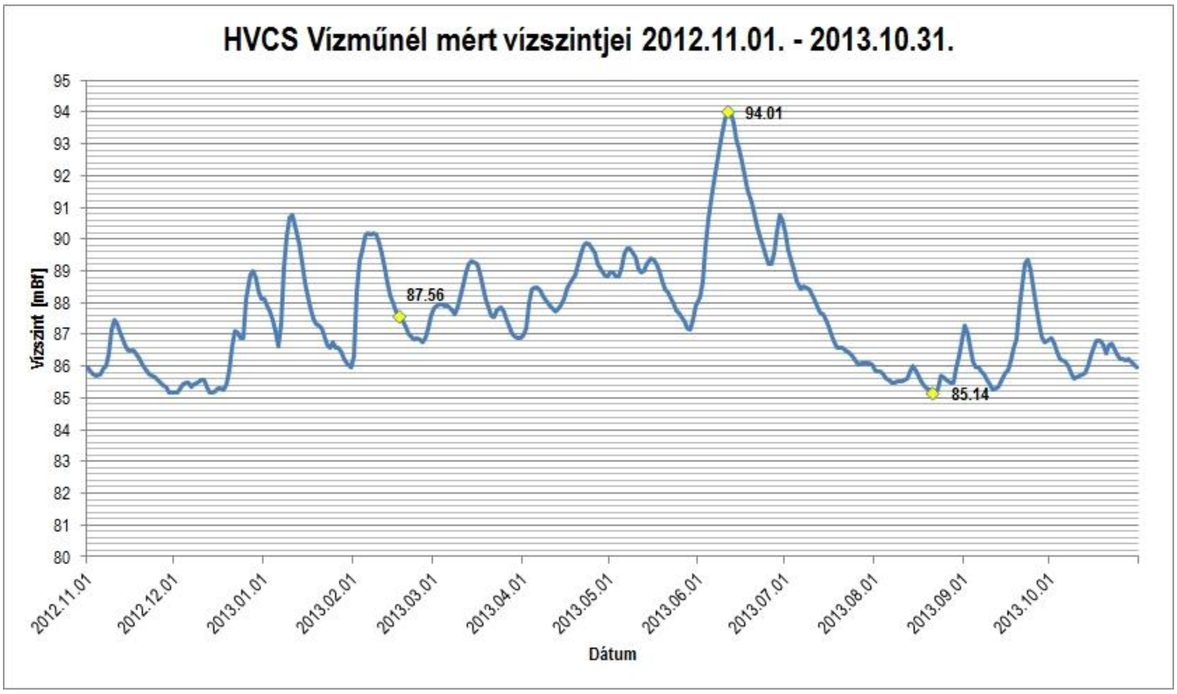
Samples from exploratory soil drillings in the vicinity of the hazardous waste collection site did not show any contamination. In the northern foreground of sludge ponds, in the subsurface soil sample obtained from the T-7 drilling (0.8 m), a minimum indication of toluene occurred, whereas at a depth of 5.5, low concentrations of barium and nickel impurities were detected. Throughout the relevant analyses, major nitrate and toxic metal contaminants were measured in the groundwater samples of the Z02 well. No direct correlation can be found between the soil and groundwater contamination.

13.4.3 HYDROLOGICAL MODELLING OF UNDERGROUND WATER ON THE SITE

The complex groundwater and confined groundwater flow model studies as well as the analysis of the spread of the most mobile related radioactive material, namely, tritium (^3H) has 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 input parameters of the hydrological site model were provided by data measured in the period between 01/11/2012 and 31/10/2013 [13-5]. We have chosen the given year because average, low and high Danube water levels had equally occurred in that period. Another criterion was to be able to demonstrate hydrological processes in the vicinity of the site with the latest data. Input parameters were as follows:

- Danube and HVCS water level at the site.
- Lake Kondor water level,
- water levels of on-site monitoring wells,
- precipitation data measured in the vicinity of the site,
- tritium activity concentration values of on-site monitoring wells,

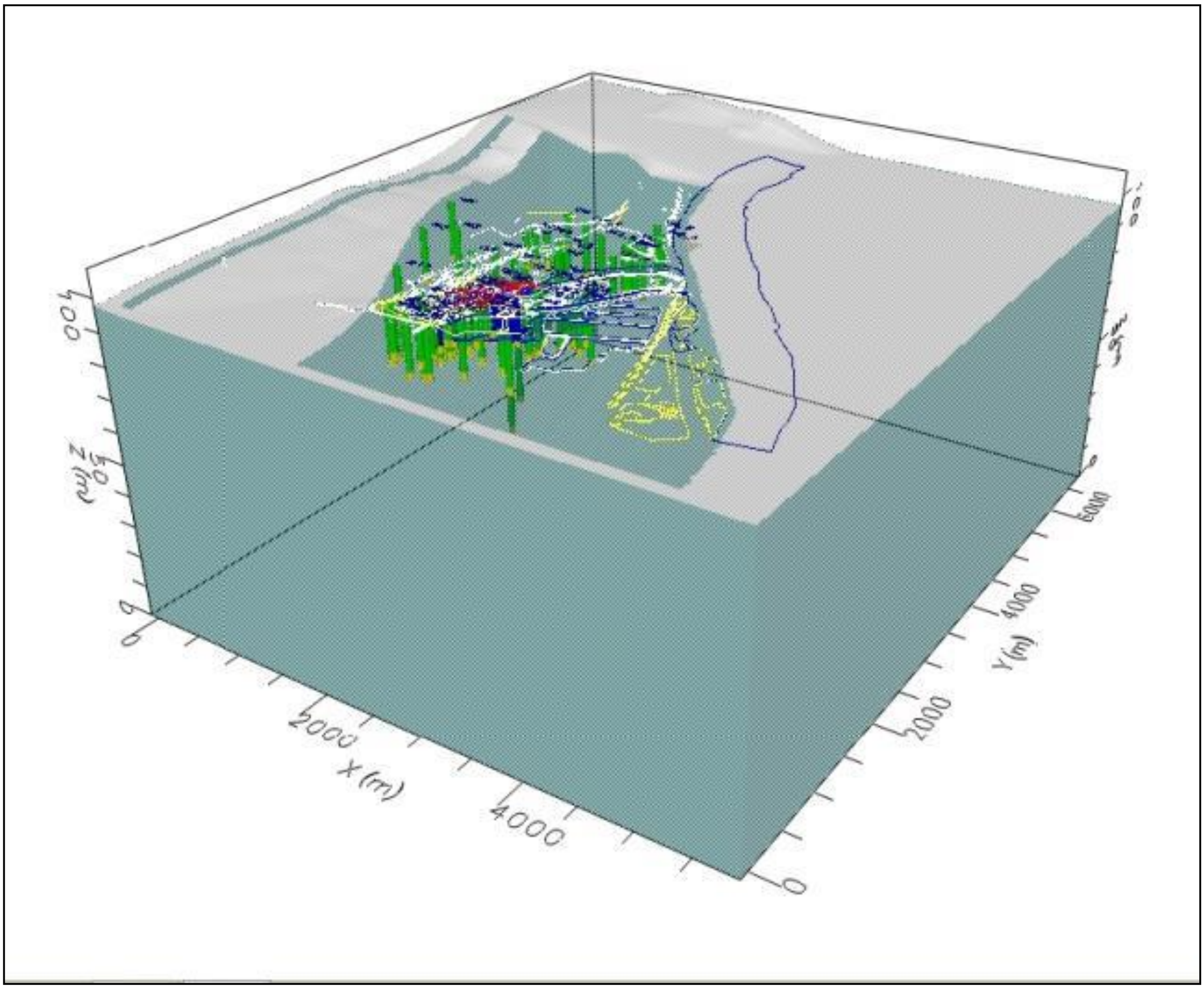


HVCS Vízműnél mért vízszintjei 2012.11.01 – 2013.10.31 - Water levels measured at HVCS Water Works between 11/01/2012 and 31/10/2013
Vízszint [mBt] - Water level [mBt]
Dátum - Date

Figure 13.4.3-1: Water levels measured at the cold water canal in the examined period

Monthly precipitation [mm]	
November	25.7
December	51.9
January	44.3-
February	83.7
March	131.9
April	33.2
May	85.7
June	41.5
July	32.3
August	15.6
September	62.2
October	38.3

Table 13.4.3-1: Monthly precipitation in the site



Note:
Major structures shown in the figure: green columns: groundwater monitoring wells (the yellow columns below show the screening locations), blue colour: base map contour bordering on surface waters, white line: plant area, yellow line: contours of major structures not belonging to the power plant area, blue spots: groundwater monitoring wells, red lines: underground effluent lines.

Figure 13.4.3-2: Model space created during the test

We have used 20 layers in the model, and the smallest cell division corresponds to 7-8 meters.

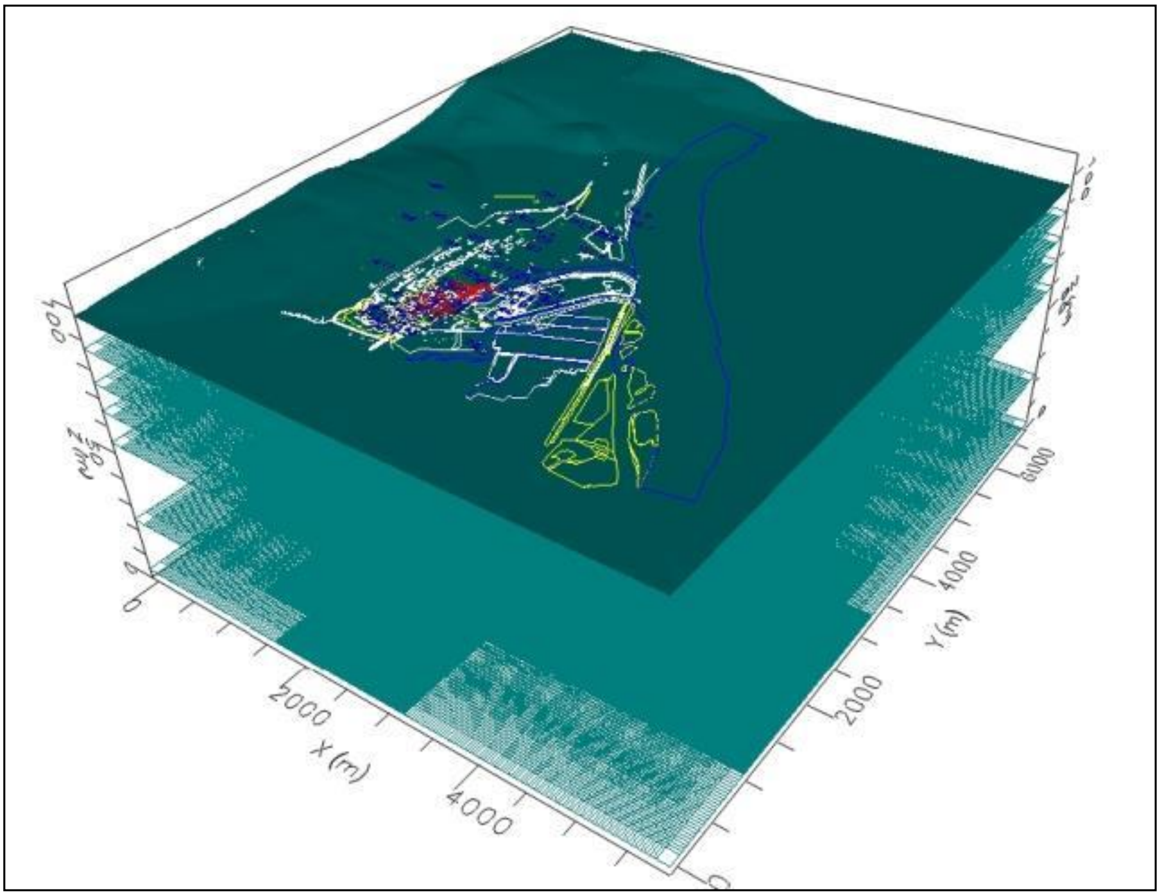


Figure 13.4.3-3: Layer structure created during the test

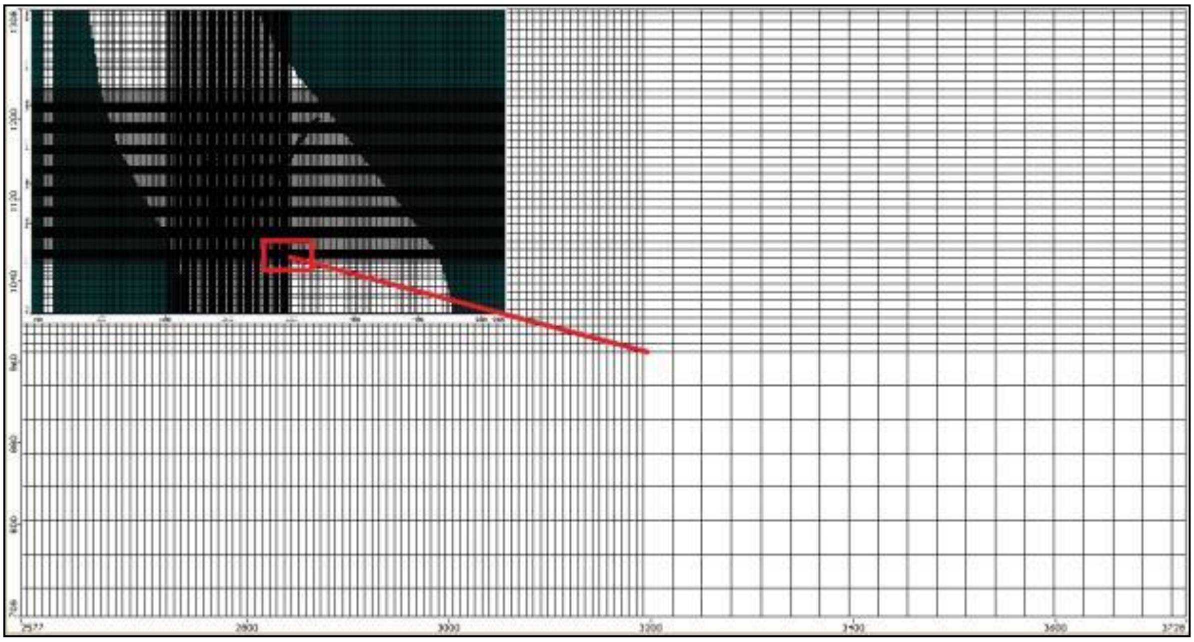
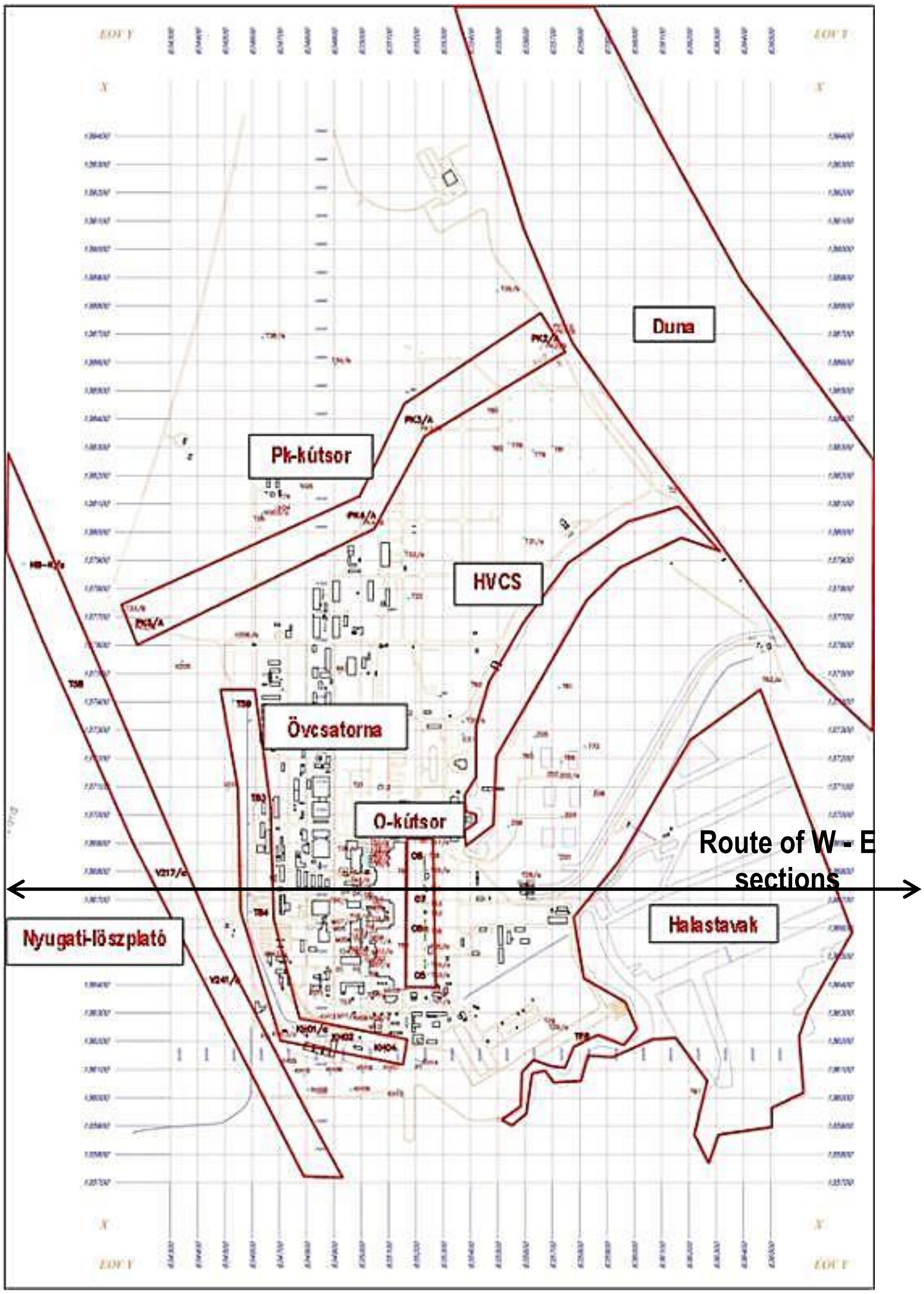


Figure 13.4.3-4: Cell structure of the grid created during the test

For the run, we defined boundary conditions (head boundaries) as follows: the PK battery of wells in the north, the Danube and the HVCS in the east, Lake Kondor and the fish -ponds in the south as well as the diversion ditch and the western loess plateau on the west. The findings obtained from the model are valid in an area enclosed by these boundary conditions (head boundaries).



Ny – K irányú szelvények-West-east sections
Duna-River Danube
Pk-kútsor-Pk-battery of wells
HVCS-Cold water canal
Övcsatorna-Diversion ditch
O-kútsor-O-battery of wells
Nyugati löszplató-Western loess plateau
Halastavak-Fish-ponds

Figure 13.4.3-5: Location of boundary conditions (head boundaries) developed during modelling

We have used the Visual MODFLOW program applying the finite difference method to define the flow of underground water. The program allows static (constant in time) and dynamic (changing in time) analysis of the vicinity of the site. We have obtained the input data of each dynamic scenario from the previously run static model result. Saturated and unsaturated zones are managed by separate modules. We have run the saturated zone, the level of which depends on the precipitation prevailing in the given hydrologic half--year and the Danube water level by using the MODFLOW 2000 module. The unsaturated zone is located above the latter and has been handled by the SURFACT module.

To build the hydrologic model, we also needed the following:

- geometry of layers,
- hydraulic infiltration parameters of the relevant layers (infiltration coefficient, effective porosity, specific storage capacity, specific yield, dispersion coefficient and diffusion coefficient).

Zone	Kx [m/s]	Ky [m/s]	Kz [m/s]
1	0.0003	0.0003	0.00009
2	0.000035	0.000035	0.0000035
3	0.00013	0.00013	0.000018
4	0.0006	0.0006	0.0005
5	0.00000048	0.00000048	0.000000008
6	1.8	1.8	1.8
7	0.00000005	0.00000005	0.000000005
8	0.00009	0.00009	0.000013
9	0.0001	0.0001	0.000015
10	0.00012	0.00012	0.000017

Note:
We have also introduced some ranges characterised by an extreme high infiltration coefficient (Kxyz =1.8 m/s) in the immediate vicinity of "constant heads". This is advisable because upon specifying boundary conditions, the levels of the top layers have shifted and become embedded in the underlying layers. Therefore, in the immediate vicinity of boundary conditions (head boundaries), the conductivity of the lower range can be unrealistic. By introducing extremely high conductivity, the adjacent layers characterized with real conductivity can detect the change in boundary conditions more rapidly.

Table 13.4.3-2: X,y, z components of infiltration coefficients applied in the model

Zone	Ss [1/m]	Sy	Eff. Por.	Tot. Por.
1	0.0005	0.25	0.15	0.25
2	0.005	0.25	0.3	0.33
3	0.0005	0.24	0.28	0.3
4	0.0005	0.22	0.26	0.3
5	0.0005	0.15	0.26	0.28

Note:
Ss (Specific Storage): Specific storage capacity Unit volume of water released as a result of a unit change in pressure divided by the volume of the aquifer originally containing the water. (Storage coefficient/vertical layer width)
Sy (Specific Yield): Specific yield Ratio of the recoverable water volume and the total rock volume In case of sandy soil, it is a value close to, equal to or less than the effective porosity.
Total porosity: In a porous medium, the ratio between the pore volume and the overall volume (Void volume).
Effective porosity::A ratio between the volume of the pore space involved in water movement and the overall volume.

Table 13.4.3-3: Other hydraulic infiltration parameters.

By using data for the above-named period, we have studied the distribution of the groundwater table and the velocity space and particle trajectories emerging in the saturated zone during typical low medium and high water levels in the Danube.

The water levels of the cold water canal fluctuated between 85.14 and 94.01 mBf in the examined period. There were such high flood waves in January, February and June which blocked the flow towards the HVCS and the Danube or during which backwater occurred towards the power plant area.

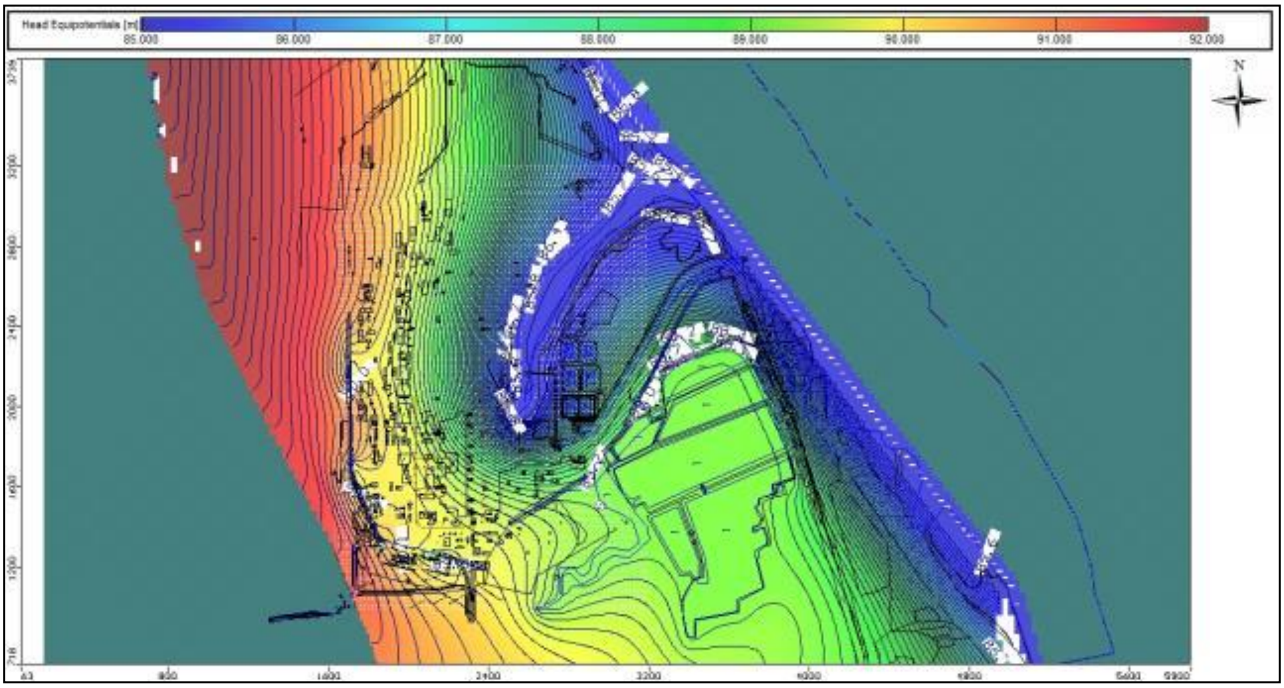


Figure 13.4.3-6: Contour map of the groundwater table on 22/08/2013 in the event of low water level in the Danube (85.14 mBf)

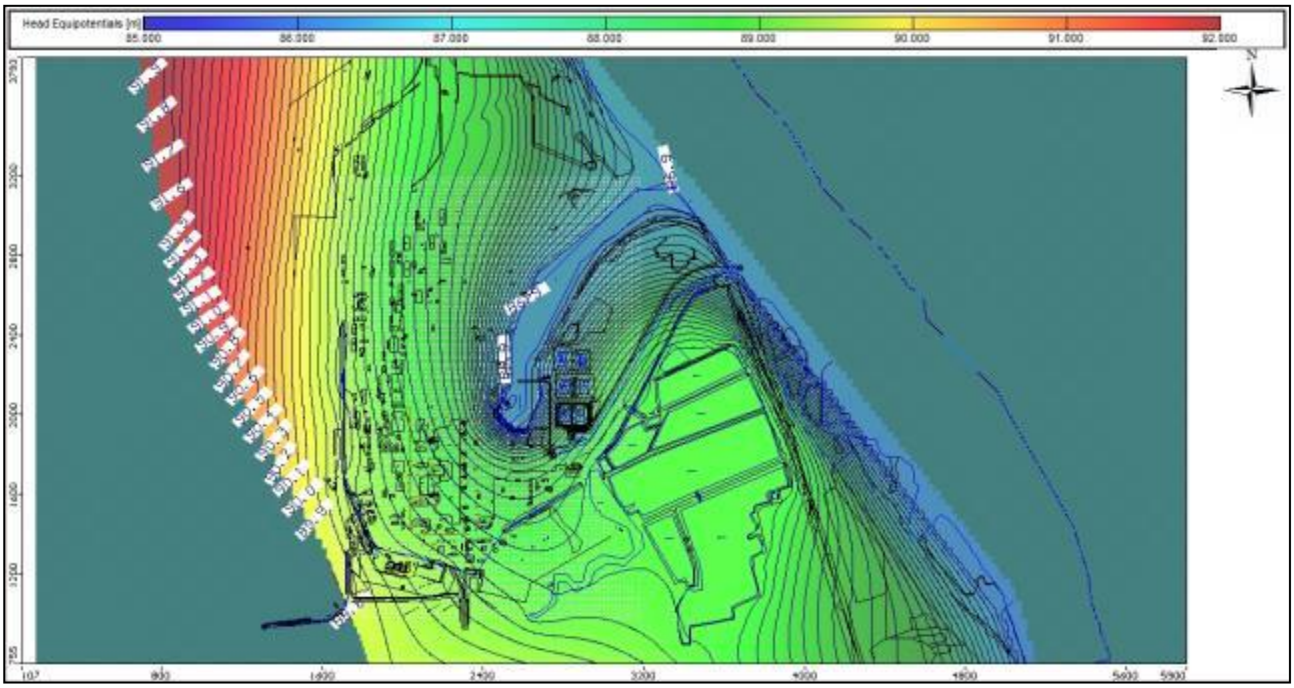


Figure 13.4.3-7: Contour map of the groundwater table on 17/02/2013 in the event of medium water level in the Danube (87.56 mBf)

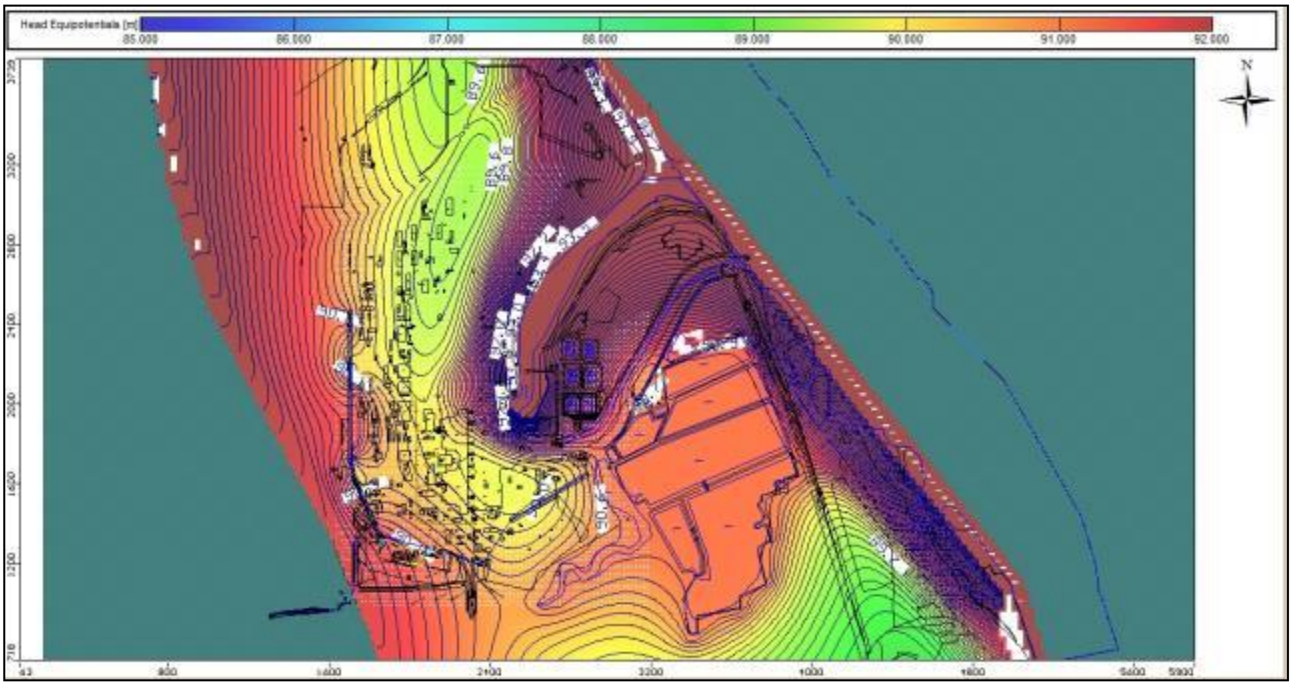


Figure 13.4.3-8: Contour map of the groundwater table on 11/06/2013 in the event of high water level in the Danube (94.01 mBf)

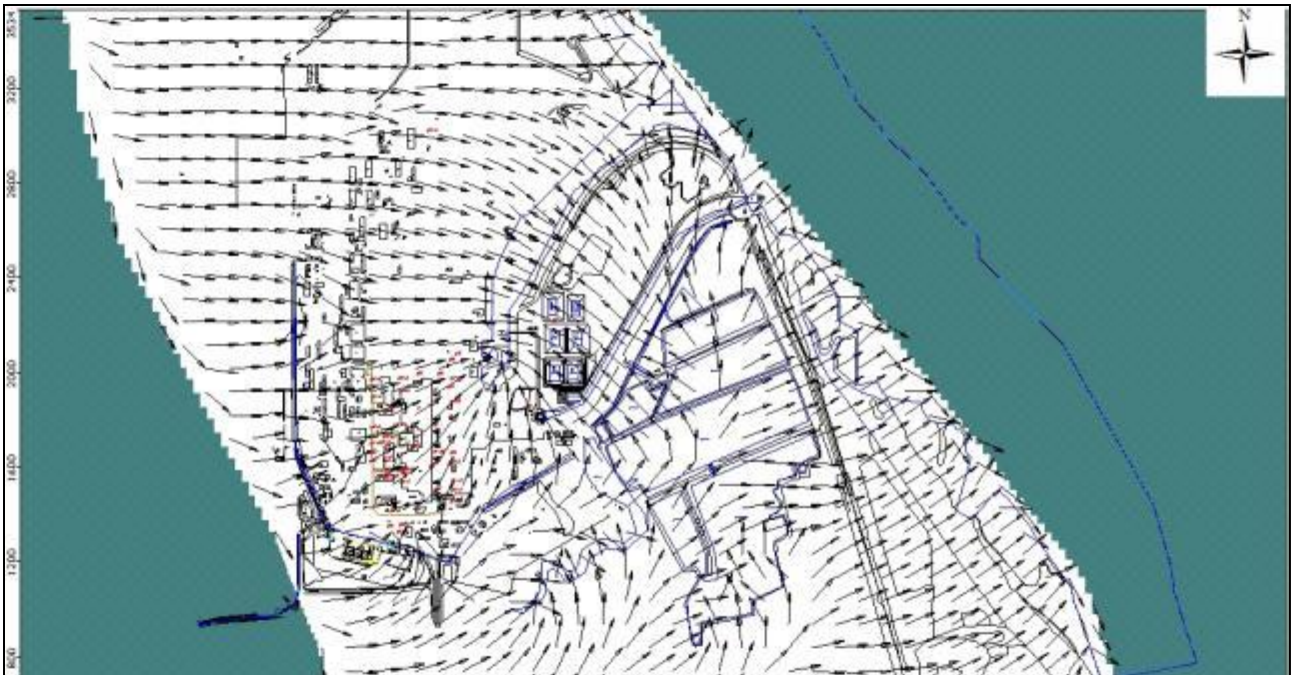


Figure 13.4.3-9: Developments in the direction of flow on 22/08/2013 in the event of low water level in the Danube (85.14 mBf)

Figure 13.4.3-10: Developments in the direction of flow on 17/02/2013 in the event of medium water level in the Danube (87.56 mBf)

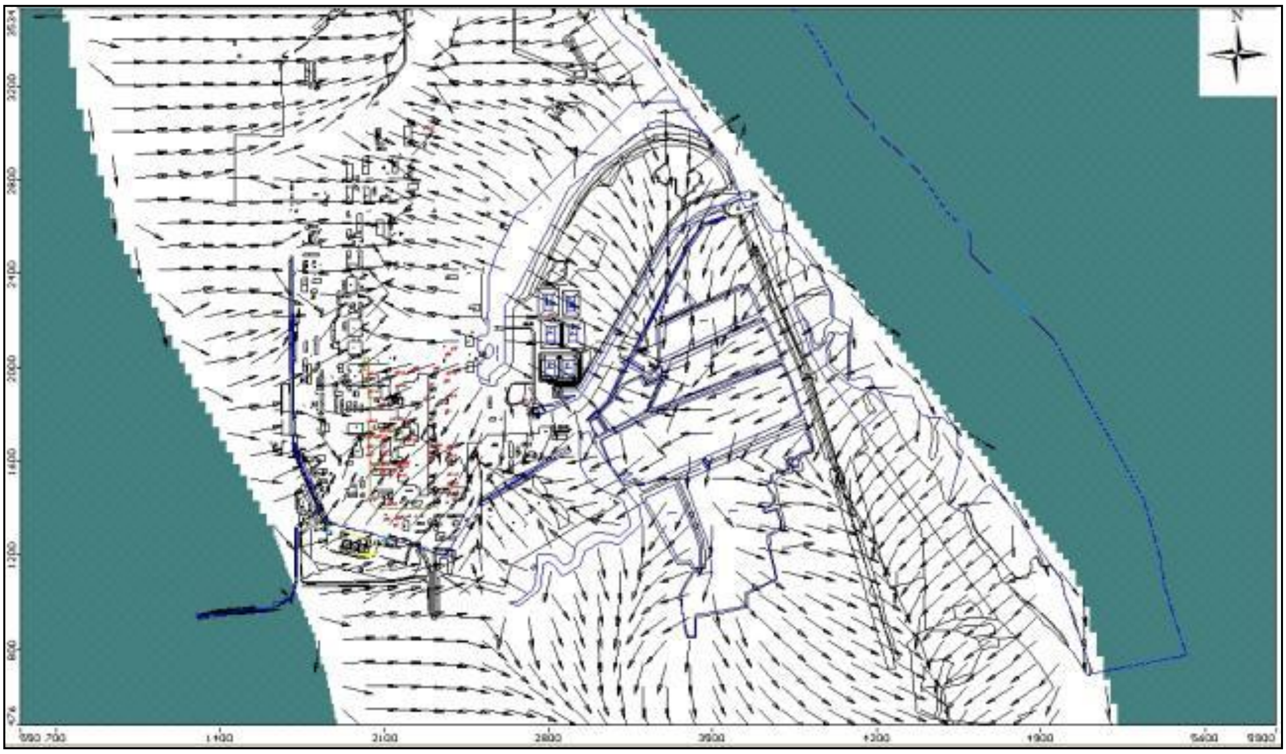
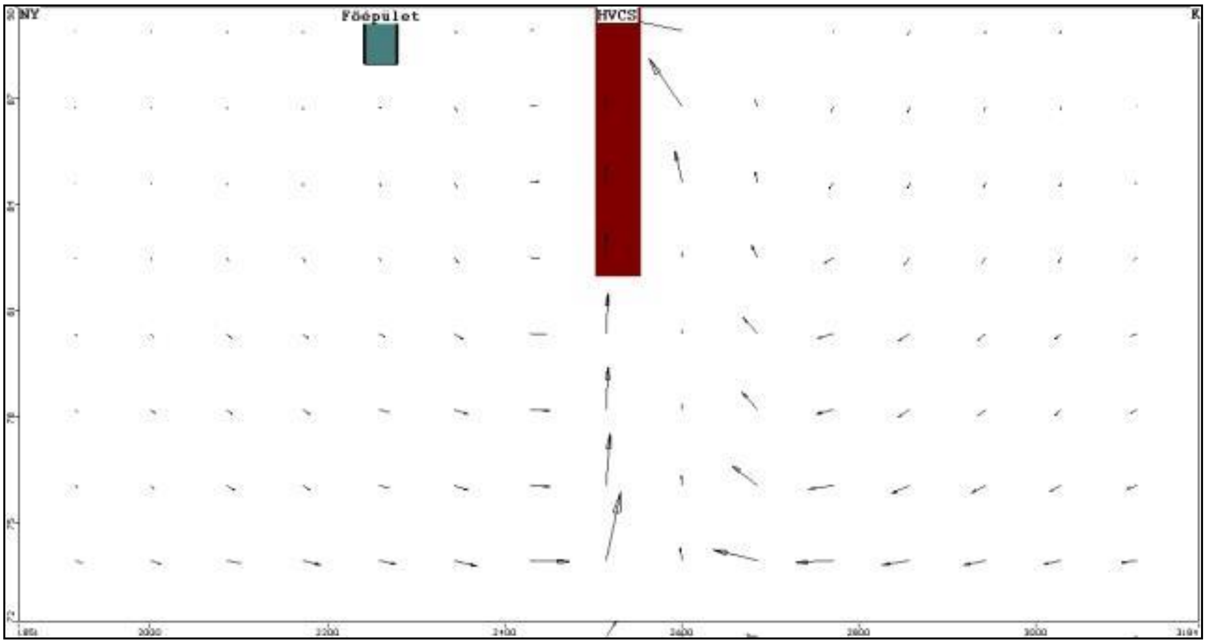


Figure 13.4.3-11: Developments in the direction of flow on 11/06/2013 in the event of high water level in the Danube (94.01 mBf)

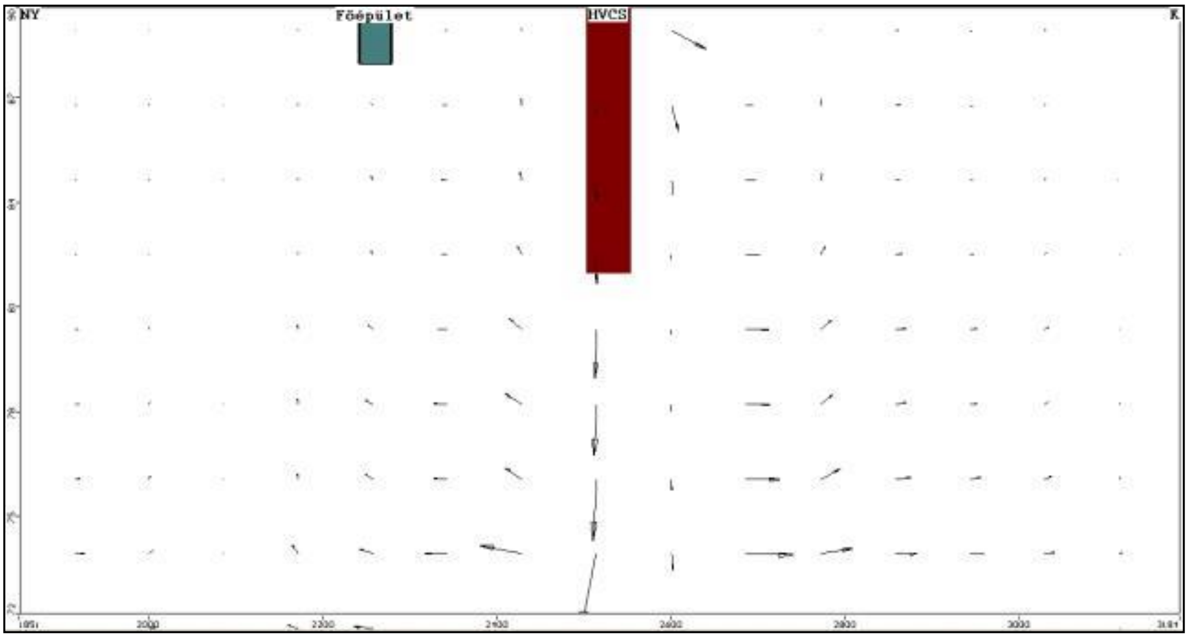
From the velocity space giving an overall characterisation of the area, it is apparent that:

- 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 had evolved (southern) during the entire examined period.



Főépület-Main building
HVCS-Cold water canal

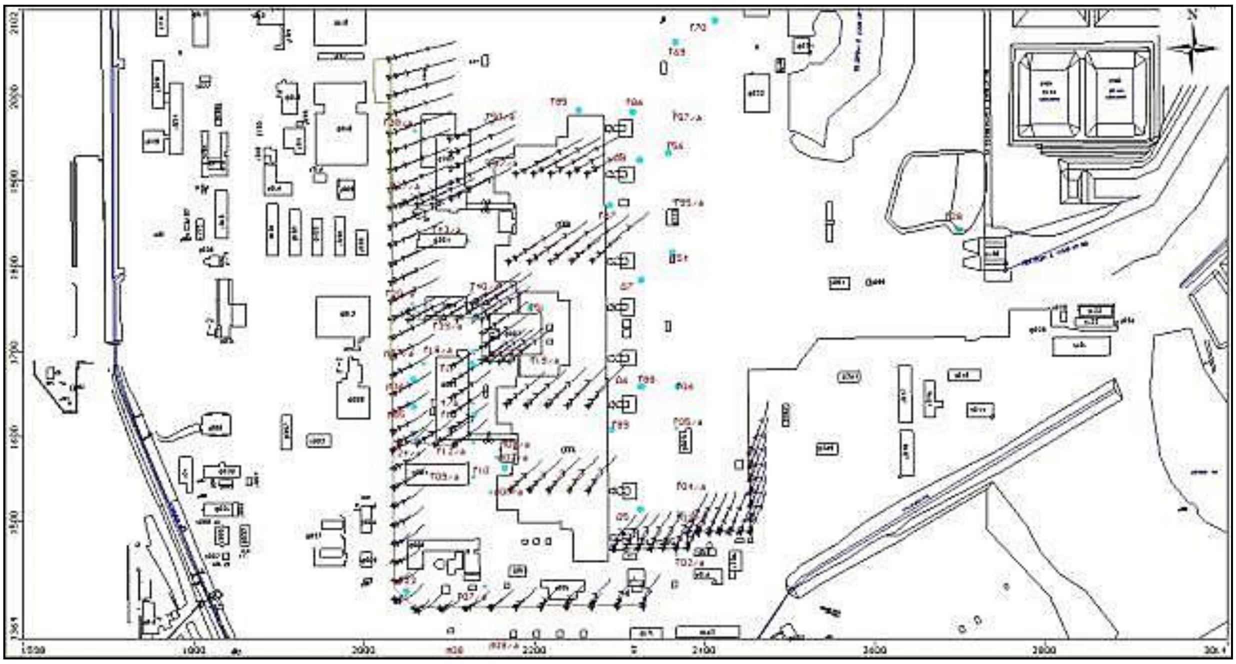
Figure 13.4.3-12: Velocity space forming in the vicinity of the main building and the HVCS in case of low water level in the Danube



Főépület-Main building
HVCS-Cold water canal

Figure 13.4.3-13: Velocity space forming in the vicinity of the main building and the HVCS in case of high water level in the Danube

By comparison of maximum velocities it can be stated that the lowest velocity had evolved during medium Danube levels, Vmin = 7,7E-6 m/s. The highest velocities were seen during minimum Danube water levels, Vmax = 1,6E-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 up to 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 in the examined period.



Note:
The markers represent the distance travelled in 100 days.

Figure 13.4.3-14: Path of water particles launched from the assumed sources.

The time-varying velocity space forces the particles in the given layer to travel on special paths. We have launched the relevant paths from potential sources (sewer system bordering on the main building unit on the west, the auxiliary buildings, units and the TM55 line). 72 – 150 days are required to travel 100 meters under the given circumstances.

13.4.3.1 Evaluation of the mutual impact of the groundwater and surface water

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 is 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 law 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 fishponds the sink components.

13.4.3.2 Results of modelling the unsaturated zone

We have used a separate module of the program (Surfact) to model the unsaturated zone. This module only takes into account the upper, more densely distributed layer, so we have created a simplified model space in order to shorten the time for calculations.

We have distinguished between the following four cases to characterize the velocity spaces emerging in the case of extreme Danube water levels in the unsaturated zone, using steady-state calculations.

- Extremely low Danube water level, taking into account the impact of the fish ponds and the diversion ditch.
- Extremely low Danube water level, disregarding the impact of the fish ponds and the diversion ditch.
- Extremely high Danube water level, taking into account the impact of the fish ponds and the diversion ditch.
- Extremely high Danube water level, disregarding the impact of the fish ponds and the diversion ditch.

It was advisable to separate the four cases in order to be able to illustrate the interaction between certain natural (fish ponds, Danube, loess plateau) and artificial (diversion ditch, HVCS) boundary conditions and the groundwater.

The outcome of processes characteristic of each case are described below.

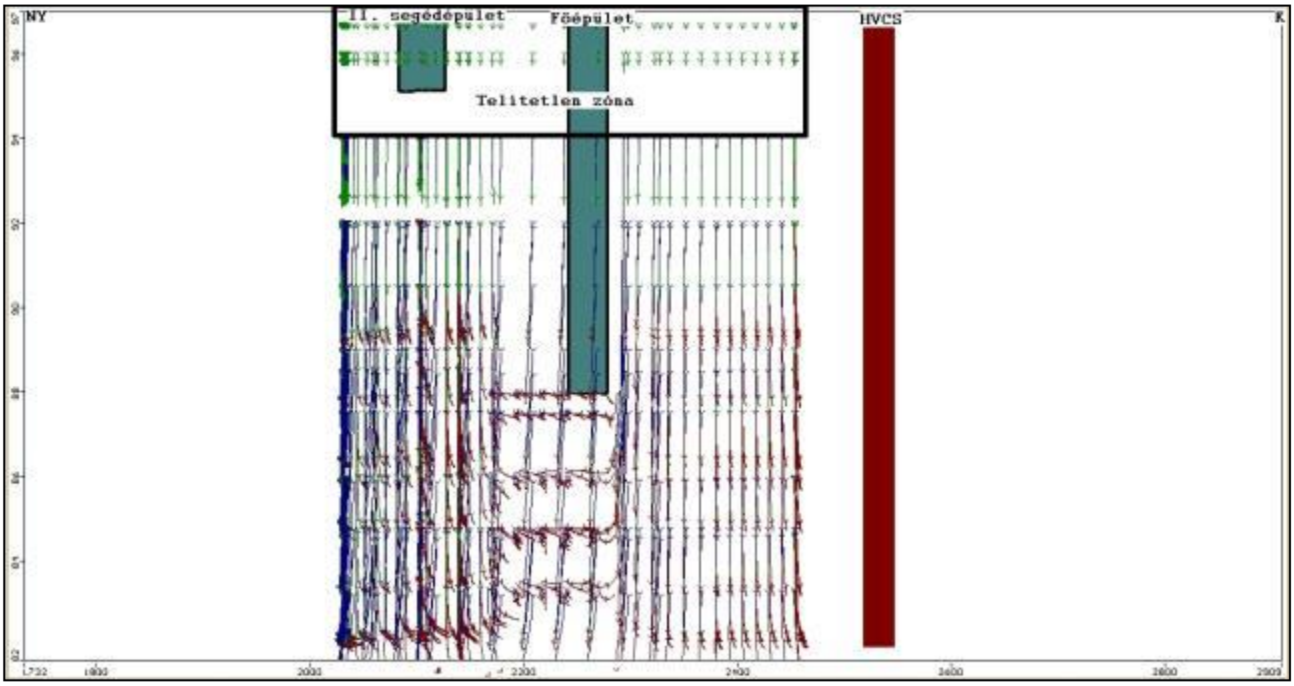
In case of extremely low Danube water levels, taking into account the impact of the fish ponds and the diversion ditch, the Danube and the HVCS function as sinks, while the ponds function as sources.

In case of extremely low Danube water levels, disregarding the impact of the fish ponds and the diversion ditch, a stronger flow develops towards the Danube and the HVCS. From a large part of the model area, flow rather occurs towards the HVCS, while the Danube only absorbs groundwater from the southern quarter of the area.

In case of extremely high Danube water levels, taking into account the impact of the fish ponds and the diversion ditch, a slow-moving velocity space is formed in the north, which speeds up when reaching the diversion ditch and in this case, the latter represents the sink component on the west. A slow-moving velocity space develops south of the HVCS, as well. In the east, the Danube and the HVCS can be defines as sources, and the fish ponds represent the sink components.

In case of an extremely high Danube water level, ignoring the impact of the fish ponds and the diversion ditch, a strong flow backward to the loess plateau can be observed since there is no natural or artificial barrier or sink which would absorb the flow of groundwater. In this case, the Danube and the HVCS are represented as source components.

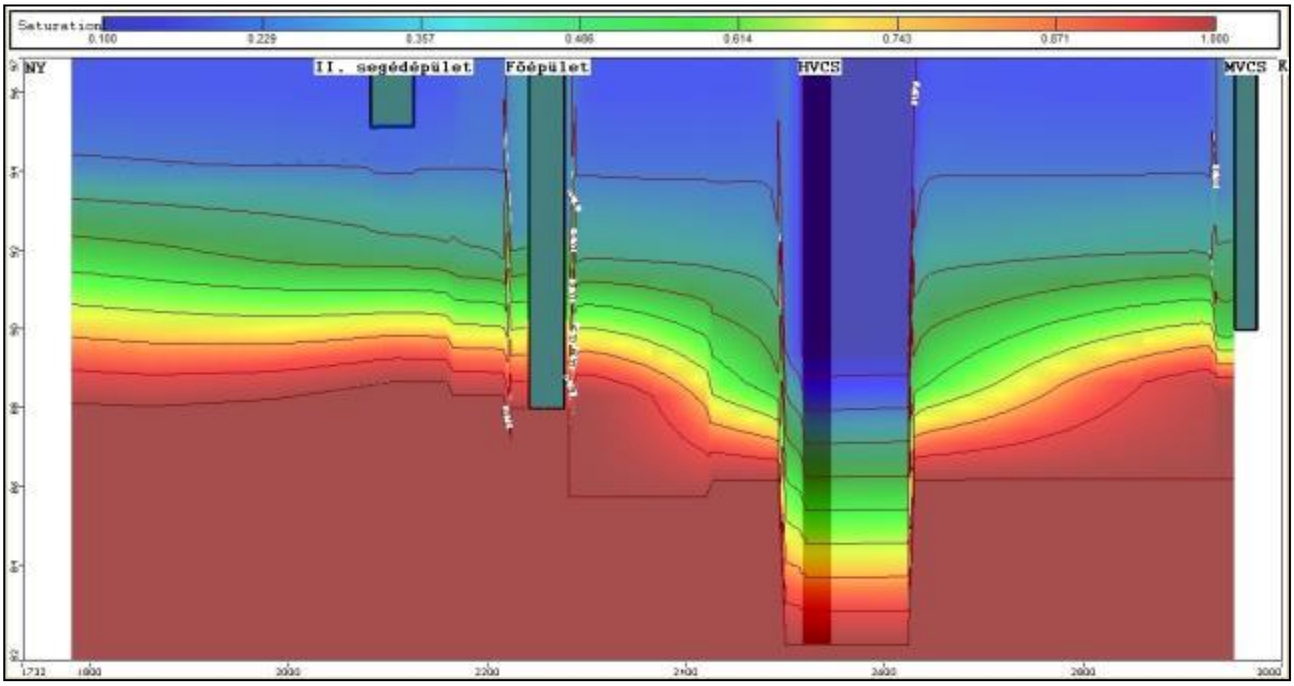
Vertical displacements are obtained in the unsaturated zone. The velocities are several orders of magnitude smaller than those in the saturated zone.



Note:
The markers represent the distance travelled in 100 days.

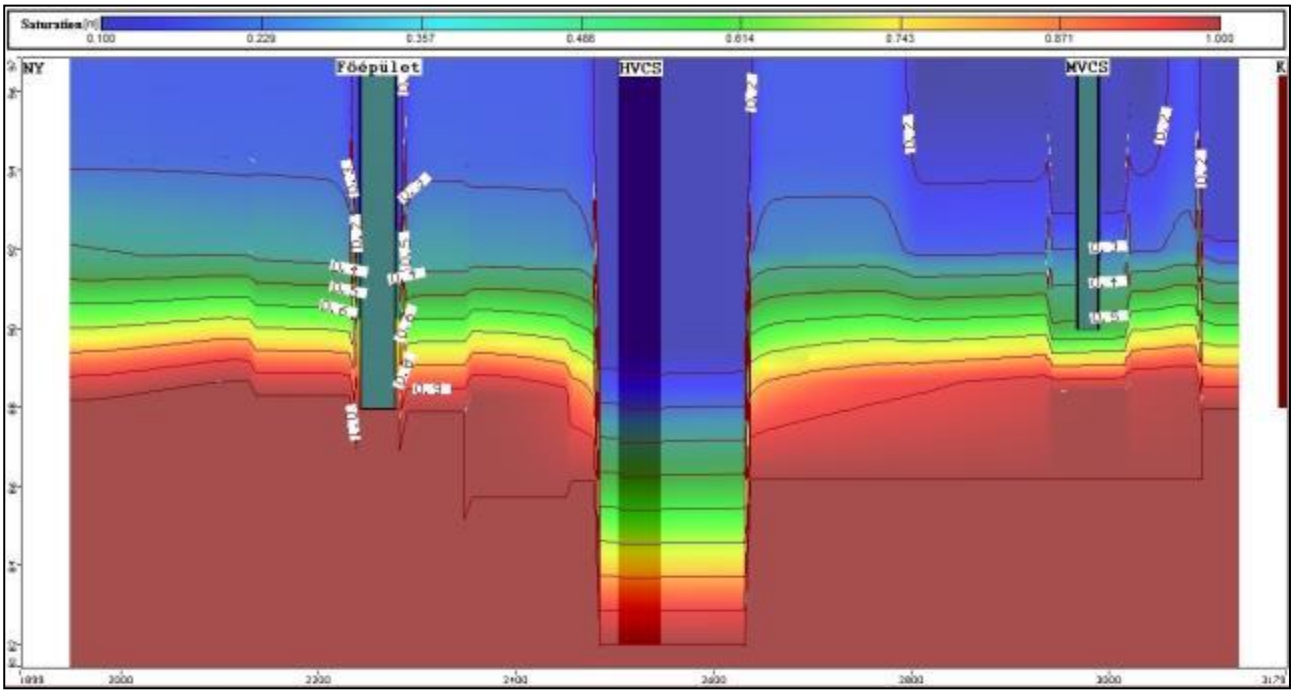
II. segédépület-Auxiliary building II
Főépület-Main building
HVCS-Cold water canal
Telítetlen zóna-Unsaturated zone

Figure 13.4.3-15: Paths of particles located in a saturated/unsaturated zone



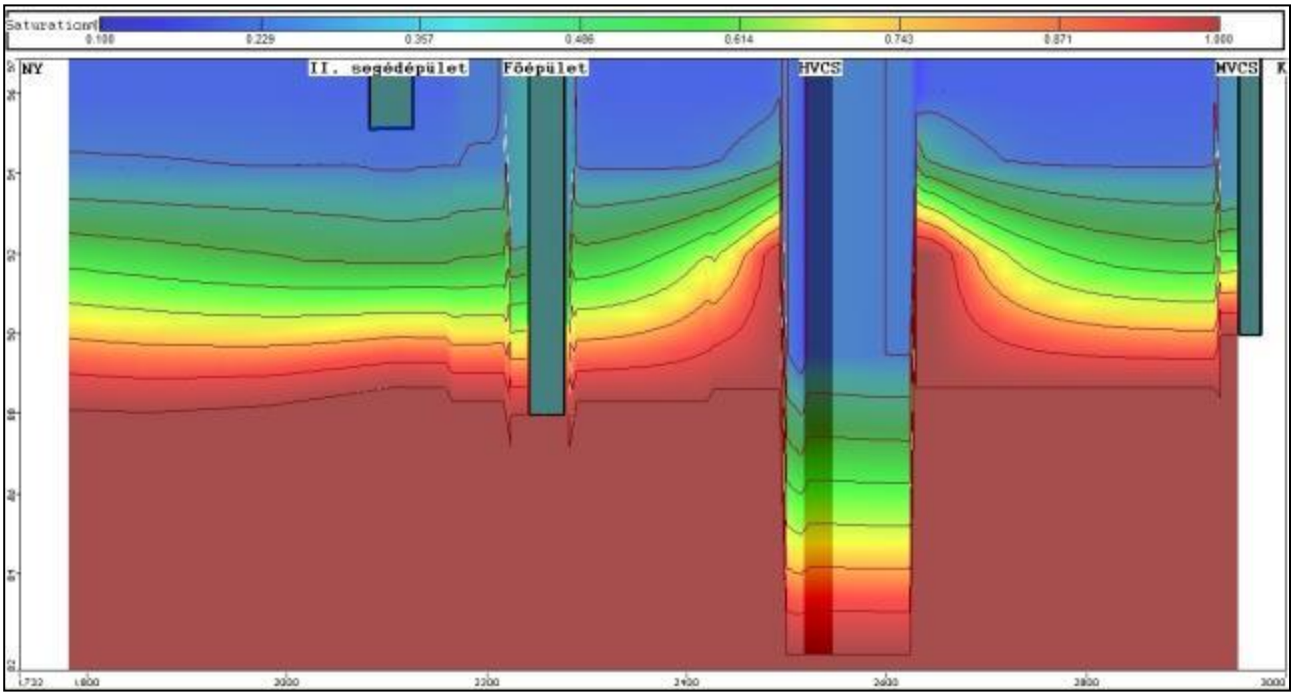
II. segédépület-Auxiliary building II
Főépület-Main building
HVCS-Cold water canal
Telítetlen zóna-Unsaturated zone

Figure 13.4.3-16: Vertical image of an unsaturated (three-phase) zone in case of low Danube water level



Főépület-Main building
HVCS-Cold water canal

Figure 13.4.3-17: Vertical image of an unsaturated (three-phase) zone in case of medium Danube water level



II. segédépület-Auxiliary building II
Főépület-Main building
HVCS-Cold water canal

Figure 13.4.3-18: Vertical image of an unsaturated (three-phase) zone in case of high Danube water level

The curves take a value in the interval between 0.1 and 1. The value 1 represents the boundary of the saturated-unsaturated zones whereas saturation is lowest in case of a 0.1 value (the value 1 represents full saturation, i. e. the pore volume is completely filled by water and a smaller value represents the extent of saturation). Consistently with earlier analyses, the results show wetting - drying in the unsaturated zone.

In line with fluctuations of the Danube water level, upward and downward flowing cycles alternate in the unsaturated zone. Consequently, the impact of a previous emission in the unsaturated zone can be detected in the fluctuating values of tritium activity concentrations measured in individual monitoring wells

The clearance of particles (tritium) exiting to the unsaturated zone can be characterized jointly by the movements oscillating in the vertical direction as well as a downward and horizontal direction respectively, on the basis of dynamic calculations in line with the flood waves.

The process takes place according to the following unit diagram.

- Oscillating movement in the unsaturated zones.
- Velocity increases in the lower layers and an outflow from the lower layers takes place.
- The developing concentration gradient drives tritium from the upper, less saturated layers to the lower, more saturated ones.

Fractures developing in the saturation curves in vicinity of the main building can be attributed to the perturbation effects of the relevant structure (main building), while the same fractures in the vicinity of the HVCS can be ascribed to the drainage and backwater effects of the channel.

13.4.3.3 Validation

We have verified the correctness of the relevant results. We have compared the calculated values with numerous measured water levels measured in the tested period (01/11/2012-31/10/2013).

In case of wells for which the input data were used as basis for creating the "constant head" levels, we have obtained total agreement of water levels. For example, there is full agreement in case of the PK2, PK3, PK4, PK5, T59, T83, T84, KH01, KH02, KH04, O5, O6, O7, O8, HVCS-waterworks levels. As regards water levels calculated the results are entirely convincing, that is the model can be considered as validated.

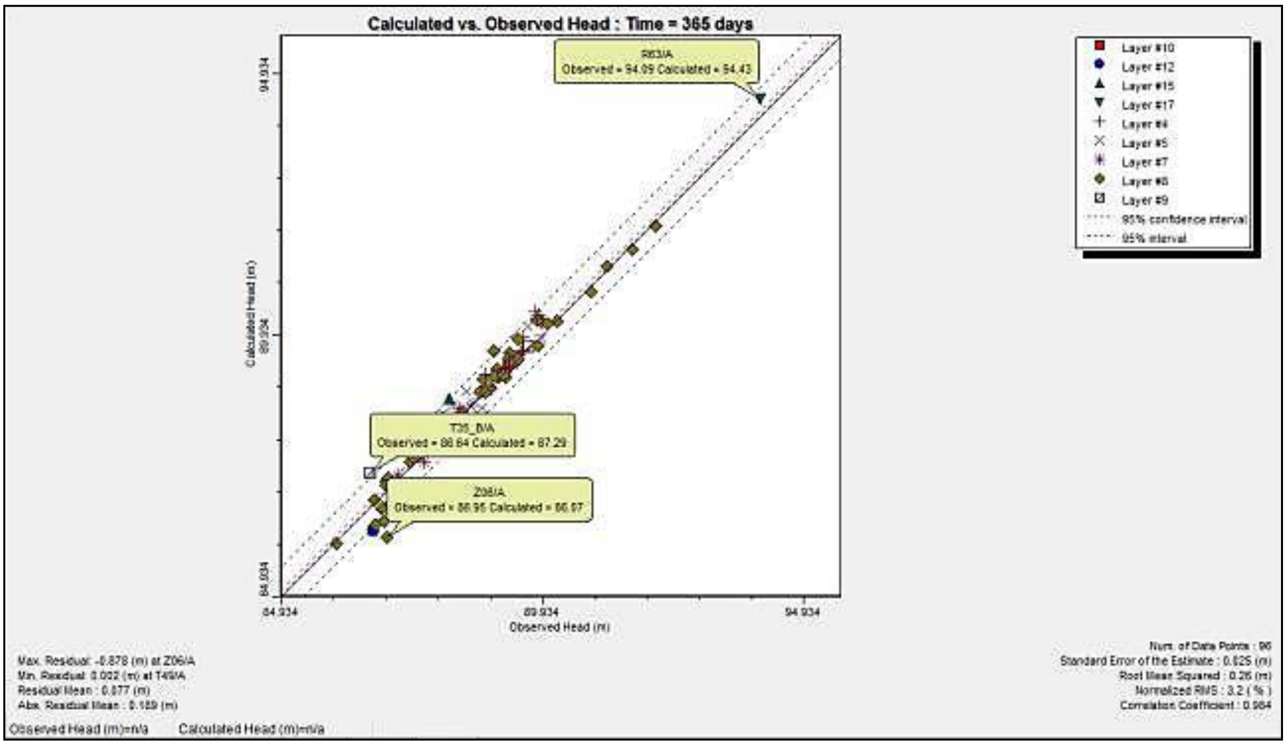


Figure 13.4.3-19: Comparison of water levels measured and calculated by the model.

Based on calibration of the relevant levels, the velocity space, the latter's anisotropy, the relevant paths and the access times can be considered realistic. The model is also validated as reliable in the long term by previous calculations, which give satisfactory results even under hydrological conditions of the year 2006 characterised by extreme water level dynamics.

13.4.3.4 Evaluation of transport processes between the groundwater and the confined groundwater

The question concerning the cause of the higher water level for the R63 well arose for the R63 and the R64 stratum wells. The R64 well communicates with the groundwater level, so it is in a hydraulic contact with the upper saturated zone. The measured value of the water level is identical to those of the surrounding wells. The R63 well is characterized by higher pressure, the measured water level is ca. 6-7 meters higher than those of the surrounding wells. We have analysed the layer structure and the grain size in the vicinity of the given wells. A possible explanation for the higher pressure is that above the screened layer of the R63 well, a second layer of clay is situated in a wavy pattern and it behaves as a much more closed, contiguous and less permeable layer. The hydrostatic pressure of the given layer is characterized by hydraulic parameters of the loess plateau at higher altitudes. Thus, screening for the R63 well occurs under the afore mentioned aquitard layer, while that of the R63 is located above. This may explain the difference in the measured water levels of the two wells. We have used this solution in the model, which properly respects the temporal changes of water levels in the two wells. As a consequence, we can speak of an upwelling (discharge) area in the vicinity of the site, so no contamination from groundwater may enter the confined groundwater.

13.4.3.5 Changes in tritium distribution in groundwater

Those places for which we have assumed tritium sources at a model level are summarised in Figure 13.4.3-20.

Under the main building (units), we have assumed places with activity concentration of 100 Bq/dm^3

We continued to take into account as a source the tritium-laden area assumed to be gradually cleared and formed due to the previous failure of the TM55 line. Here, we reduced the activity concentration value from 230 Bq/dm^3 to 160 Bq/dm^3. We approximated certain sections of the wastewater line with places with activity concentration of 100 and 30 Bq/dm^3, and assumed activity concentrations of 220 and 60 Bq/dm^3 along the infirmary building and the 1st auxiliary building.

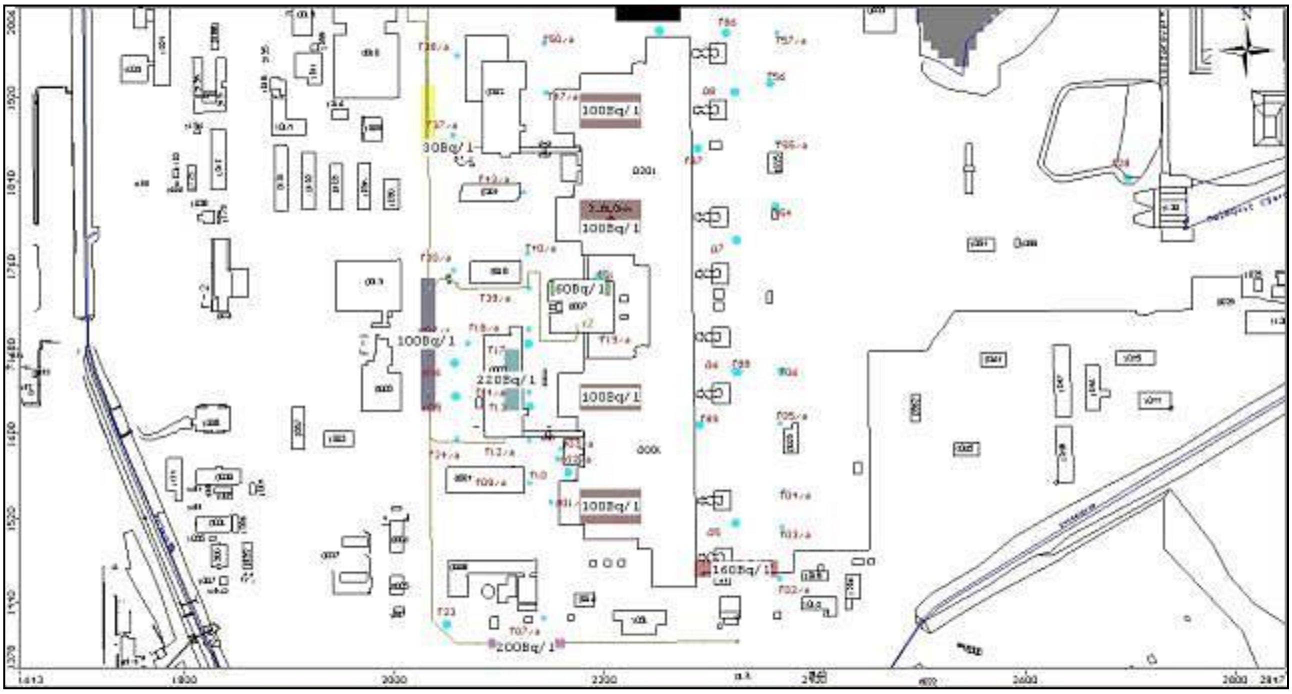


Figure 13.4.3-20: Summary of tritium sources assumed under the power plant building.

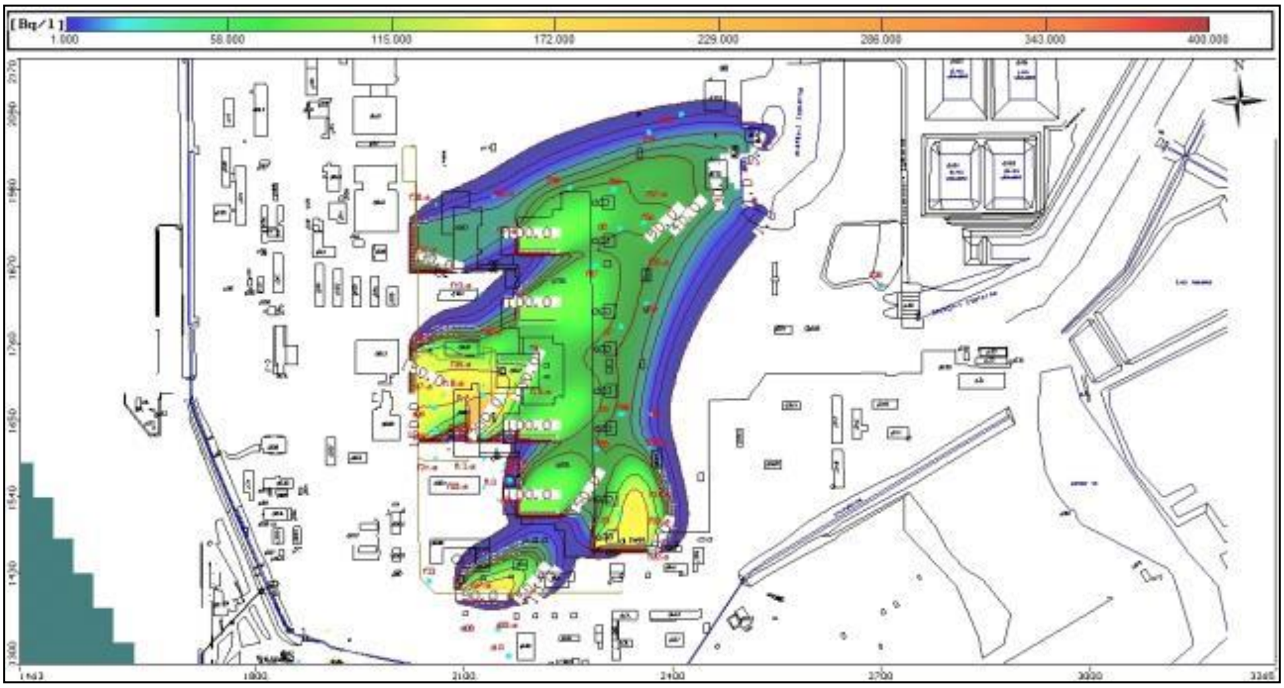


Figure 13.4.3-21: Contour map of tritium lens distribution at the end of the analysis period.

We have connected the model velocity space with places for which we have assumed that the given location, e. g. area under a unit 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 taking into account the conditions on 31 October 2012 solving equations corresponding to a time-constant conditions. 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.

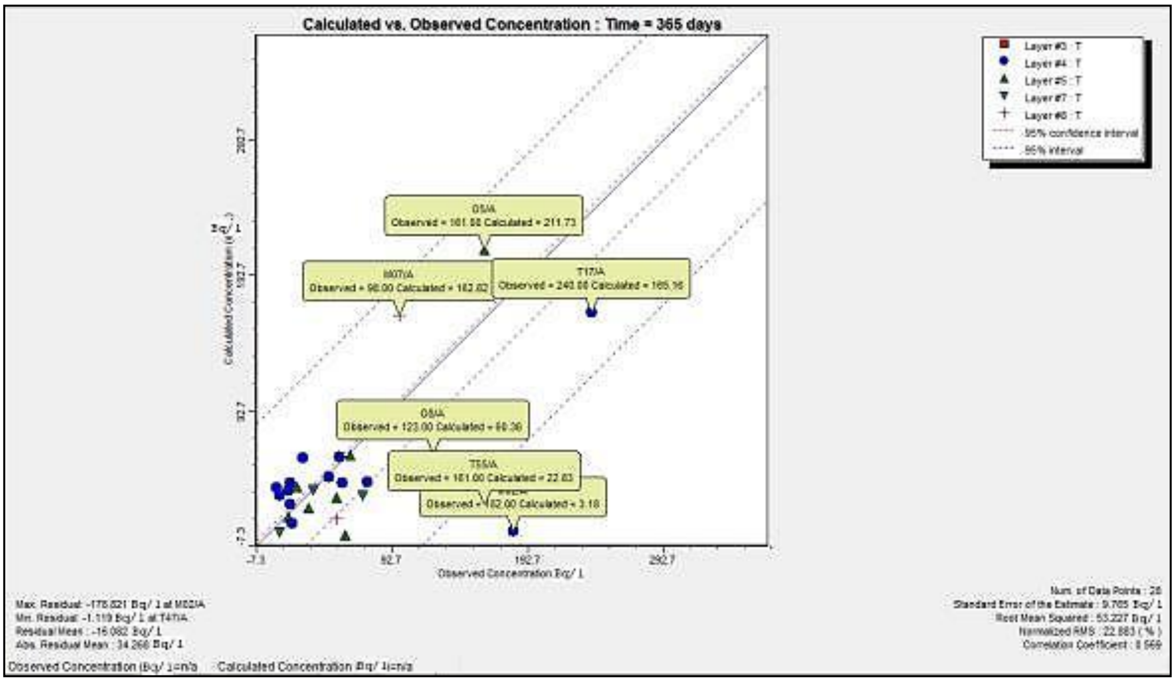


Figure 13.4.3-22: Comparison of the tritium activity concentration measured and calculated by the model.

The load level was typically overestimated in some periods during previous modelling. This is less typical in the current calculation. Calculated trends and orders of magnitude correspond to measured values. In case of the O5 well, the program shows an overestimated value, while for the T17 well, it is underestimated when compared with measured values. Thanks to the repair of the TM55 line and the sewer (which took place in 2011), the measured values are at a stable level below 300 Bq/dm^3 and due to this fact, they indicate a decreasing trend on the whole. The normalized RMS value is under 25% both at the beginning and the end of the examined period. The standard error of the estimate remains below 10 Bq/dm^3.

13.4.4 OPERATIONAL CONFINED GROUNDWATER WORKS IN CSÁMPA

The waterworks wells of the Csámpa waterworks installed on Pannonian confined groundwater are situated to a W-SW direction from the power plant.

13.4.4.1 General hydrogeological characterisation

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^3. 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 can speak of positive wells. Pressure levels vary between +0.1 – +6.7 m, characterized 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 .water 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.

13.4.4.2 Basic data

Drinking water supply for the Paks Nuclear Power Plant is provided by confined groundwater wells installed on the Pannonian sand layers in the Csámpa-puszta water base. The water base is vulnerable, diagnostic and safeguarding analyses were performed between 2006-2007.

13.4.4.3 Quality status of the water body

Data from laboratory studies performed on samples of detection and production wells from the period between 1990-2010 were available to a qualitative assessment of the water body.

During evaluation of individual measured parameters. the contamination limits set forth in Annexes 2 and 2B of Joint KvVM-EüM-FVM Decree 6/2009 (IV. 14) were used. The base water quality of production wells of the Csámpa waterworks belongs to the calcium magnesium hydrogen carbonate type.

Toxic metal analysis has also been performed in the test wells, but measured concentrations were below measurement limits. Out of the components measured, only an ammonium ion concentration of layer origin was present in an amount exceeding the relevant limit. As it is apparent from the above table, the limits is not exceeded significantly. Generally speaking, the quality of the water produced can be assessed as having a very low solute content.

Anaerobic conditions prevail within the body of water, which is derived from sedimentological conditions. The ammonia produced during decomposition of organic material in the relevant layer is not broken down further to nitrite and nitrate due to the lack of a proper amount of oxygen.

13.4.4.4 Quantitative status of the water body

Out of the producing wells, 2 each filter the poorer (shallower) and better (deeper) aquifers, respectively.

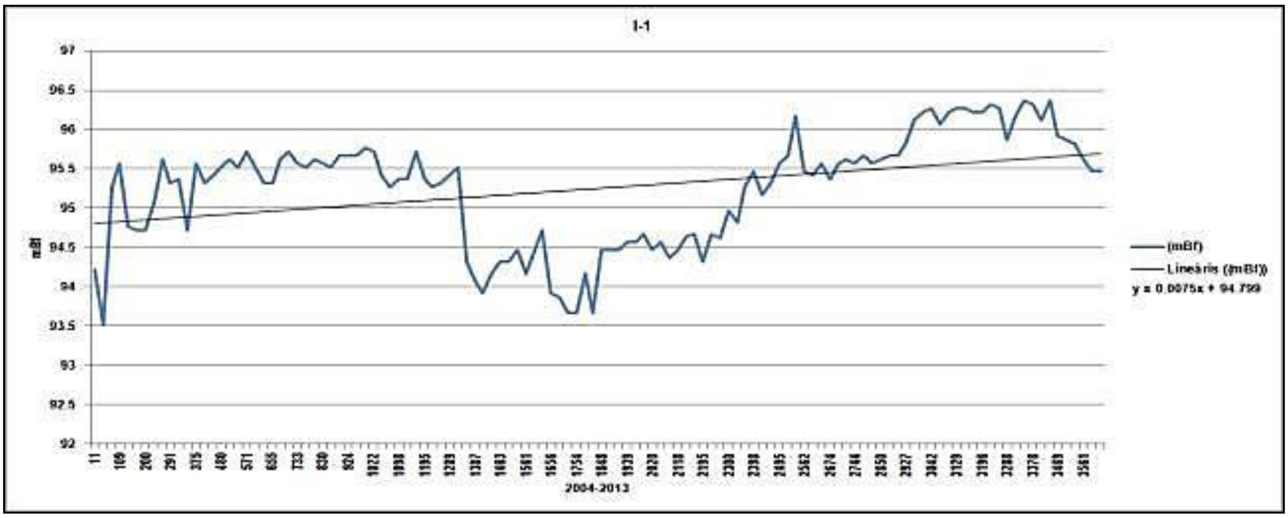
According to measurements in 2011, the original positive static water level of the confined groundwater wells decreased significantly as a result of several decades of production. Based on authorized water extraction, the utilization level of production wells is 83%, and other wells also produce water from the layers of the Csámpa waterworks. Based on all these facts, it is unlikely that too large reserves are present in the replenishing confined groundwater.

13.4.4.5 Hydrogeological model of the water body (impact of increased water extraction on the pressure levels of confined groundwater).

The Csámpa puszta water base provides drinking water to the Paks Nuclear Power Plant. 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 646 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. Well data are included in Table 13.4.4-1, whereas the time series of water levels of operating and monitoring wells are displayed in the Figure 13.4.4-1 - Figure 13.4.4-7 series of figures.

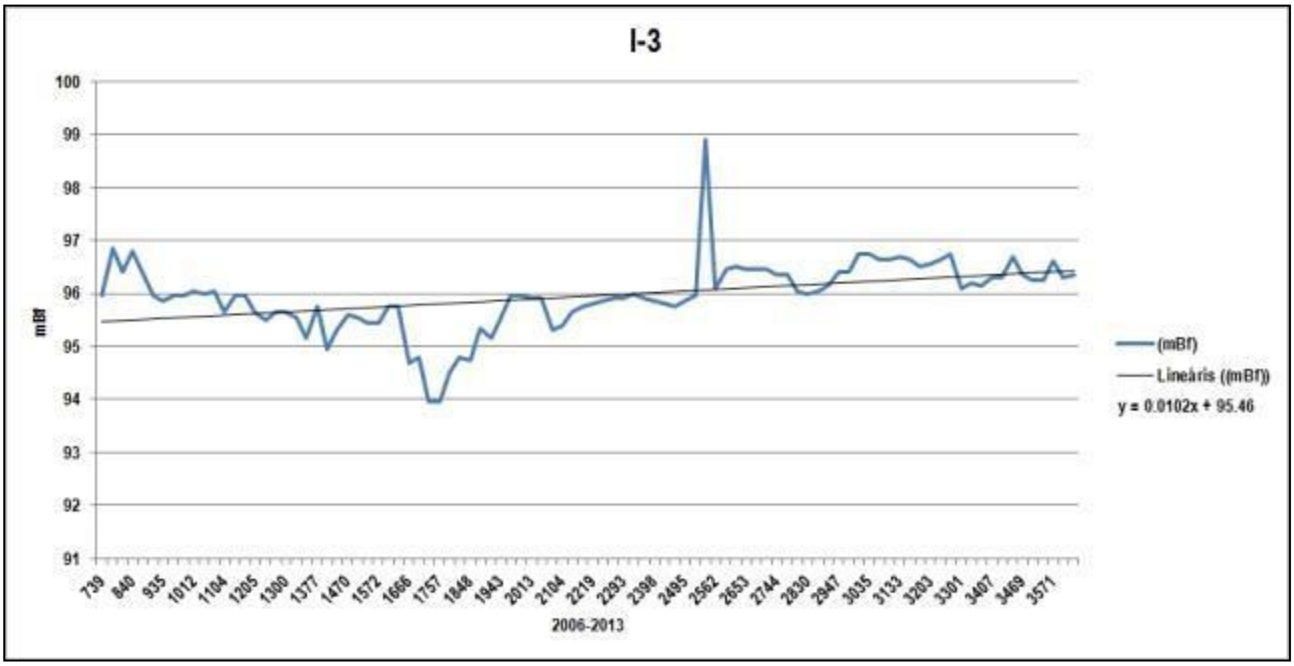
Csámpa 1, 2, 3 - Water works site					
Number of well	**EOV X**	**EOV Y**	**Well depth**	**Water yield extractable**	**Filtering**
I/1.	137785.43	632753.61	117 m	200 l/min	77.1-91.5; 98.8-107.4
I/3.	137840.97	632718.93	76 m	200 l/min	63.3-69.7
I/7.	137825.38	632722.28	117 m	500 l/min	58.0-69.0; 78.0-93.0; 68.0-107.0
II/2.	137201.25	632204.16	142 m	1200 l/min	76.1-91.6; 101.4-107.2; 117.6-136.6
II/6.	137227.84	632417.43	154 m	900 l/min	77.0-89.0; 92.5-103.5; 111.0-125.0; 129.0-
8.	136511.53	632570.97	129 m	870 l/min	68-80.7; 85.1-93.7; 96.3-118.8
9.	136293.03	632277.22	125 m	870 l/min	86.8-93; 98.6-108.6

Table 13.4.4-1: Parameters of the Csámpa wells



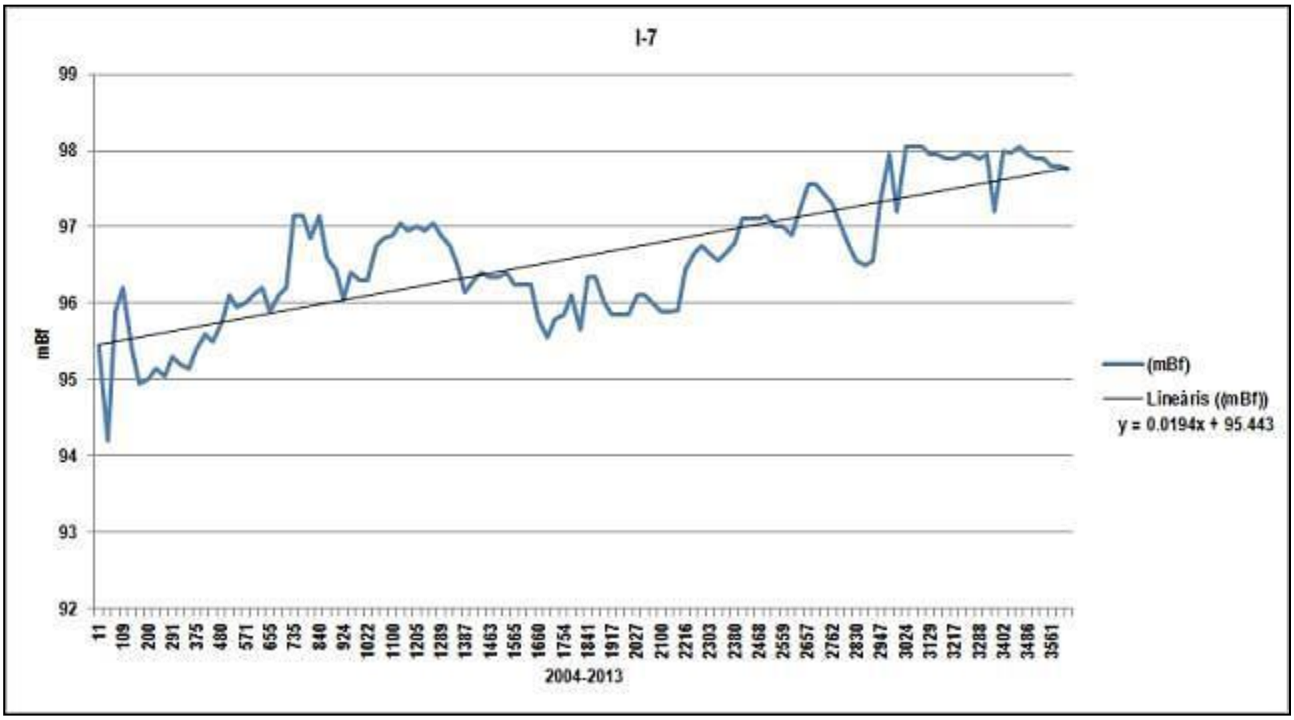
lineáris - linear

Figure 13.4.4-1: 10-year time series of the water level of the I-1 observation well on the 1st site.



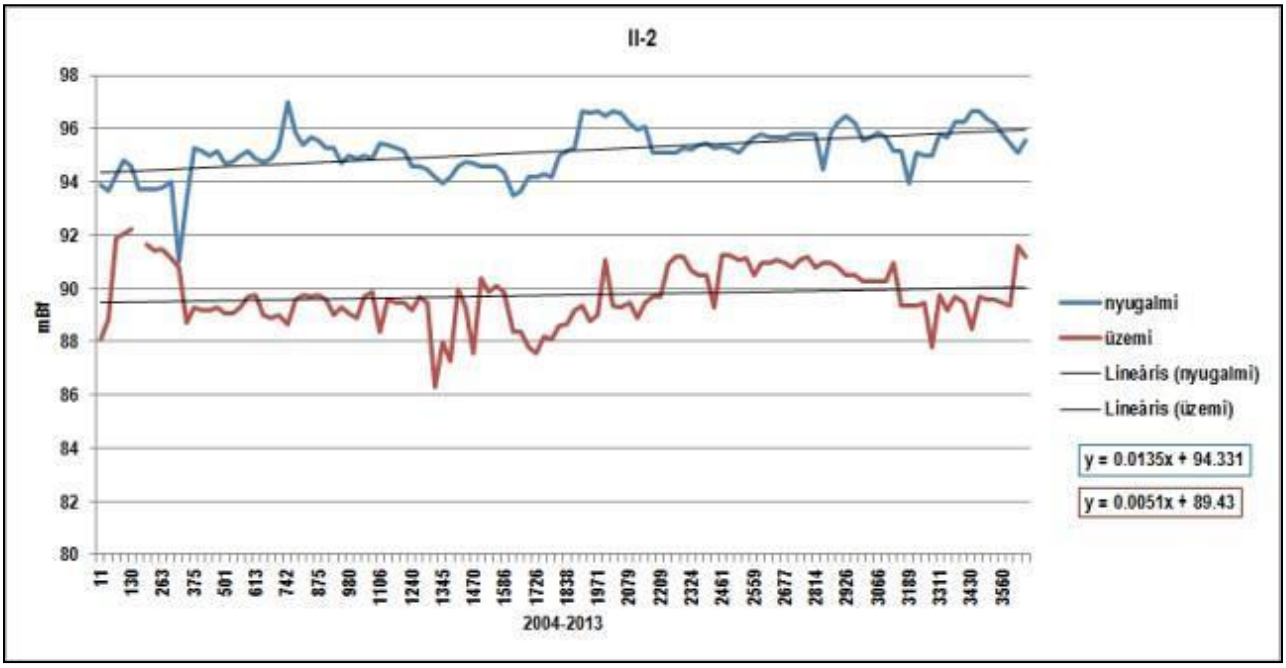
lineáris - linear

Figure 13.4.4-2: 8-year time series of the water level of the I-3 observation well on the 1st site.



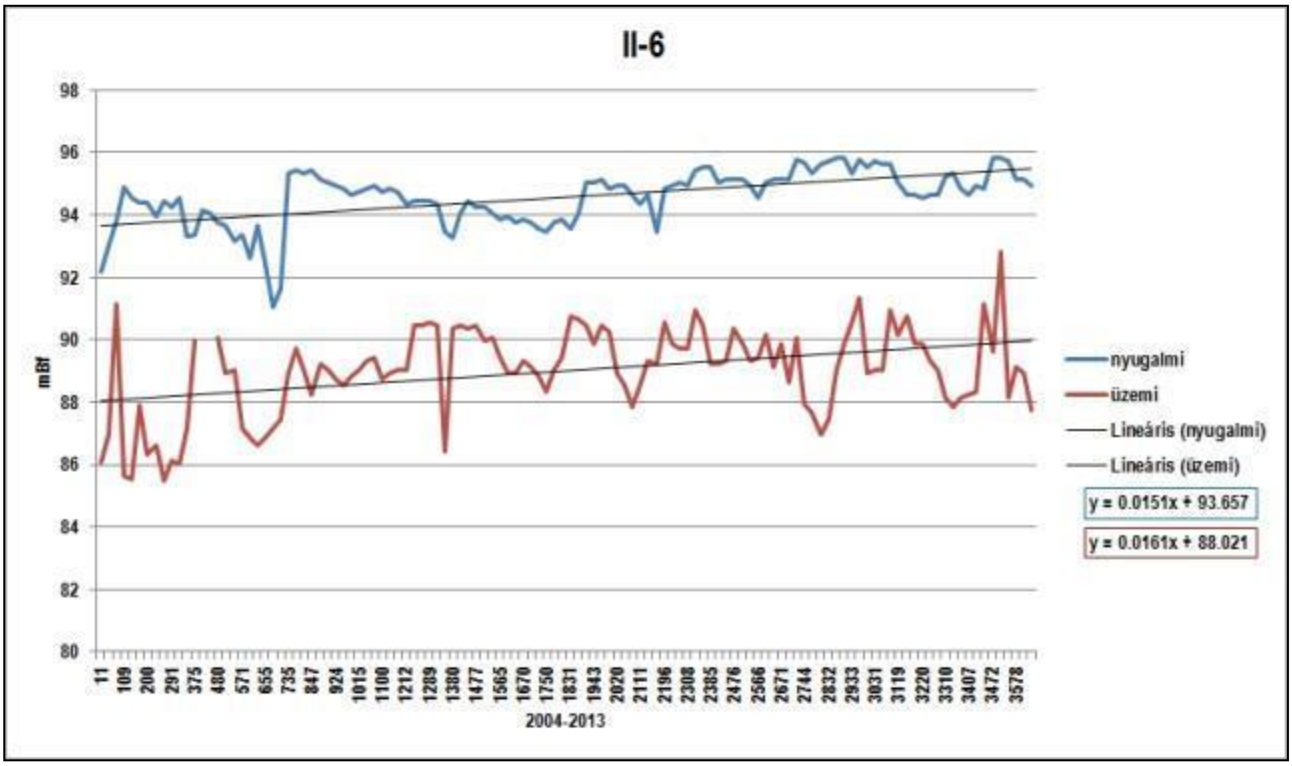
lineáris - linear

Figure 13.4.4-3: 10-year time series of the water level of the I-7 observation well on the 1st site.



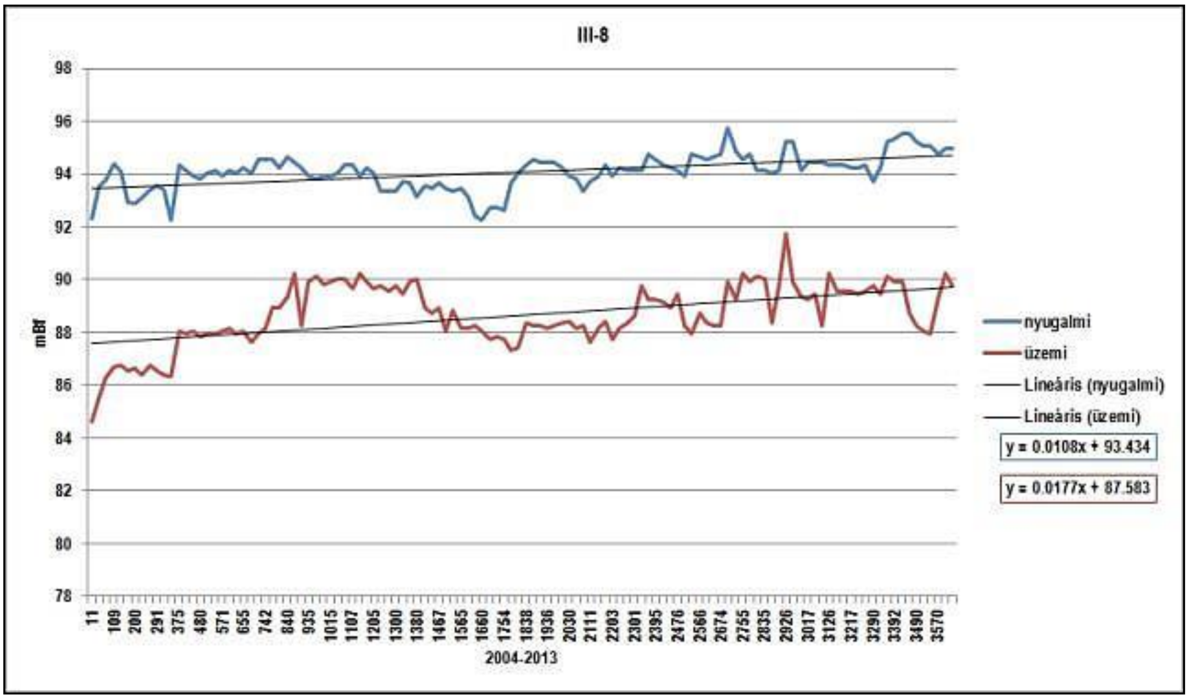
nyugalmi-static
üzemi-operational
Lineáris (nyugalmi)-Linear (static)
Lineáris (üzemi)-Linear (operational)

Figure 13.4.4-4: 10-year time series of the water level of the II-2 producing well on the 2nd site.



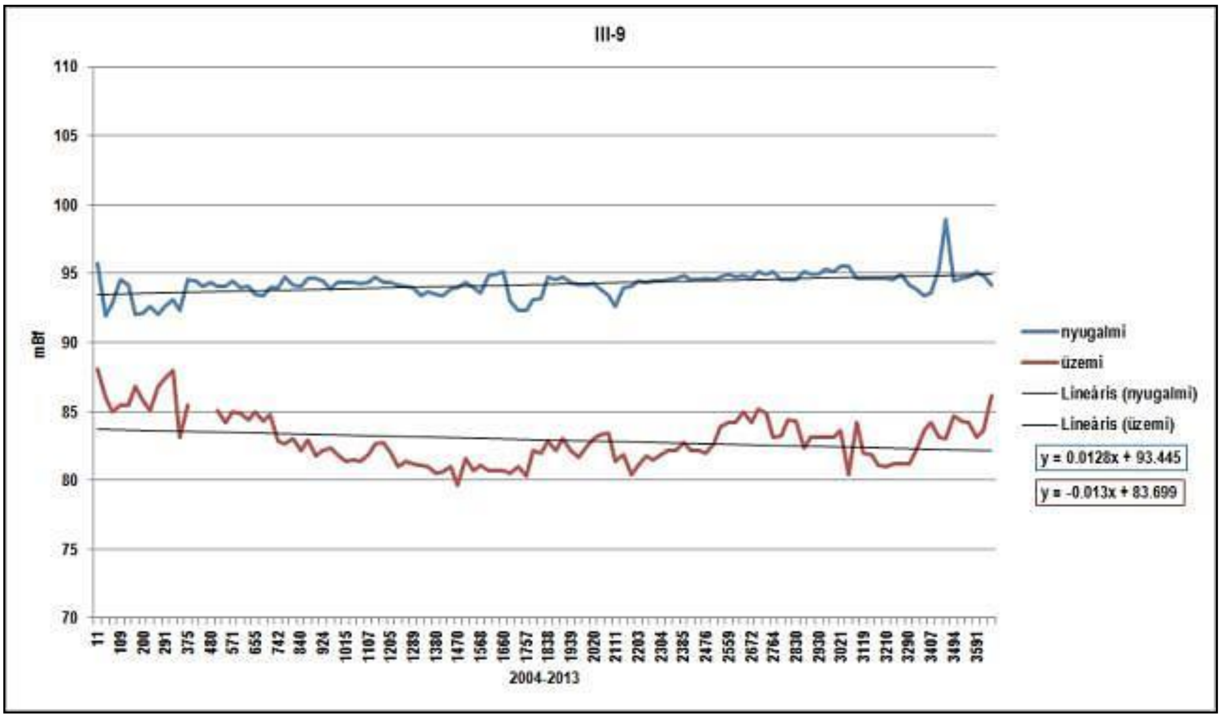
nyugalmi-static
üzemi-operational
Lineáris (nyugalmi)-Linear (static)
Lineáris (üzemi)-Linear (operational)

Figure 13.4.4-5: 10-year time series of the water level of the II-6 producing well on the 2nd site.



nyugalmi-static
üzemi-operational
Lineáris (nyugalmi)-Linear (static)
Lineáris (üzemi)-Linear (operational)

Figure 13.4.4-6: 10-year time series of the water level of the III-8 producing well on the 3rd site.



nyugalmi-static
üzemi-operational
Lineáris (nyugalmi)-Linear (static)
Lineáris (üzemi)-Linear (operational)

Figure 13.4.4-7: 10-year time series of the water level of the III-9 producing well on the 3rd site.

A decreasing trend in the operating water level can be only observed in this single well, which is not progressing drastically, but rather gradually. In our opinion, this phenomenon can be caused by the clogging of filters since production is only done using two of the four producing wells and even they belong to different waterworks sites, moreover, they are constantly changed on a weekly basis.

The probability of groundwater with higher concentrations of tritium under the Paks Nuclear Power Plant entering the Csámpa-puszta aquiver or the confined groundwater layers is so small that its hydrogeological assessment is unwarranted. Namely, this is an upwelling area, so the pressure increases with depth and the Danube represents the base of upwelling of confined groundwater. However, as the competent authority requested such assessment, we have created a hydrogeological model which was extended both vertically and horizontally, for which we have used certain elements of models prepared for assessing the site and .long-term waterbases. We have applied 5 layers to prepare the relevant bases, the spatial geometry of which is displayed in Figure 13.4.4-8.

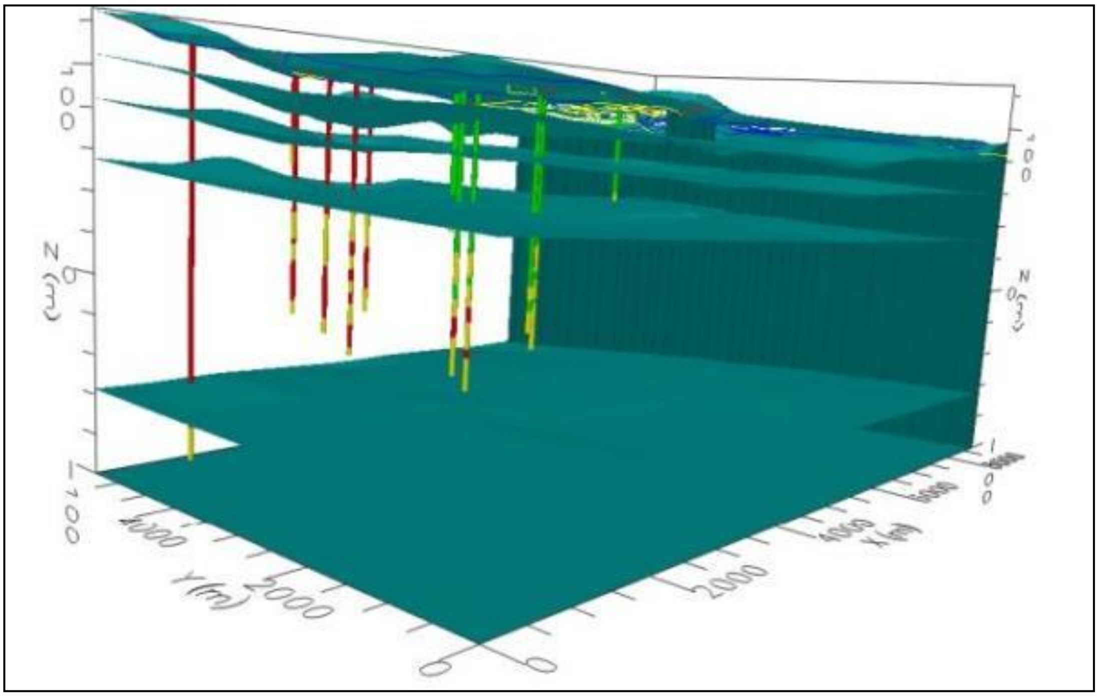


Figure 13.4.4-8: Geometry of the extended model.

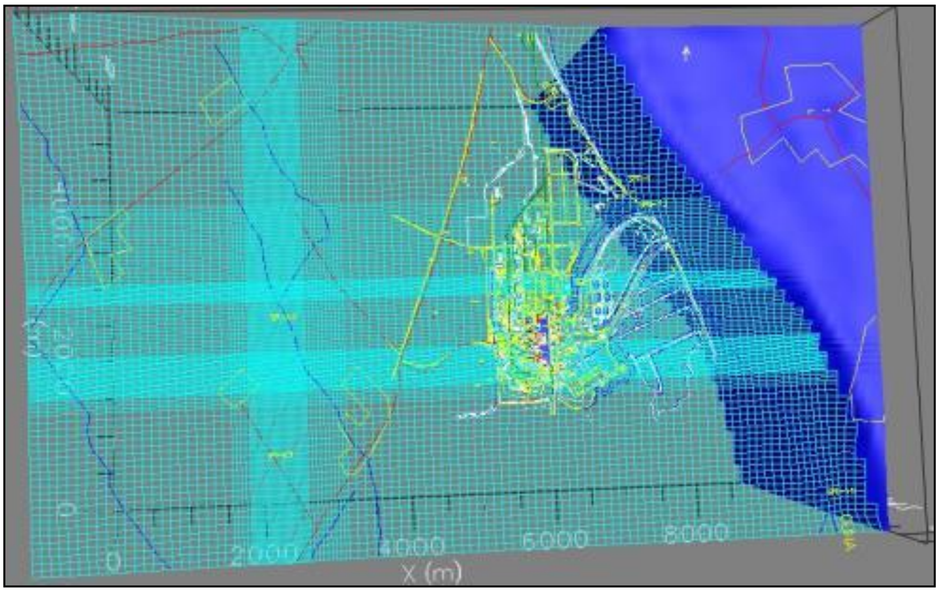


Figure 13.4.4-9: Model grid

The relevant zones and data of hydraulic infiltration parameters are shown in Figure 13.4.4-10

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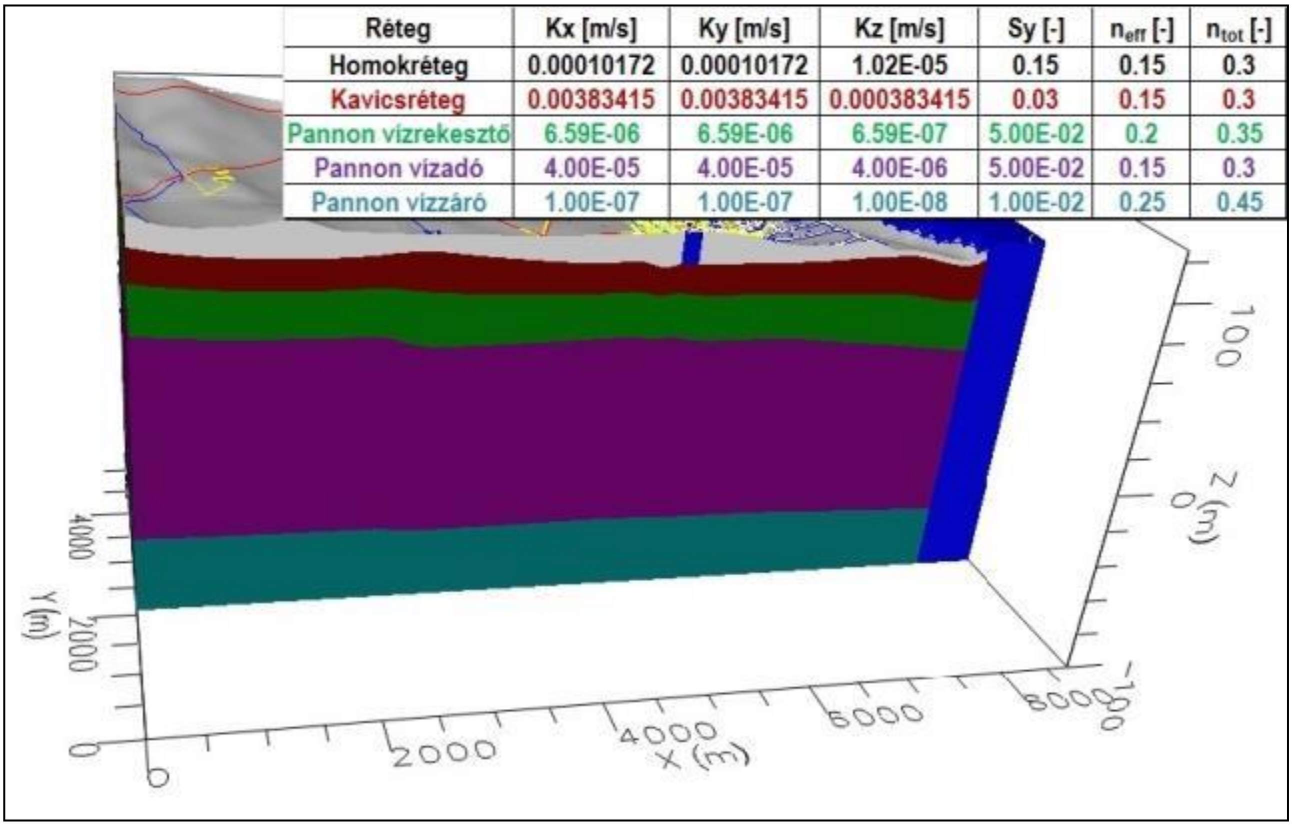


Réteg	Kx [m/s]	Ky [m/s]	Kz [m/s]	Sy [-]	n_{eff} [-]	n_{tot} [-]
Homokréteg	0.00010172	0.00010172	1.02E-05	0.15	0.15	0.3
Kavicsréteg	0.00383415	0.00383415	0.000383415	0.03	0.15	0.3
Pannon vízrekesztő	6.59E-06	6.59E-06	6.59E-07	5.00E-02	0.2	0.35
Pannon vízadó	4.00E-05	4.00E-05	4.00E-06	5.00E-02	0.15	0.3
Pannon vízzáró	1.00E-07	1.00E-07	1.00E-08	1.00E-02	0.25	0.45

Réteg-Layer
Homokréteg-Sand layer
Kavicsréteg-Gravel layer
Pannon vízrekesztő-Pannon aquatard
Pannon vízadó-Pannon aquifier
Pannon vízzáró-Pannon watertight

Figure 13.4.4-10: Hydraulic infiltration parameters of relevant layers

Since the Danube pressure wave cannot be detected at a distance of 200 meters from the bank in case of flood conditions, we did not consider the simulation of high water events to be important, so we only took into account the medium Danube water level (88 mBf) and the average precipitation infiltration (85 mm/year). The model has been run for permanent conditions for a 10-year period of construction of the new power plant. We have defined the yield of producing wells with the highest value of the past 10 years whereas the water levels measured in the monitoring wells were identified with the average of the static water levels of the past 10 years. In the vicinity of producing wells, we have taken into account the average operating water level of the last 10 years. In comparison with the current conditions, we have assessed the impact of increased water extraction to the pressure levels of confined groundwater. We have taken into account the extent of increased water extraction due to construction with a value of 646 m^3/day. We have defined the boundary conditions from the north, west and south by using general boundary conditions (GHB - "general head boundary") in the aquifers. From the east, the Danube has been considered as a constant boundary condition (CHB - "constant head boundary"). Furthermore we have envisaged the application of a precipitation infiltration level of 85 mm/year (recharge boundary). We have excluded the volume to the east of the Danube by using inactive cells. The results clearly show that contaminants that may exit the power plant (e. g tritium and accordingly, any other material) cannot reach the potential water base and the aquifers.- We have also confirmed this by relevant measurements by taking water samples from the R63 confined groundwater monitoring well on site and the 4 producing wells in Csámpa and measured their tritium content with a high accuracy T/^{3}He method. Practically, the results yielded "0" values, which are included in Table 13.4.4-2.

Name of well	Sampling on	TU	Error
Csámpa_II/2	15/04/2014	-0.076	0.037
Csámpa II/6	15/04/2014	0.082	0.053
Csámpa III/8	15/04/2014	-0.064	0.038
Csámpa III/9	15/04/2014	-0.105	0.037
Paks_R63	15/04/2014	-0.024	0.177

Table 13.4.4-2: Tritium activity of the R63 in Paks and the 4 producing wells in Csámpa.

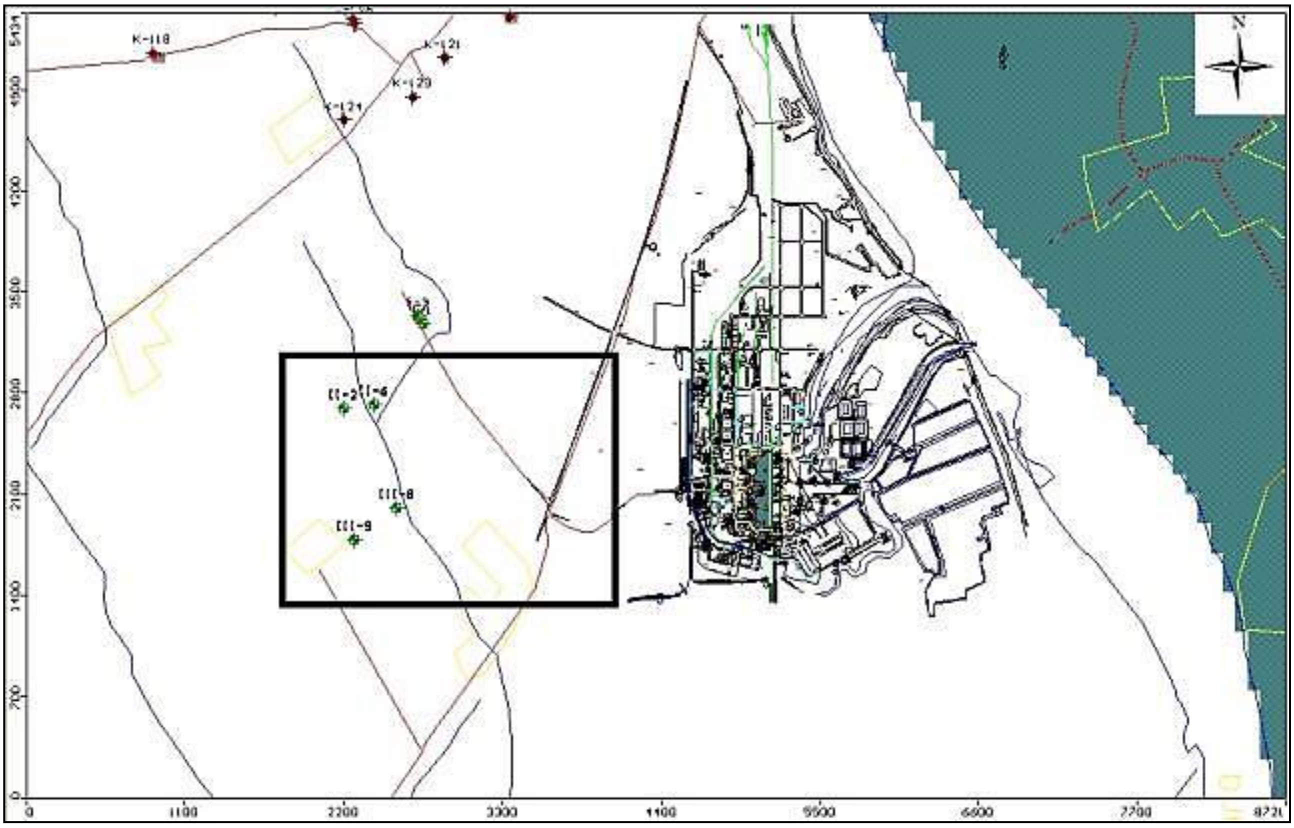
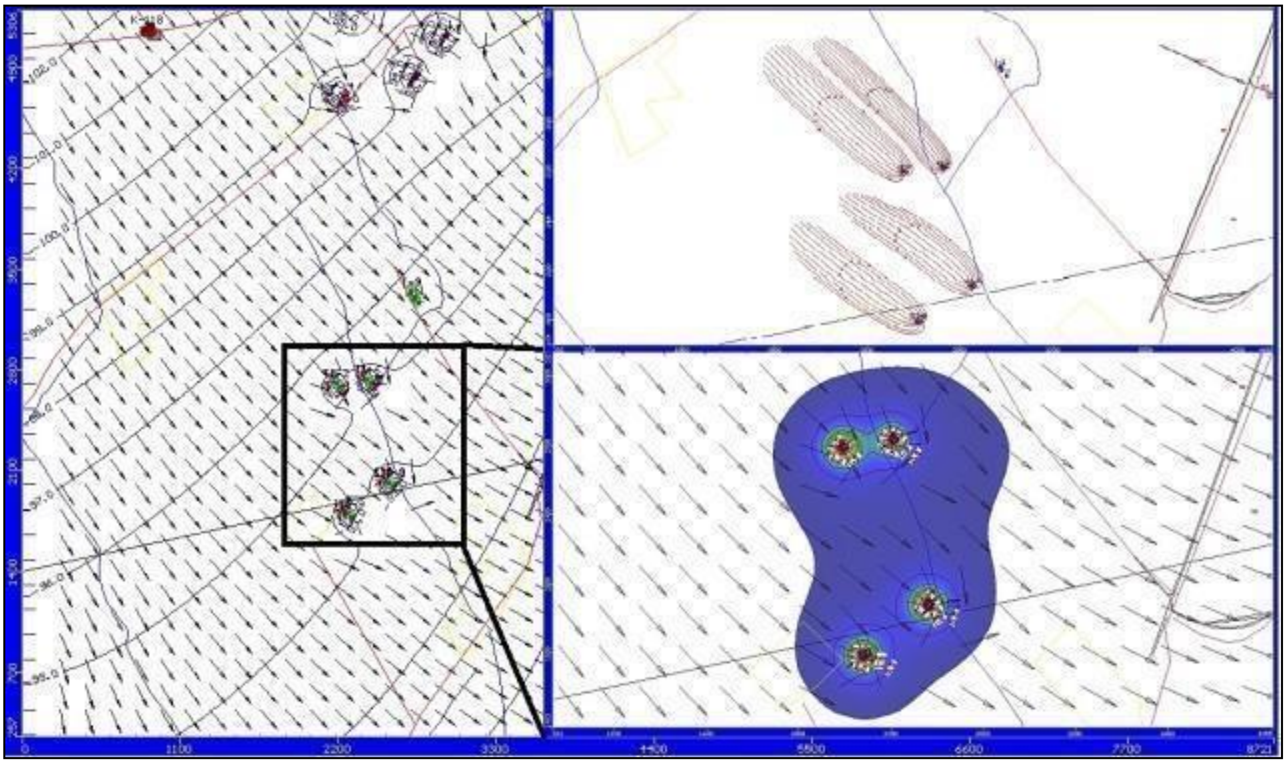
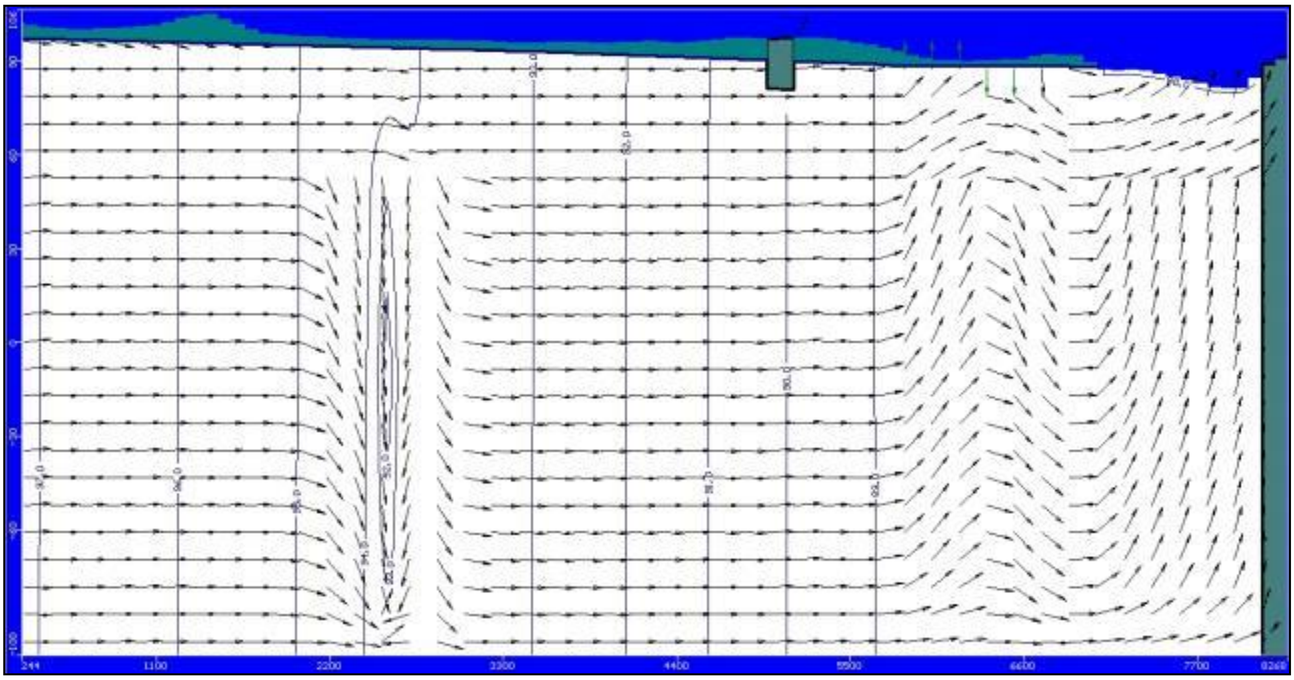


Figure 13.4.4-11: General map of the model area



Note: current status

Figure 13.4.4-12: Flow directions in the vicinity of the wells, 50 years migration paths and depression cones.



Note: current status

Figure 13.4.4-13: Flow direction along a W - E section.

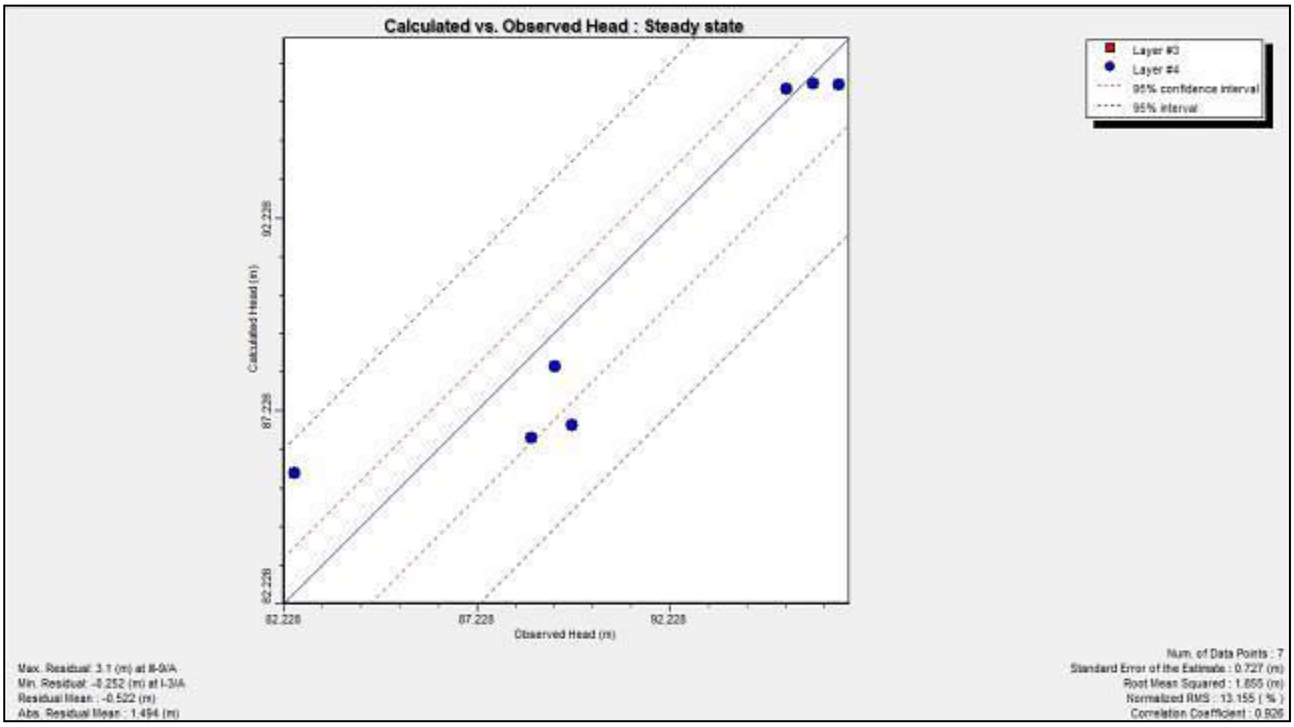
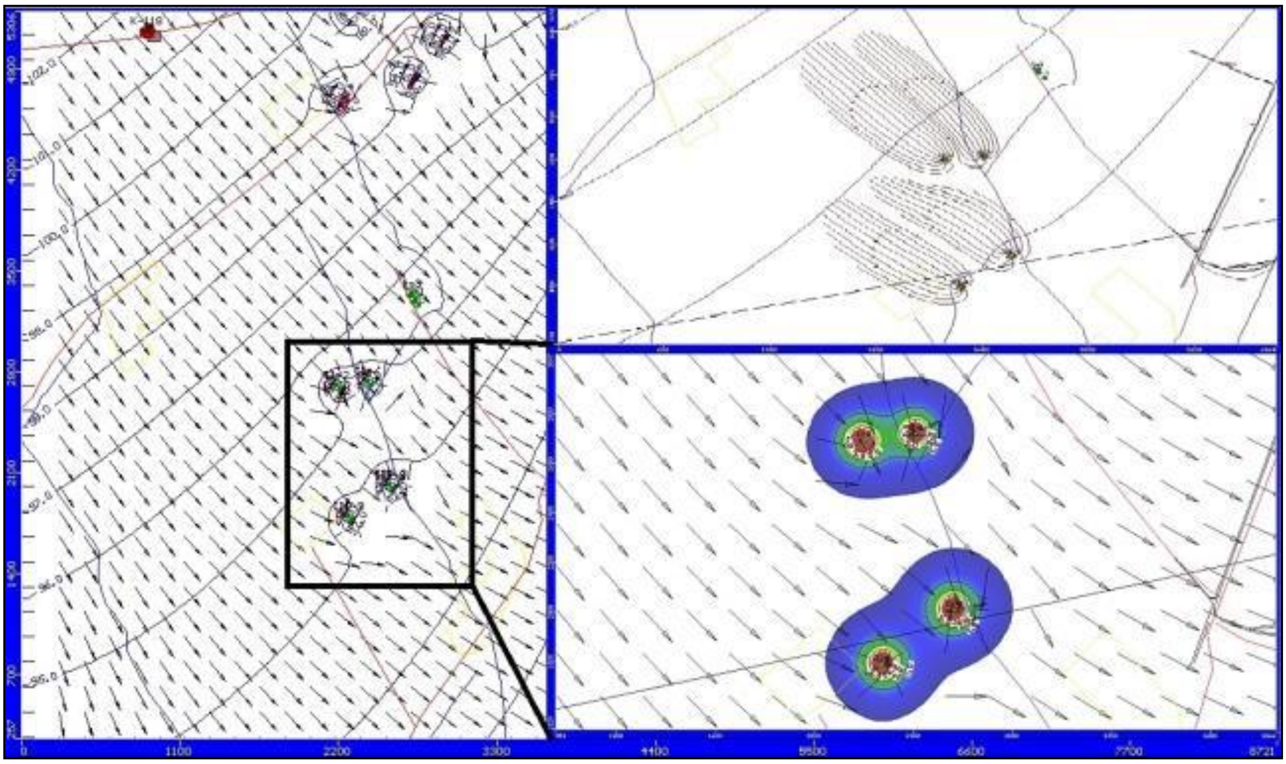
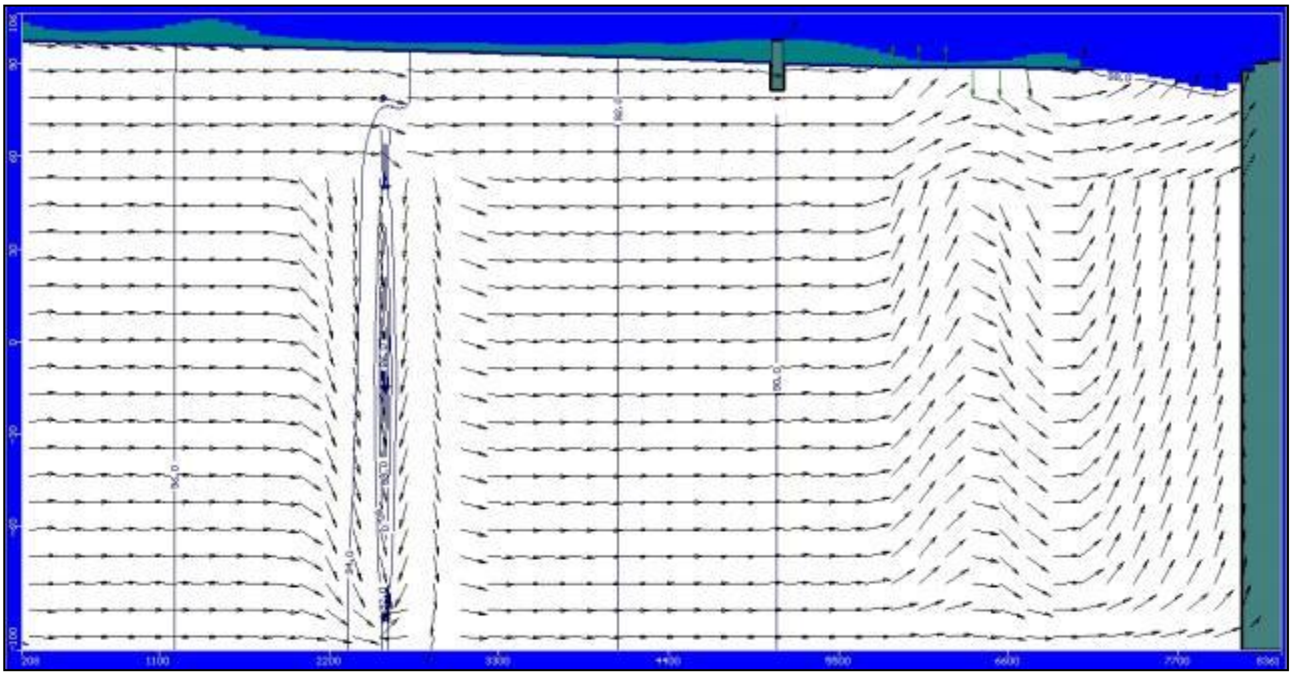


Figure 13.4.4-14: Validation curve of the current status.



Note: effect of the 646 m^3/day increment compared to the current status.

Figure 13.4.4-15: Flow directions in the vicinity of the wells, 50 years migration paths and depression cones.



Note: effect of the 646 m^3/day increment compared to the current status.

Figure 13.4.4-16: Flow direction along a W - E section.

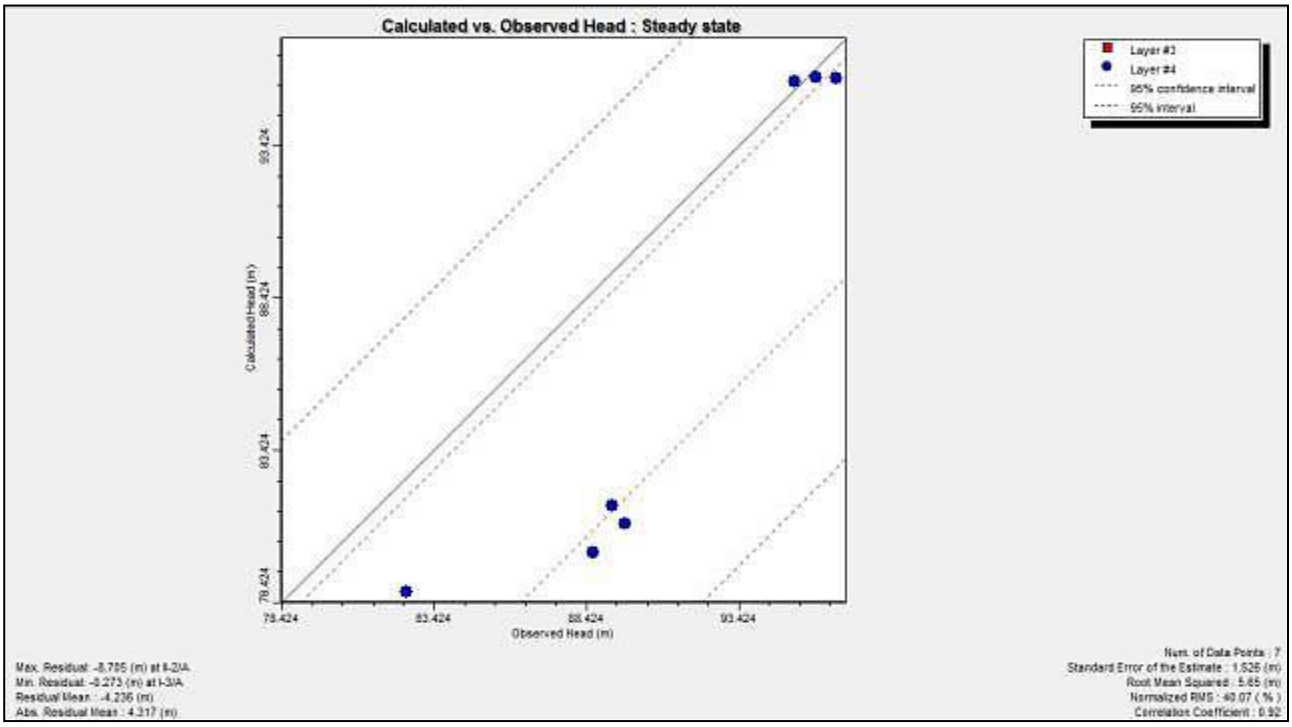


Figure 13.4.4-17: Validation curve of the 646 m^3/day increment compared to the current status.

From the extent of suction (validation curve deviation, 4-5 m) and the spatial location of depression cones it can be clearly seen that increased extraction cannot elicit an effect of contaminants travelling from the groundwater down to the confined groundwater layer. The intactness of this layer is confirmed by the fact that the tritium concentration in the relevant water amount is zero both under the power plant and Csámpa. Nevertheless, we recommend that drillings reaching the confined groundwater should only be performed with great caution in the narrow vicinity of the power plant in order to maintain the status quo.

13.5 *IMPACT OF CONSTRUCTION OF PAKS II ON THE GEOLOGICAL MEDIUM BENEATH THE SITE AS WELL AS THE UNDERGROUND WATER.*

13.5.1 IMPACT OF CONSTRUCTION ON UNDERGROUND WATER BENEATH THE SITE.

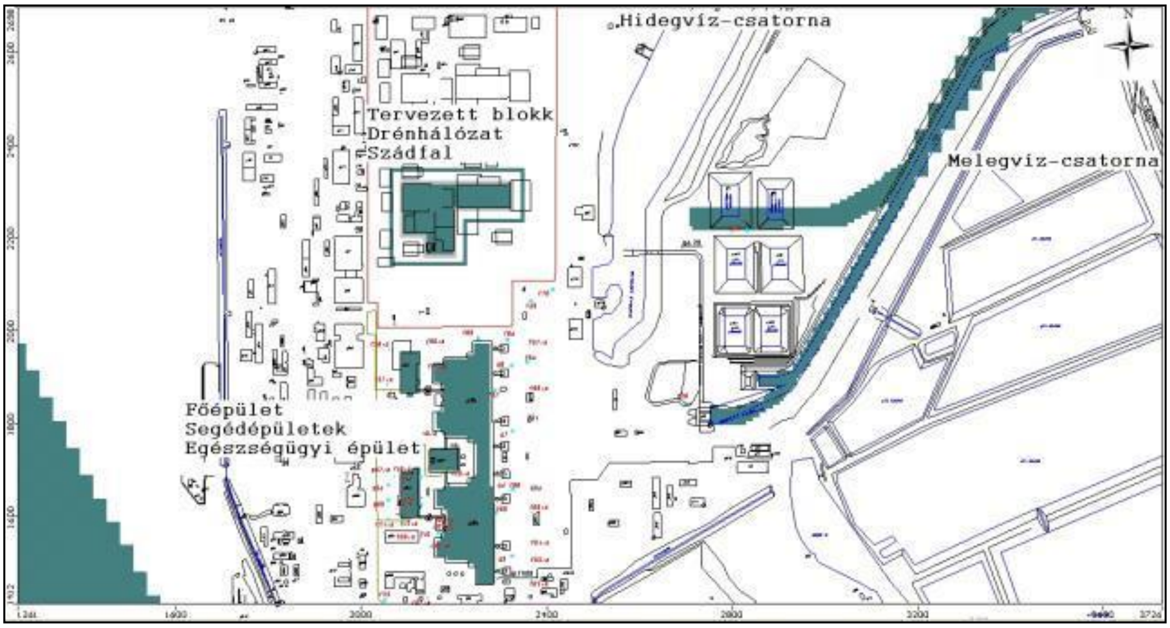
We have defined the boundary conditions (head boundaries) needed for demarcation of the impact area, as the impact of dewatering resulting in the reduction of groundwater with the average values of annual water level fluctuations detected in all monitoring wells of the site (~3.12 m = 3 m).

13.5.1.1 Direct effects

13.5.1.1.1 Effects of dewatering the working pit on groundwater

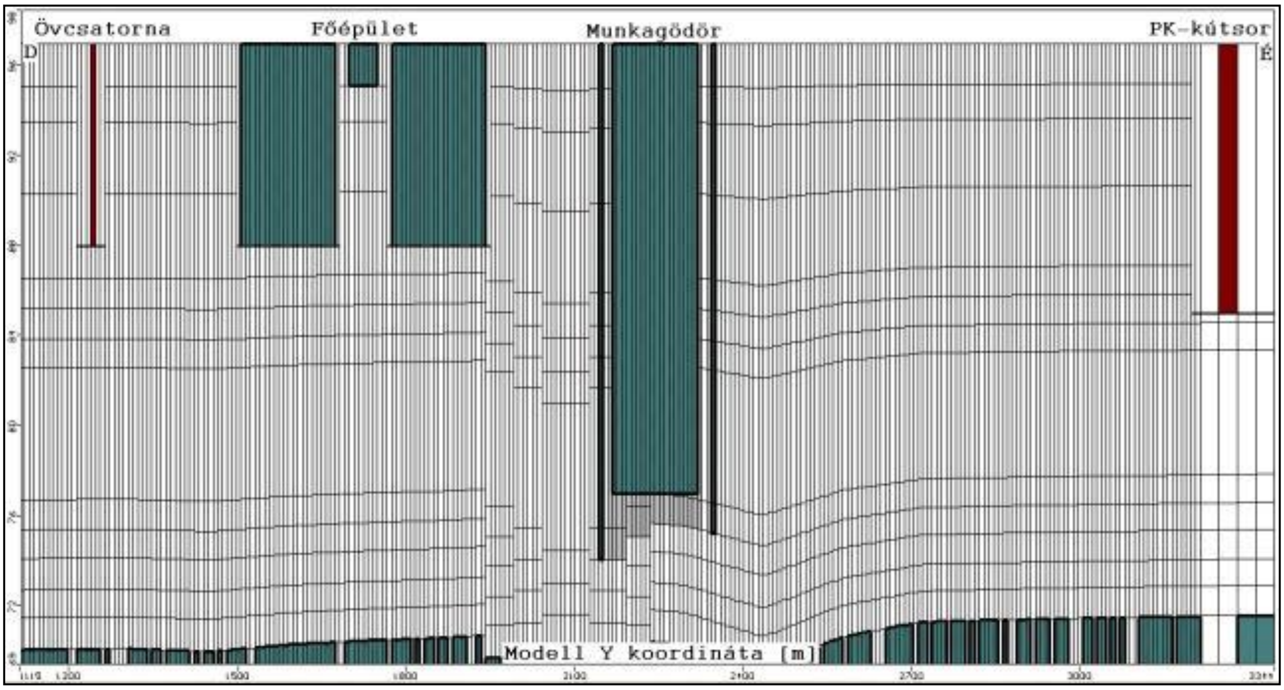
During construction of the new power plant, dewatering of the working pit created for foundation will impact the groundwater level and a high amount of groundwater will be removed by dewatering which will end up in the Danube. We have placed the planned deep foundation buildings of the relevant units 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 14 and 20 m. In our study, we assumed a depth of 20 m. Foundation works for the new units is not likely to be performed simultaneously, therefore, in the model, we have examined their impacts separately (first Paks Unit II. 1 then Unit 2).

We have surrounded the working pit, taken into account by the model as an inactive cell by a drainage network. This is due to technical reasons, because dewatering of the working pit can be simulated in this way. The drainage network fully removes water from the system (working pit) and helps to estimate the amount of water passing through the latter, which will also be plotted in a graph. 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 meters. The analysis is based on hydrological processes prevailing during the period from 1 November 2012 to 31 October 2013.



Hidegvíz-csatorna-Cold water canal
Melegvíz-csatorna-Hot water canal
Tervezet blokk-Planned unit
Drénhálózat-Drain network
Szádfal-Sheeting wall
Főépület-Main building
Segédépületek-Auxiliary buildings
Egészségügyi épület-Medical building

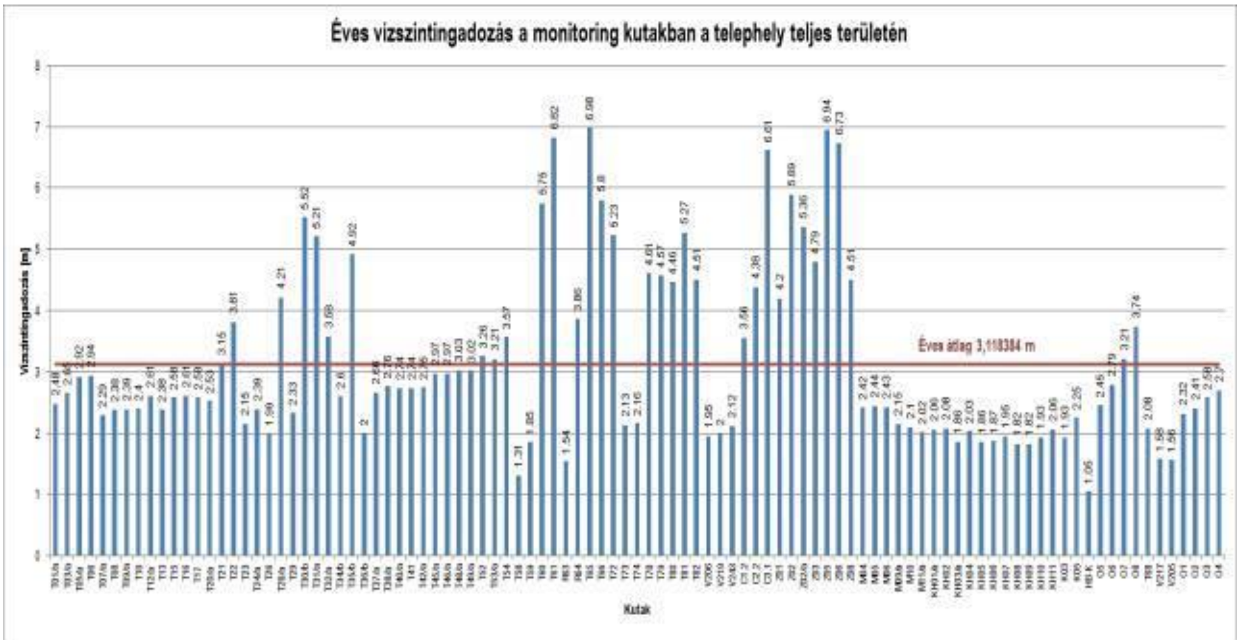
Figure 13.5.1-1: Horizontal position of the working pit



Övcsatorna-Diversion ditch
Főépület-Main building
Munkagödör-Working pit
PK-kútsor-PK battery of wells
Modell Y koordináta [m]-Model Y co-ordinate

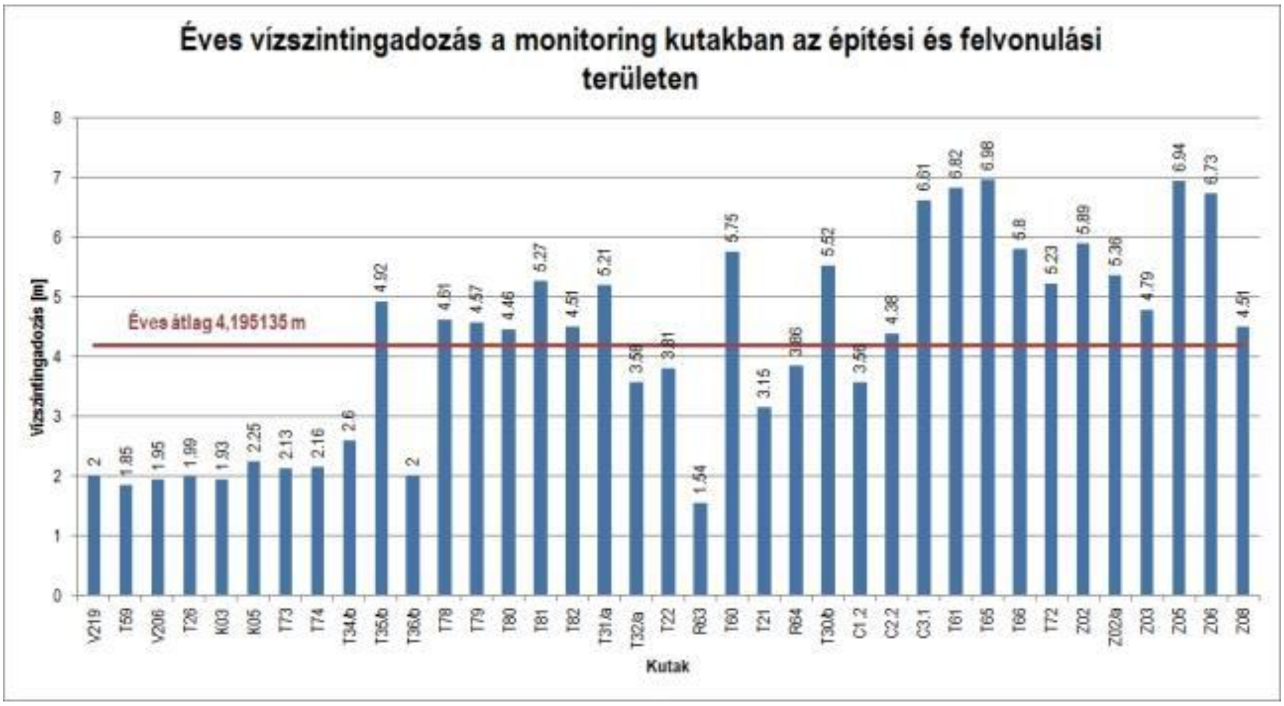
Figure 13.5.1-2: Vertical position of the working pit

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. Moreover, 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.



Éves vízszintingadozás a monitoring kutakban a telephely teljes területén-Annual water level fluctuations of all on-site monitoring wells
Vízszintingadozás [m]-Water level fluctuation [m]
Éves átlag-Annual average
Kutak-Wells

Figure 13.5.1-3: Annual water level fluctuations of all on-site monitoring wells.



Éves vízszintingadozás a monitoring kutakban az építési és felvonulási területen-Annual water level fluctuations of monitoring wells in the construction and mobilisation area
Vízszintingadozás [m]-Water level fluctuation
Éves átlag-Annual average
Kutak-Wells

Figure 13.5.1-4: Annual water level fluctuations of monitoring wells in the construction site and the mobilisation area.

In view of this, for demarcation of the impact area, we have taken the first value as a basis in order to remain conservative. Thus, 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). The impact area extends to the line of 3-meter water level reduction (marked by red contour).

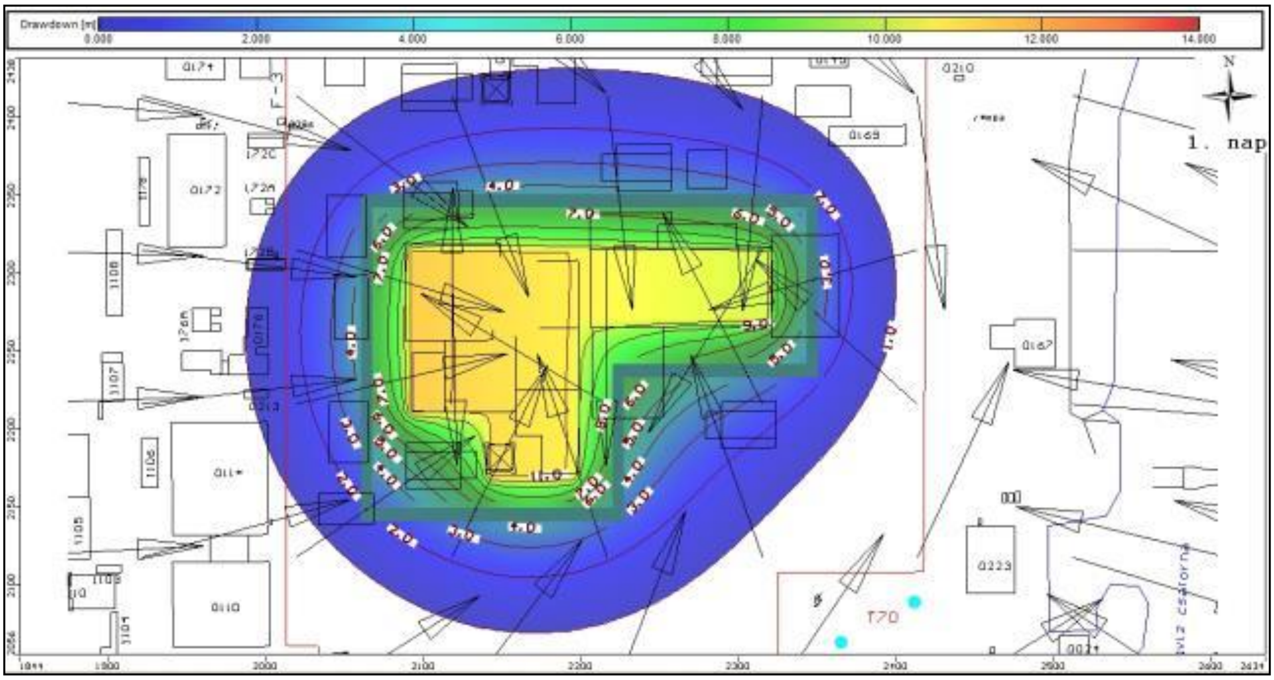


Figure 13.5.1-5: Extent of the depression cone and the flow field at the beginning of the assessment period.

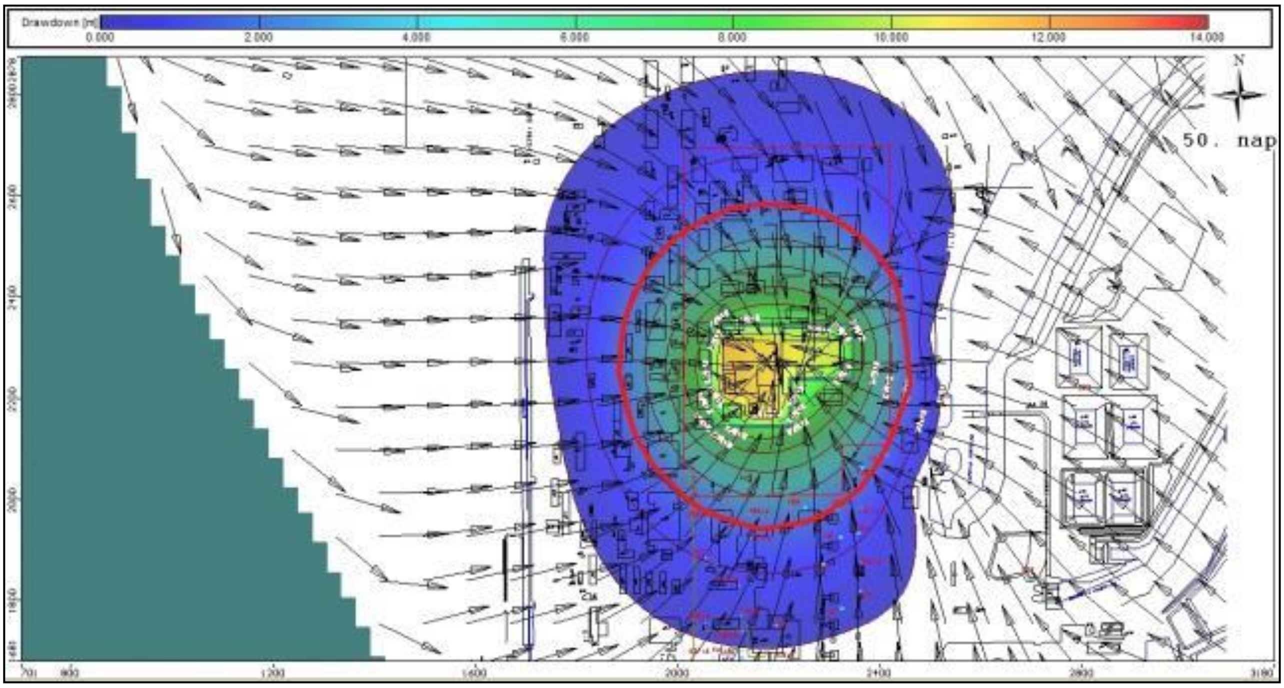


Figure 13.5.1-6: Extent of the depression cone and the flow field on the 50th day of the assessment period.

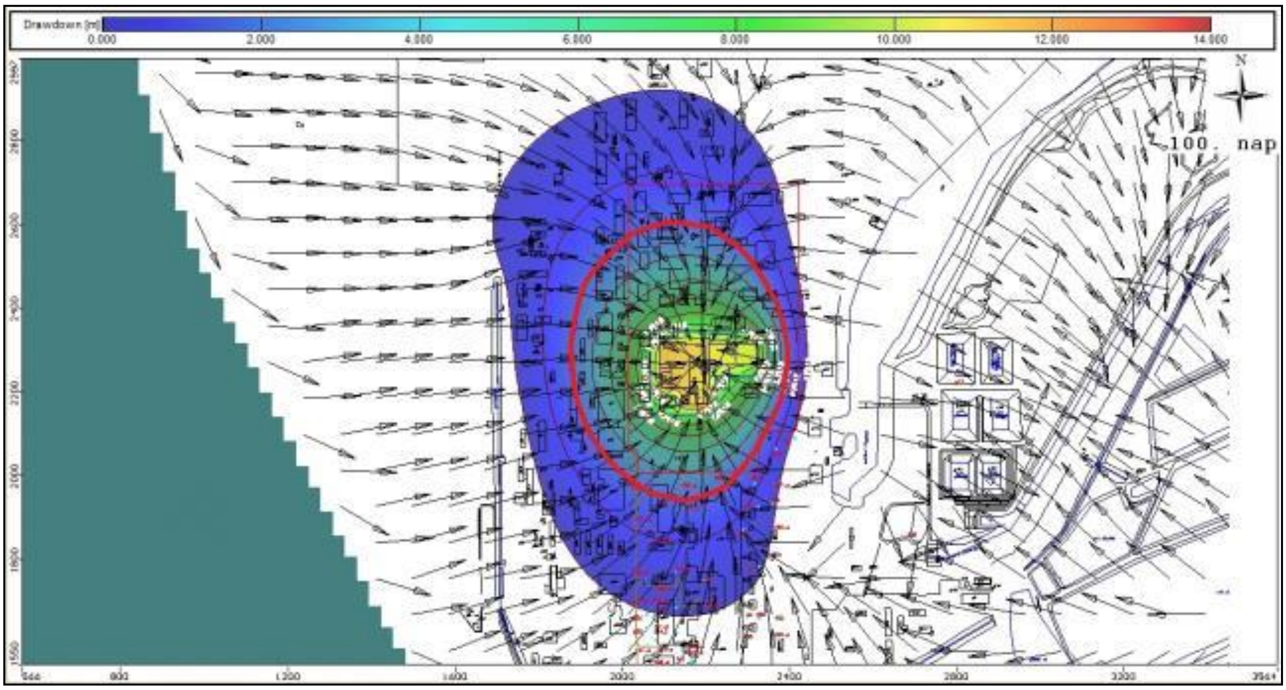


Figure 13.5.1-7: Extent of the depression cone and the flow field on the 100th day of the assessment period.

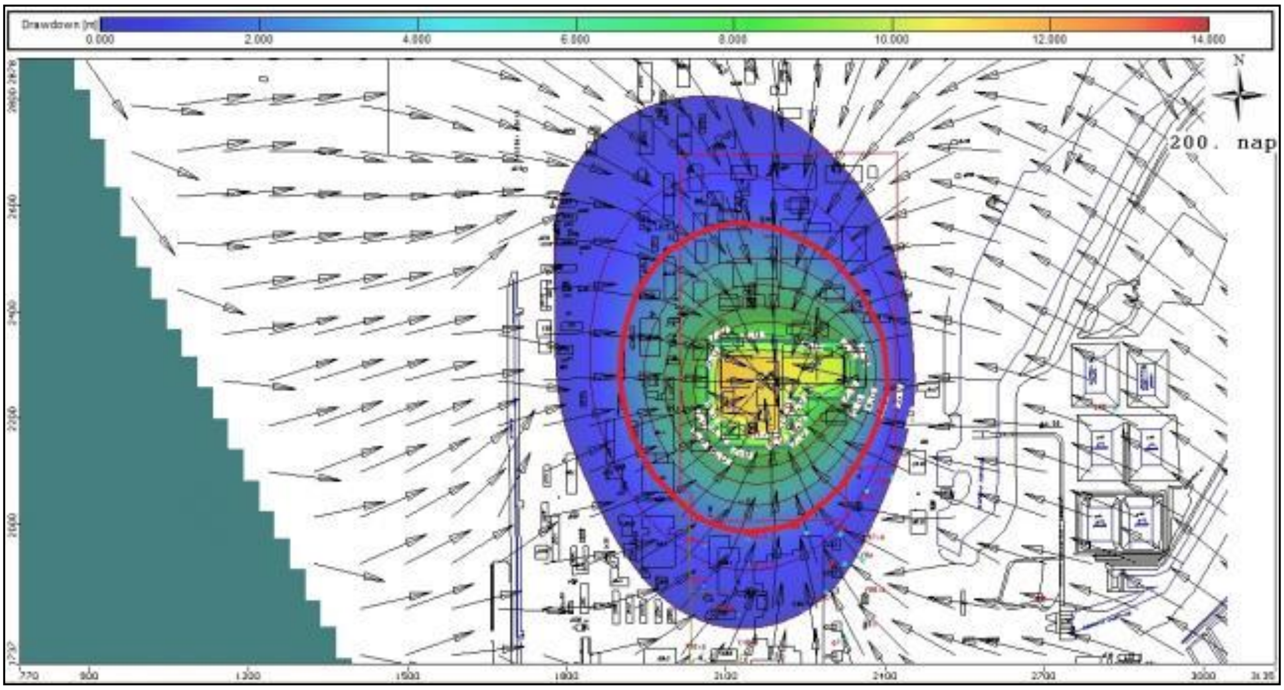


Figure 13.5.1-8: Extent of the depression cone and the flow field on the 200th day of the assessment period.

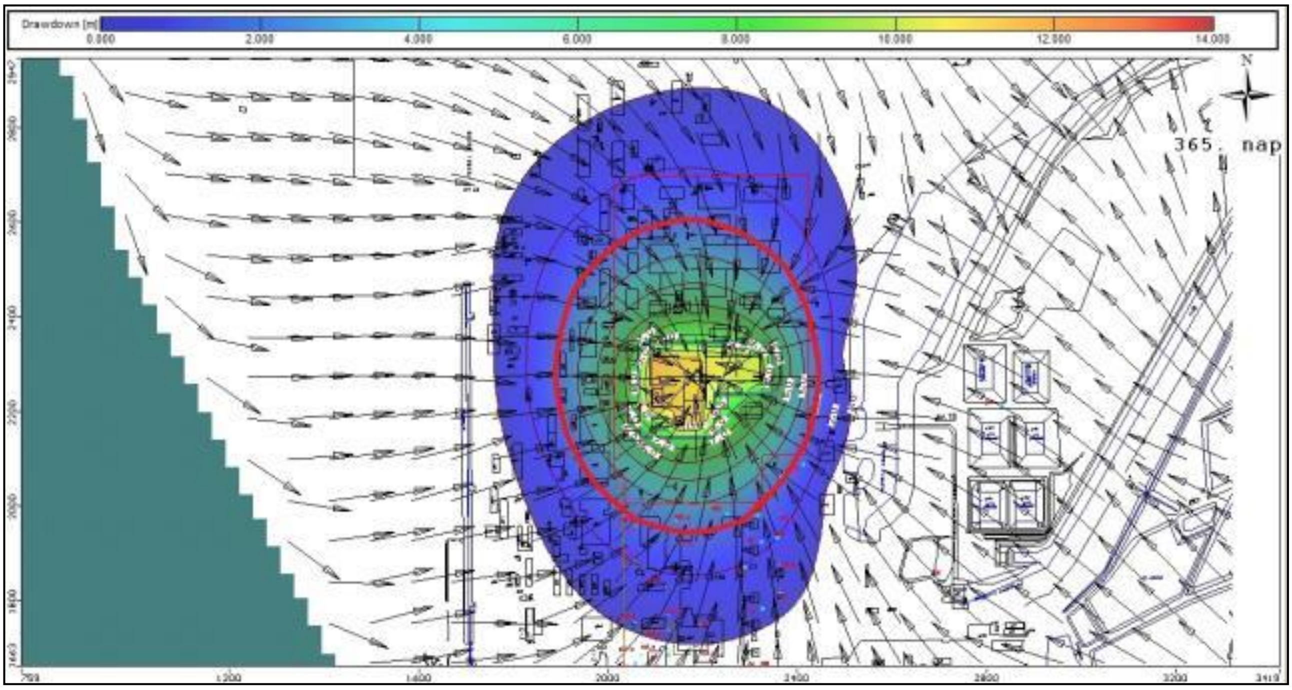


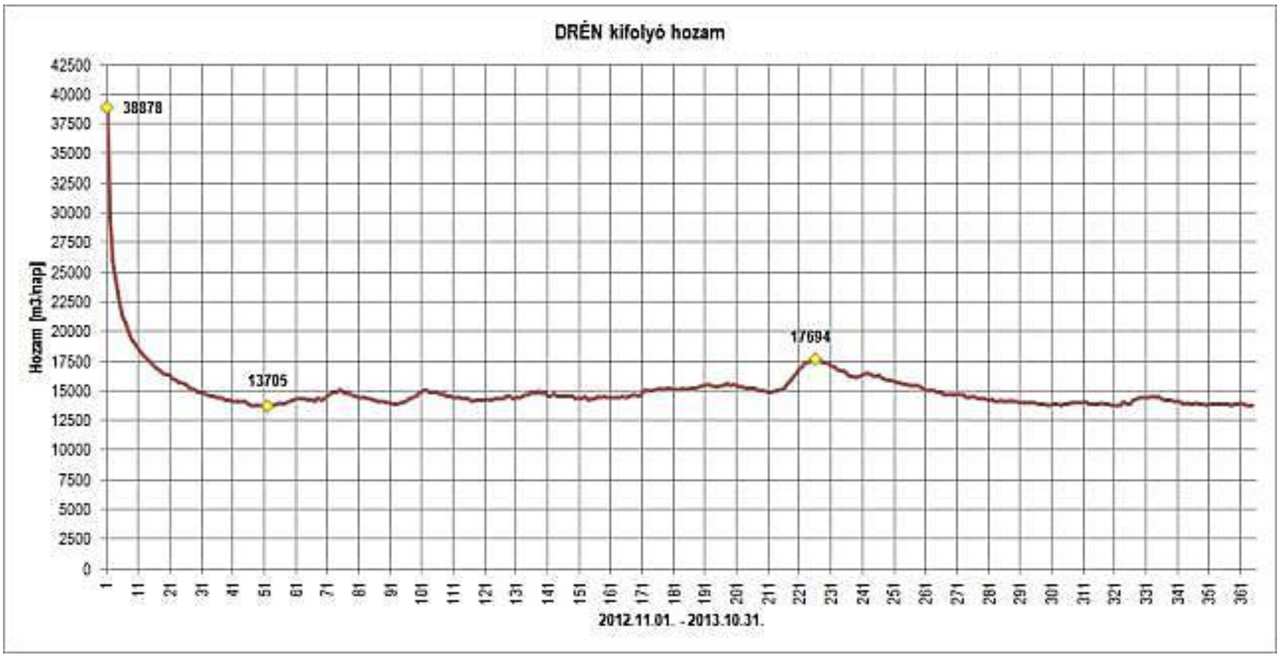
Figure 13.5.1-9: Extent of the depression cone and the flow field on the 365th day of the assessment period.

We have arranged the monitoring wells having suffered a water level decrease more than 3 meters in a table, out of which the T38/A, T46/A, T48/A and the T49/A wells are closest to the current nuclear power plant. Based on these wells, it is likely that 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 during the years, and impacts of at least this extent are still present as a consequence of fluctuations of the Danube water level.

Name of well	X-Model	Y-Model	X-Local	Y-Local	Measured water level [mBf]	Calculated water level [mBf]	Calculated-measured [m]	Time
C1.2/A	2189.277	2177.291	1265.416	11990.45	88.4	77	-11.4	365
C2.2/A	2245.759	2423.758	1324.59	12236.29	87.95	81.97668	-5.973323	365
R64/A	2280.675	2124.917	1356.236	11937.08	88.15	84.5181	-3.631903	365
T38/A	2058.694	1960.146	1132.466	11774.75	89.09	85.83922	-3.250782	365
T46/A	2144.098	1908.944	1217.306	11722.61	88.92	85.90364	-3.016359	365
T48/A	2142.025	1941.282	1215.587	11754.97	88.86	85.46479	-3.39521	365
T49/A	2142.69	1954.825	1216.399	11768.51	88.84	85.25167	-3.588329	365

Table 13.5.1-1: Effect of dewatering of the working pit in individual monitoring wells.

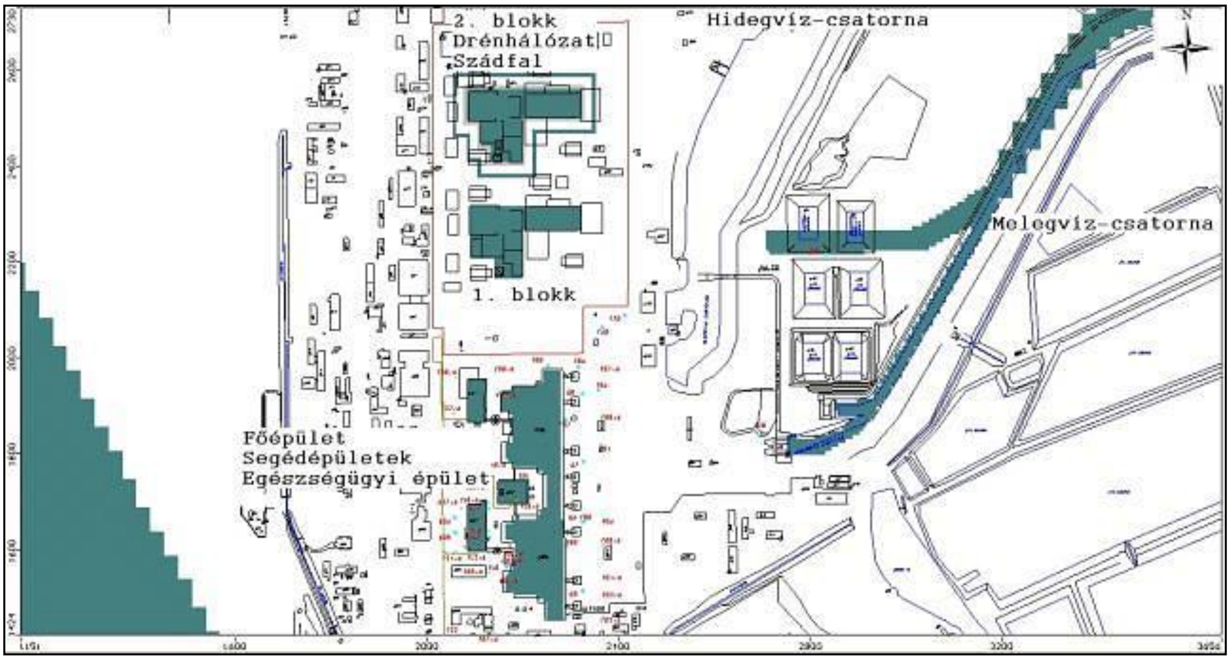
Total dewatering of the working pit can be achieved over a period of 50 days at a water extraction yield of 16930 m^3/day. In order for the working pit to remain dry during the relevant works, a theoretical 13705 m^3/day water extraction yield is necessary, which is highly dependent on the current water level of the Danube. The Danube flood waves may increase the amount of water to be extracted as shown in Figure 13.5.1-10. On 11/06/2013, the Danube water level exceeded 94 mBf and at that time, the water amount to be extracted increased to 17694 m^3/day.



DRÉN kifolyó hozam-DRAIN discharge
Hozam [m³/nap]-Discharge rate [m³/day]

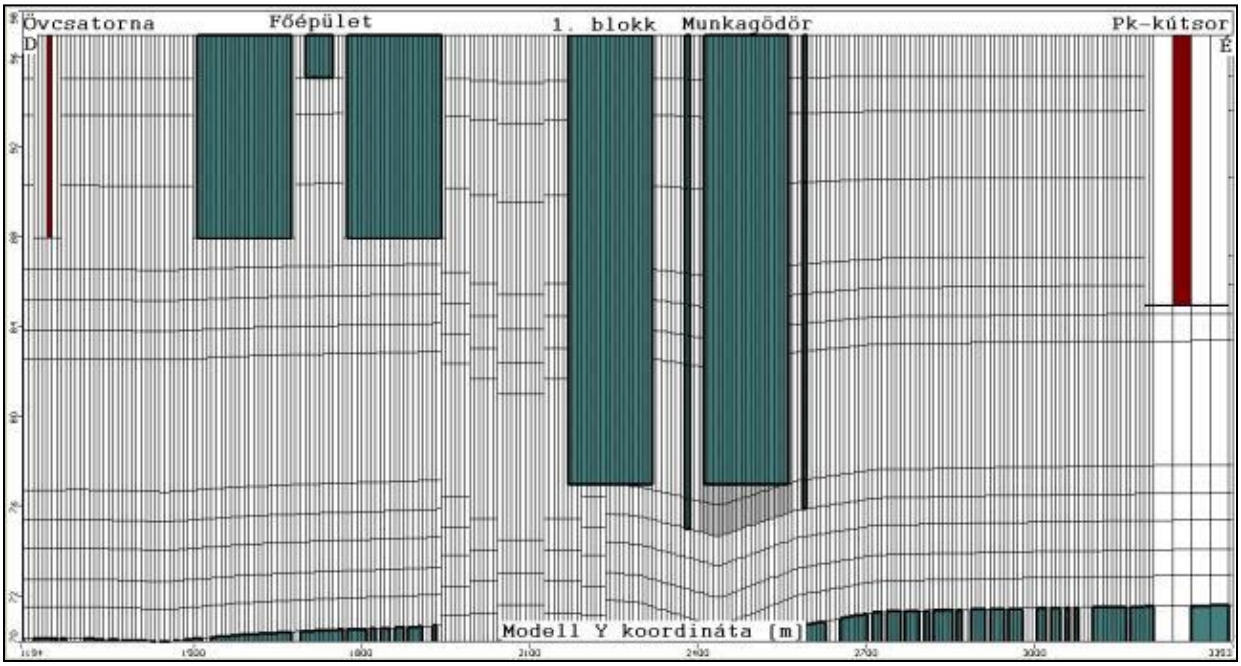
Figure 13.5.1-10: Effluent water quantity needed for draining the working pit and keeping it dry.

The deepening and dewatering of the working pit of the second unit will shift in time, so we have assumed that the static water level is restored after the foundation of the first unit is completed, which already includes the impact of the first unit compared to the baseline condition.



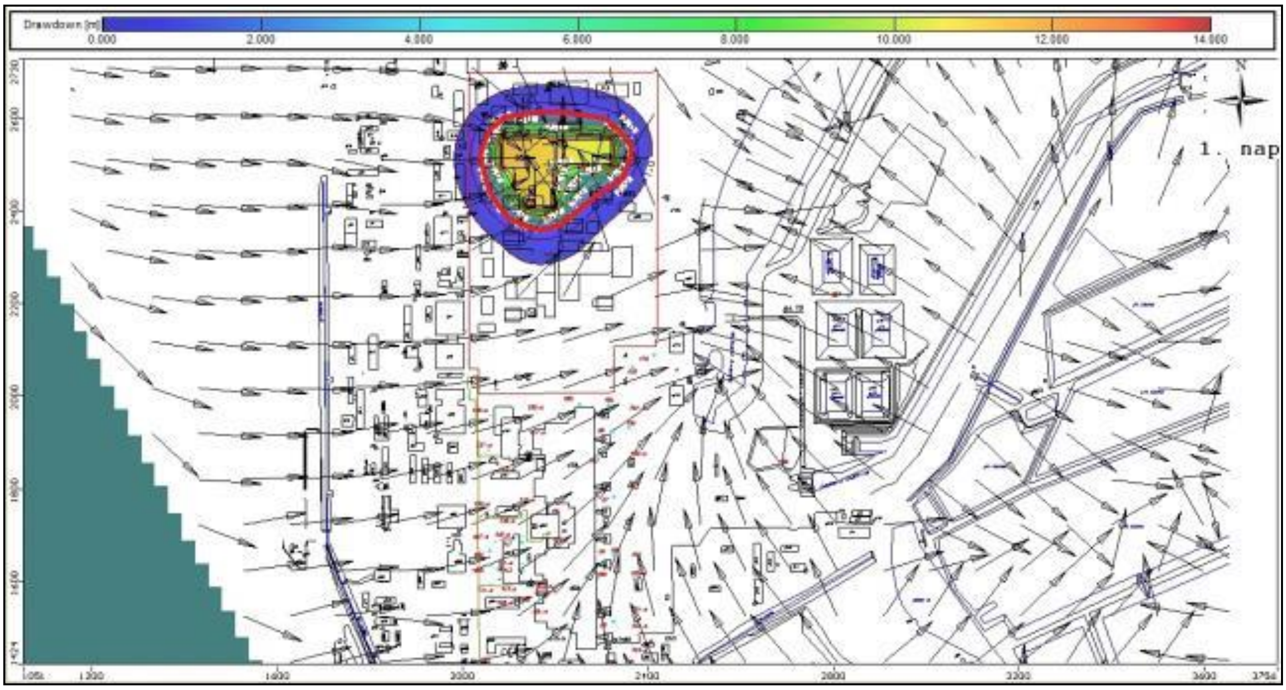
Hidegvíz-csatorna-Cold water canal
Melegvíz-csatorna-Hot water canal
2. blokk-Unit 2
Drénhálózat-Drain network
Szádfal-Sheeting wall
1. blokk-Unit 1
Főépület-Main building
Segédépületek-Auxiliary buildings
Egészségügyi épület-Medical building

Figure 13.5.1-11: Horizontal position of the second working pit.



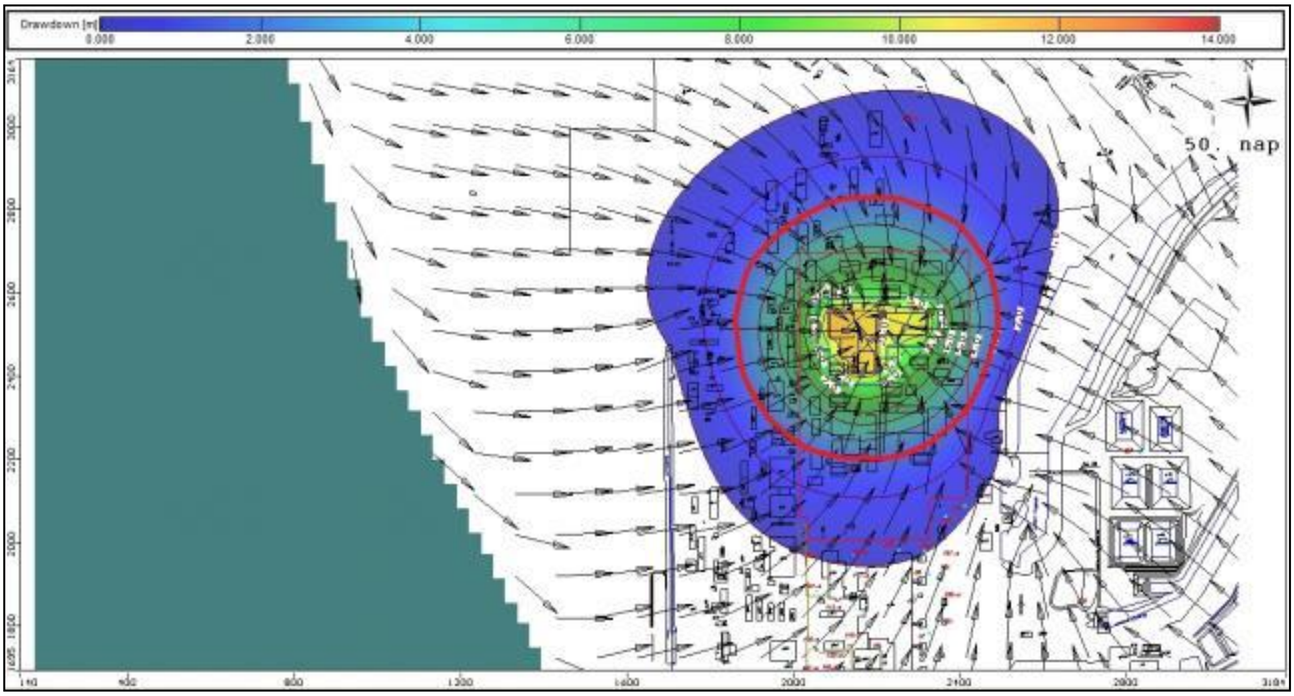
Övcsatorna-Diversion ditch
Főépület-Main building
1. blokk-Unit 1
Munkagödör-Working pit
PK-kútsor-PK battery of wells
Modell Y koordináta [m]-Model Y co-ordinate [m]

Figure 13.5.1-12: Vertical image of the second working pit.



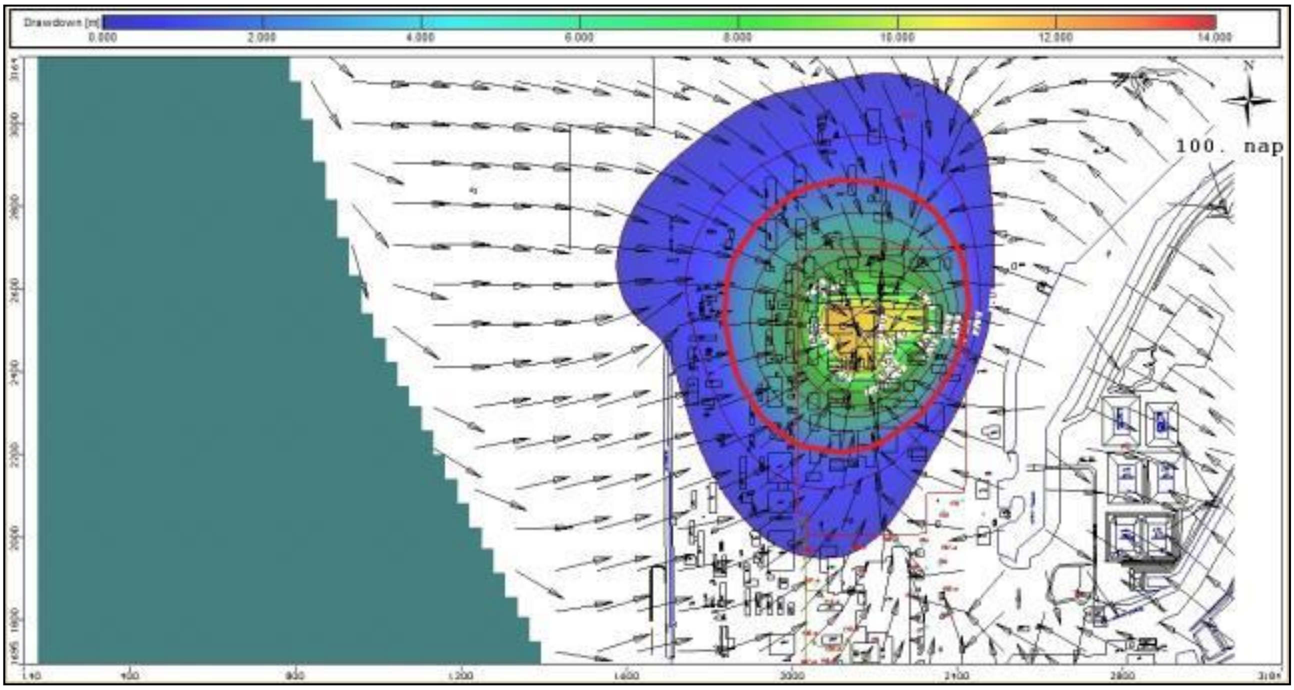
1. nap – 1st day

Figure 13.5.1-13: Extent of the depression cone and the flow field at the beginning of the assessment period.



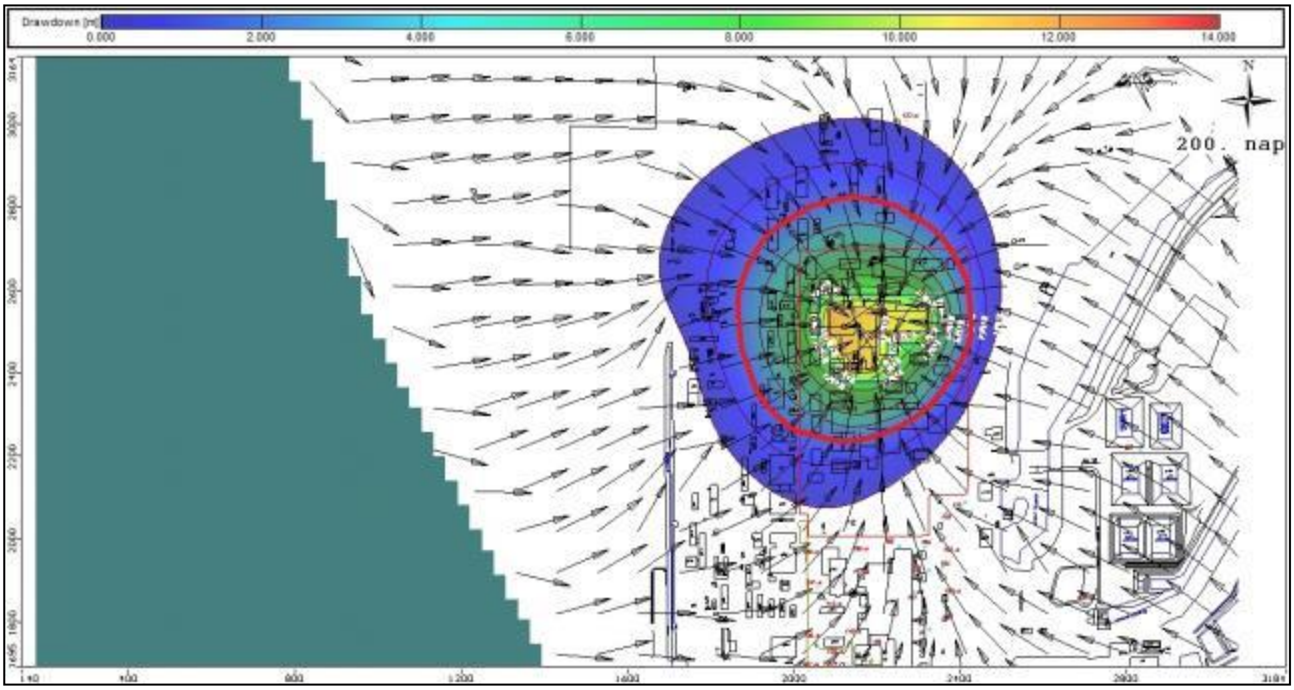
50. nap – 50th day

Figure 13.5.1-14: Extent of the depression cone and the flow field on the 50th day of the assessment period.



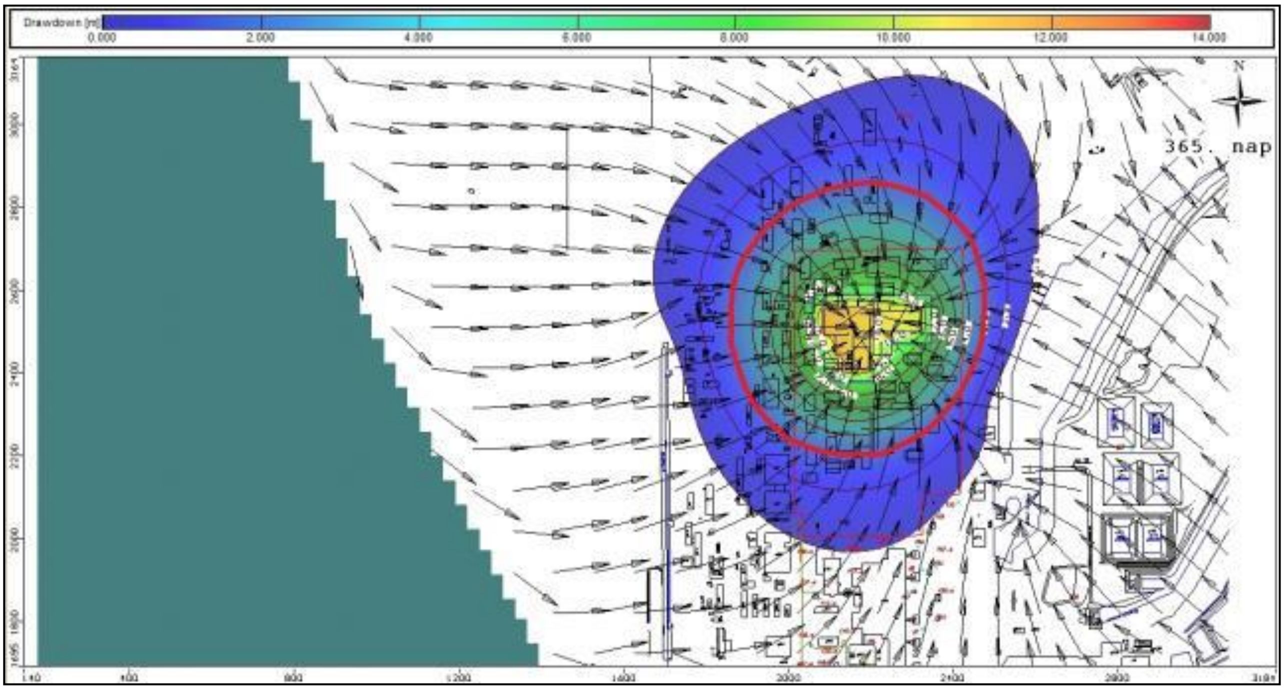
100. nap – 100th day

Figure 13.5.1-15: Extent of the depression cone and the flow field on the 100th day of the assessment period.



200. nap – 200th day

Figure 13.5.1-16: Extent of the depression cone and the flow field on the 200th day of the assessment period.



365. nap – 365th day

Figure 13.5.1-17: Extent of the depression cone and the flow field on the 365th day of the assessment period.

During dewatering of the working pit of the second unit, a minor decrease of the water level can be observed because the floor areas of facilities belonging to the 2nd unit are smaller. The impact area does not extend to the northern tip of the current units, so no effect whatsoever can be expected in the area of existing units. However, when making the foundation of the first unit, the impact of dewatering of the second unit must be taken into account.

Name of well	X-Model	Y-Model	X-Local	Y-Local	Measured water level [mBf]	Calculated water level [mBf]	Calculated-measured [m]	Time
C1.2/A	2189.277	2177.291	1265.416	11990.45	88.4	85.42711	-2.97289	365
C2.2/A	2245.759	2423.758	1324.59	12236.29	87.95	79.38374	-8.56626	365
R64/A	2280.675	2124.917	1356.236	11937.08	88.15	86.828	-1.32201	365
T38/A	2058.694	1960.146	1132.466	11774.75	89.09	87.8017	-1.2883	365
T46/A	2144.098	1908.944	1217.306	11722.61	88.92	87.74595	-1.17405	365
T48/A	2142.025	1941.282	1215.587	11754.97	88.86	87.56118	-1.29882	365
T49/A	2142.69	1954.825	1216.399	11768.51	88.84	87.47144	-1.36856	365

Table 13.5.1-2: Effect of dewatering of the working pit in individual monitoring wells.

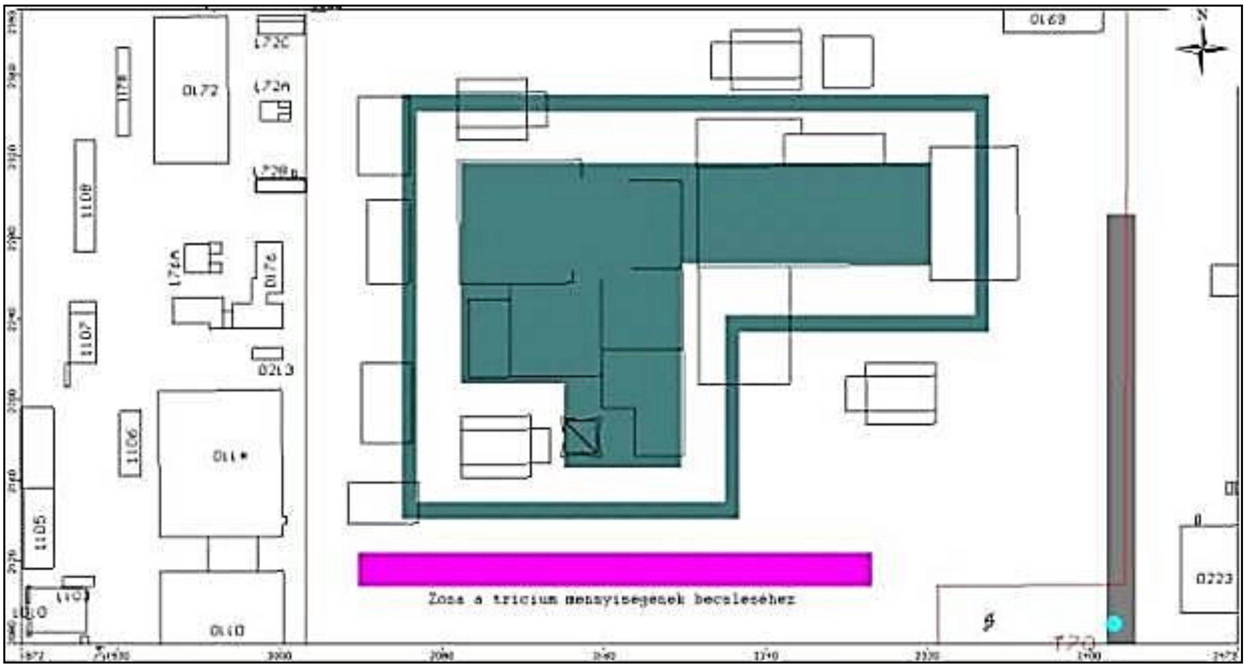
Total dewatering of the second working pit can be achieved over a period of 50 days at a water extraction yield of 16186 m^3/day. In order for the working pit to remain dry during the relevant works, a theoretical 12846 m^3/day water extraction yield is necessary, which is highly dependent on the current water level of the Danube. The Danube flood waves may increase the amount of water to be extracted as shown in Figure 13.5.1-18. On 11/06/2013, the Danube water level exceeded 94 mBf and at that time, the water amount to be extracted increased to 16209 m^3/day.

DRÉN kifolyó hozam-DRAIN discharge
Hozam [m³/nap]-Discharge rate [m³/day]

Figure 13.5.1-18: Effluent water quantity needed for draining the second working pit and keeping it dry.

13.5.1.1.2 Estimate of the tritium quantity of water removed from the working pit

We have used two methods to estimate the amount of tritium. One method calculated with the product of the water quantity passing through the zone defined in the southern vicinity of the foundation working pit and the tritium activity concentration. To do this, we have to place a zone for which the program calculates the amount of water passing through during the study period. Among the values, we will select the maximum and minimum amount of water. This is associated with the value of the maximum tritium activity concentration measurable in the vicinity of the zone, which means approximately 80 Bq/dm^3 in the present case. The product of the two may yield an approximate value.



Zóna a tricium mennyiségének becsléséhez - A zone defined for estimating the amount of tritium

Figure 13.5.1-19: A zone defined for estimating the amount of tritium.

Zónán áthaladó vízmennyiség-Volume of water passing through the zone
Vízmennyiség [m³/nap]-Water volume [m³/day]
Napok-Days

Figure 13.5.1-20: Annual volume of water passing through the zone

Full volume rate of flow in the zone: Qv = 2701.5 – 4171.1 m^3/day

Typical maximum activity concentration along the zone: I = 80 Bq/dm^3

Daily amount of tritium activity passing through the zone. QT = Qv x I = (216 - 333) MBq/day

For this second method, we have recorded a tritium activity concentration distribution in an east-west section along the give zone, on which a grid with a surface of ~9 m^2 has been placed. The average flow velocity along the zone was found to be 3.2E-6 m/s, which corresponds to ~0.28 m/day. We have multiplied the velocity with the activity concentrations characteristic of the relevant surfaces and the size of elementary surfaces and then, we have summed the values obtained.

Q = [(385 x 9 x 0.1+
289 x 9 x 0.5+
256 x 9 x 1+
224 x 9 x 2+
185 x 9 x 5+
152 x 9 x 10+
117 x 9 x 20+
97 x 9 x 30+
80 x 9 x 40+
62 x 9 x 50+
45 x 9 x 60+
29 x 9 x 70+
17 x 9 x 80) x 1000](Bq/m) x 0.28 (m/day)

Qtotal = 52.9 MBq/day

The second method gives a much more realistic estimate of the tritium quantity than the first one because it does not calculate with the extreme values of the tritium concentration of water passing through the zone, but it divides the latter to smaller (9m^2) cells and with the expected value of the tritium concentration there. At the same time, it is also sufficiently conservative, because we did not consider porosity, i. e. we considered as if water was flowing through the entire cross-section of the given surface although only ca. 30% of the latter is "useful" in terms of water flow.

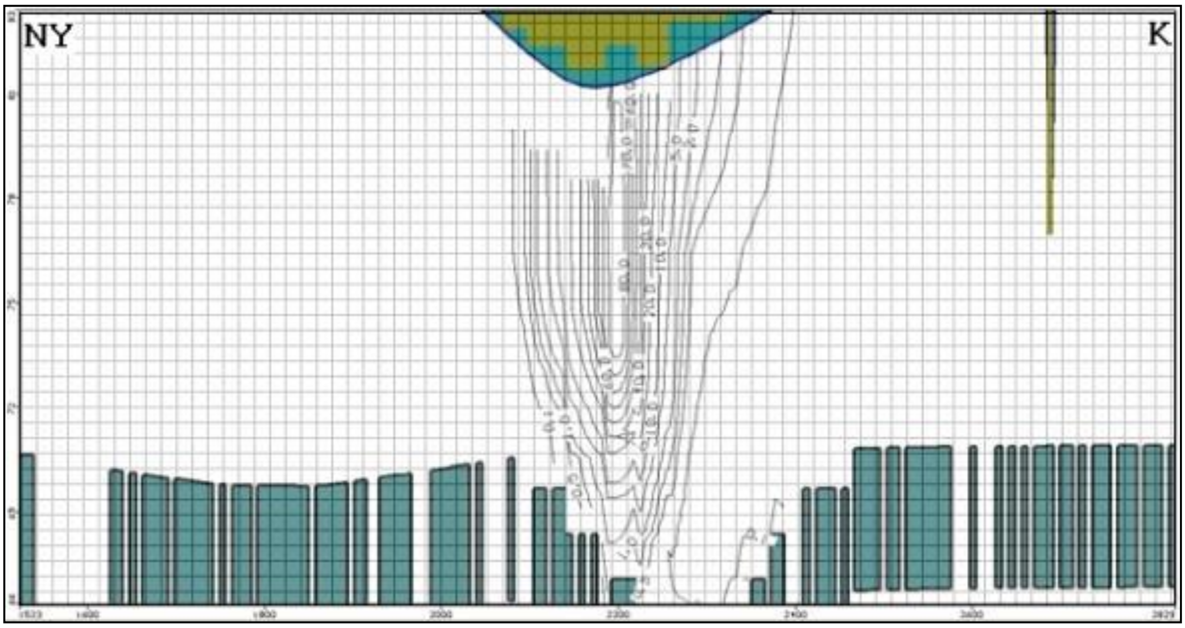


Figure 13.5.1-21: Distribution of tritium along the east-west section.

13.5.1.2 Indirect effects

13.5.1.2.1 Impact of draining into the Danube of water removed during dewatering

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.

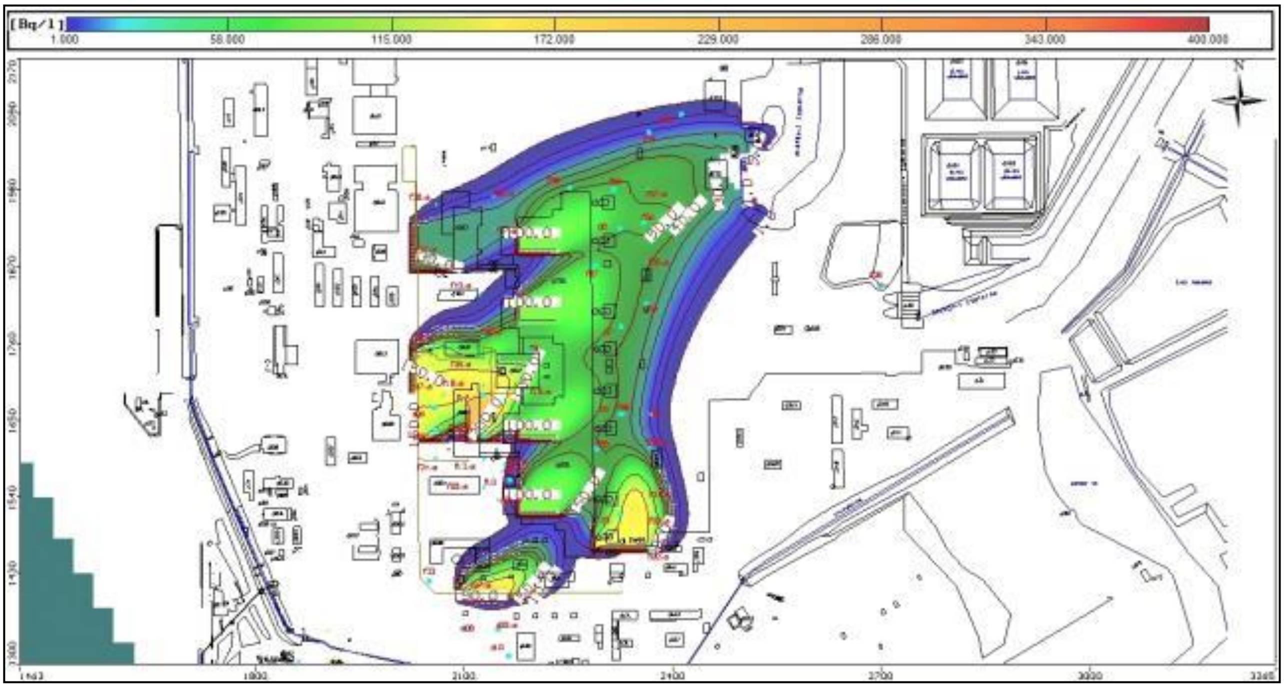
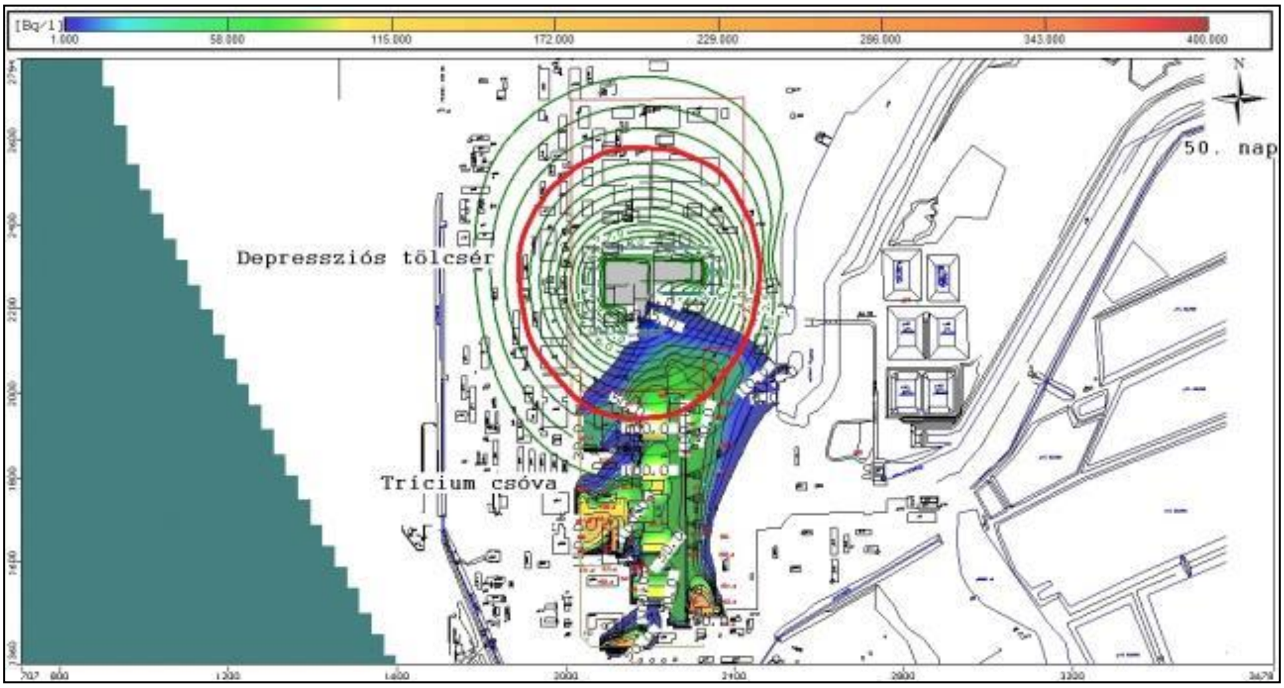


Figure 13.5.1-22: Direction of the tritium plume flow in a baseline status.

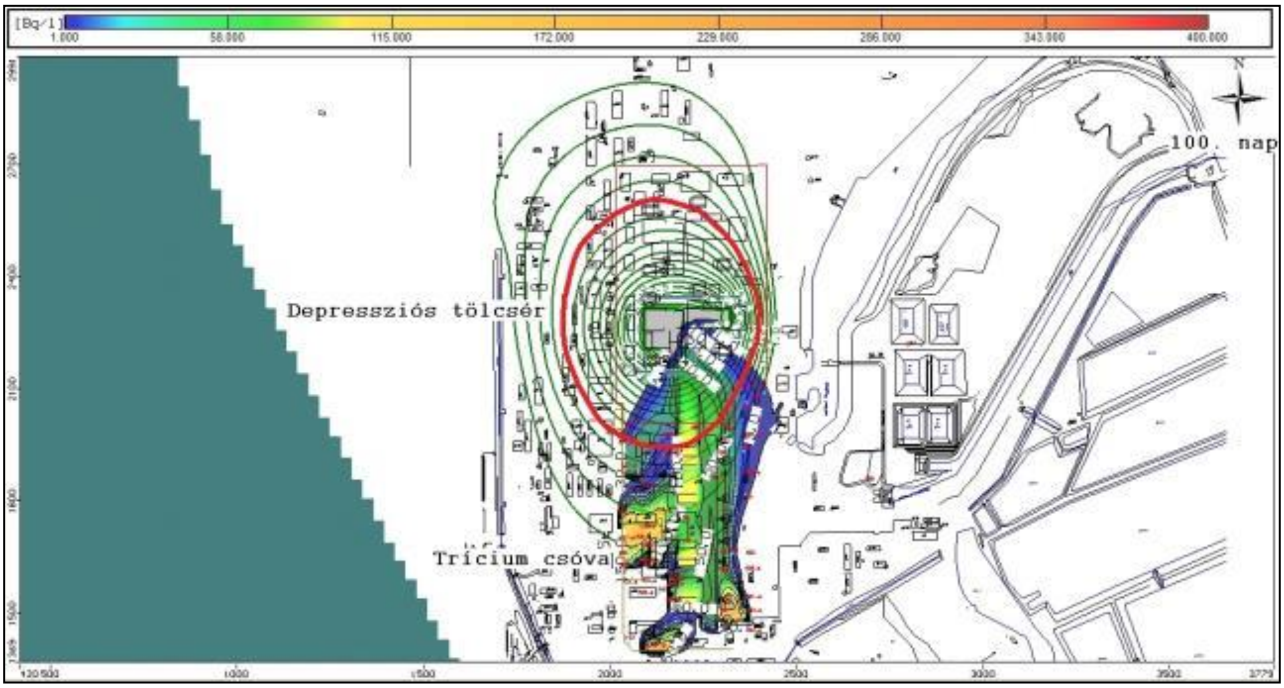
Depressziós tölcsér-Depression cone
Trícium csóva-Tritium plume
1. nap-1st day

Figure 13.5.1-23: Impact of the depression cone on the flow direction of the tritium plume (1st day)



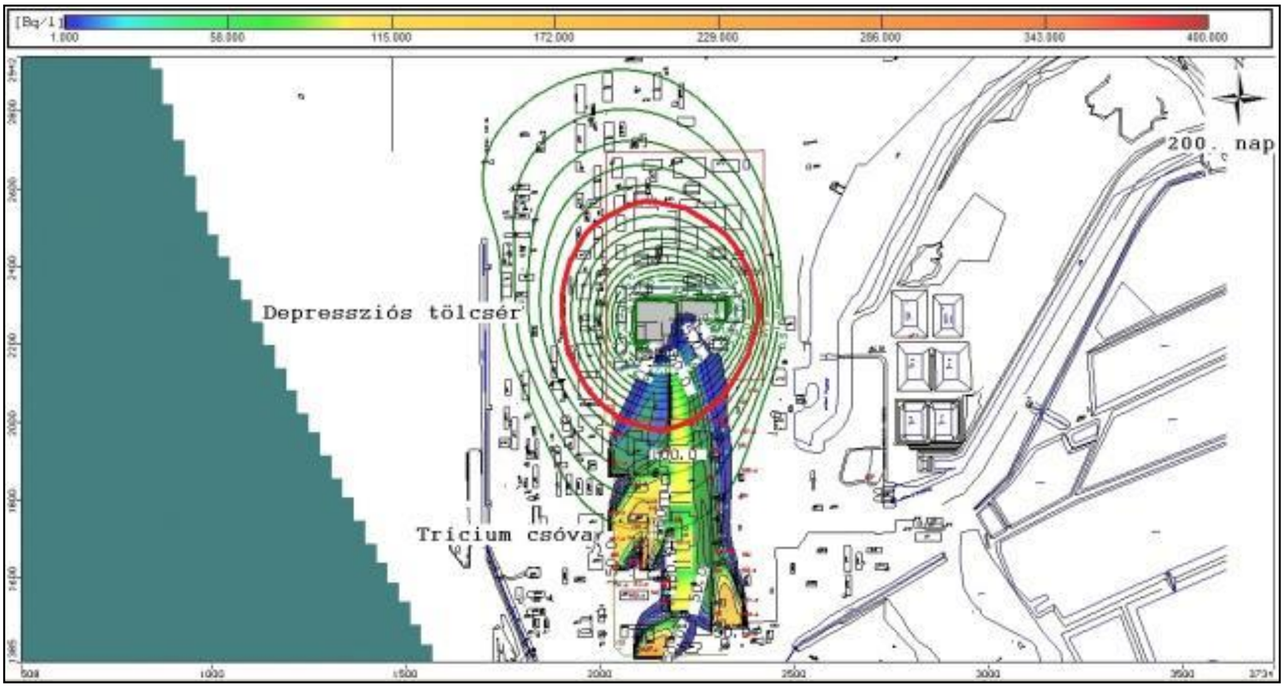
Depressziós tölcsér-Depression cone
Trícium csóva-Tritium plume
50. nap-50th day

Figure 13.5.1-24: Impact of the depression cone on the flow direction of the tritium plume (50th day)



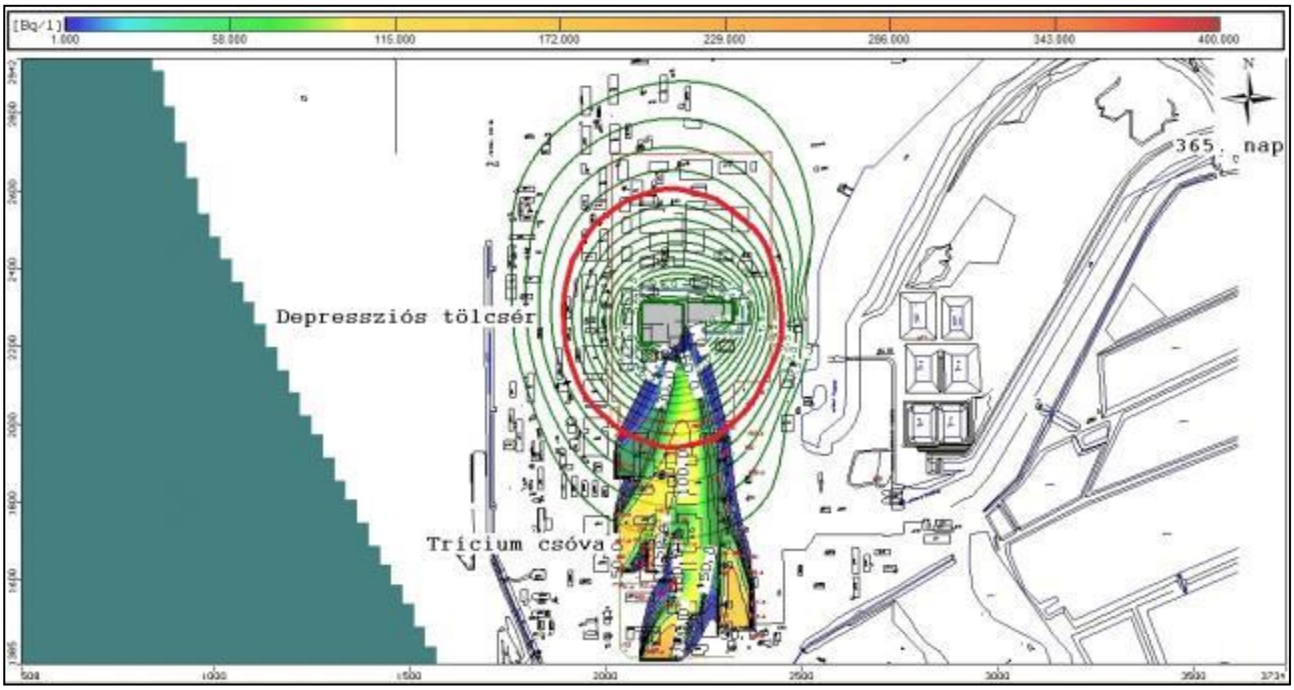
Depressziós tölcsér-Depression cone
Trícium csóva-Tritium plume
100. nap-100th day

Figure 13.5.1-25: Impact of the depression cone on the flow direction of the tritium plume (100th day)



Depressziós tölcsér-Depression cone
Trícium csóva-Tritium plume
200. nap-200th day

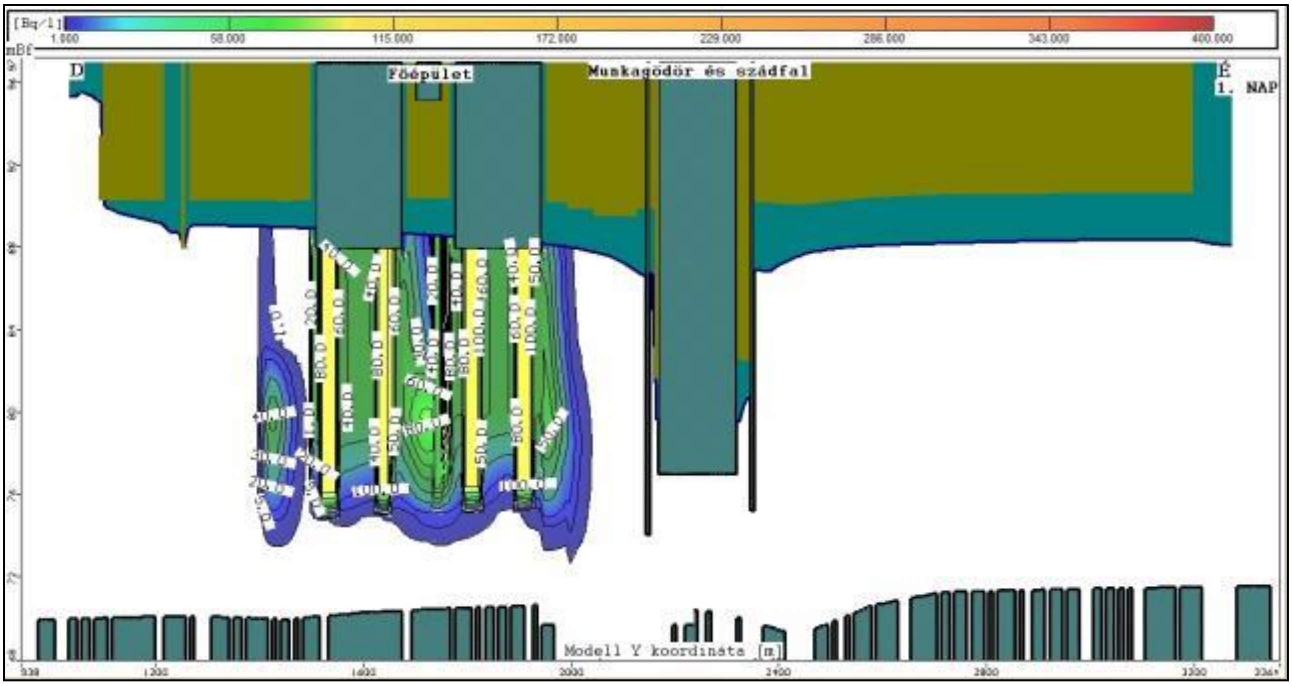
Figure 13.5.1-26: Impact of the depression cone on the flow direction of the tritium plume (200th day)



Depressziós tölcsér-Depression cone
Trícium csóva-Tritium plume
365. nap-365th day

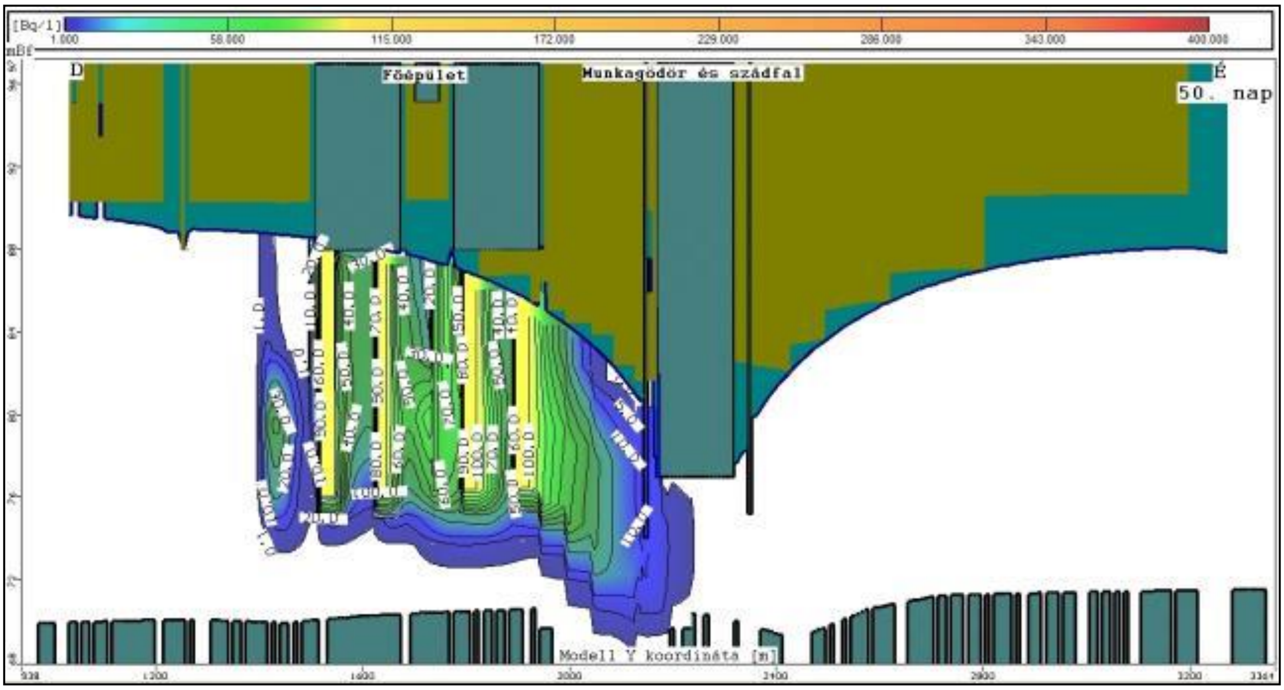
Figure 13.5.1-27: Impact of the depression cone on the flow direction of the tritium plume (365th day)

To monitor the changes as a function of depth, we have also depicted the tritium plume movement along the north-south section.



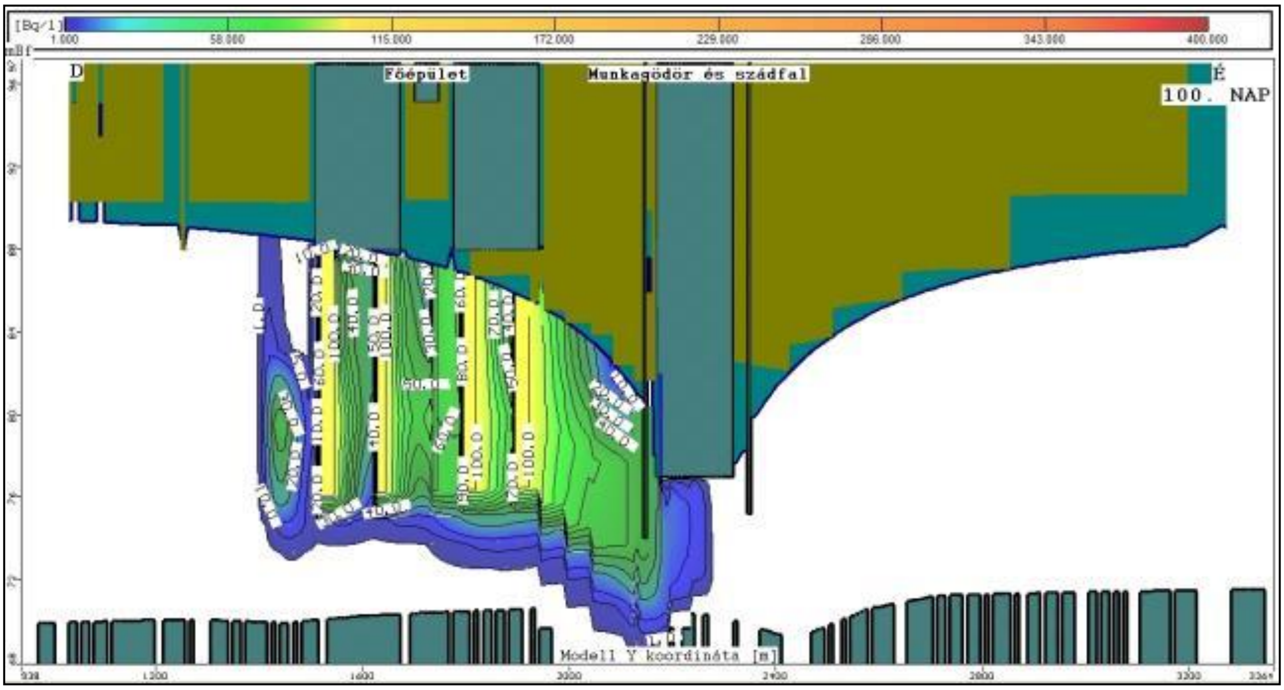
Főépület-Main building
Munkagödör és szádfal-Working pit and sheeting wall
Modell Y koordináta [m]-Model Y co-ordinate [m]
1. nap – 1st day

Figure 13.5.1-28: Vertical spread of the tritium plume (1st day).



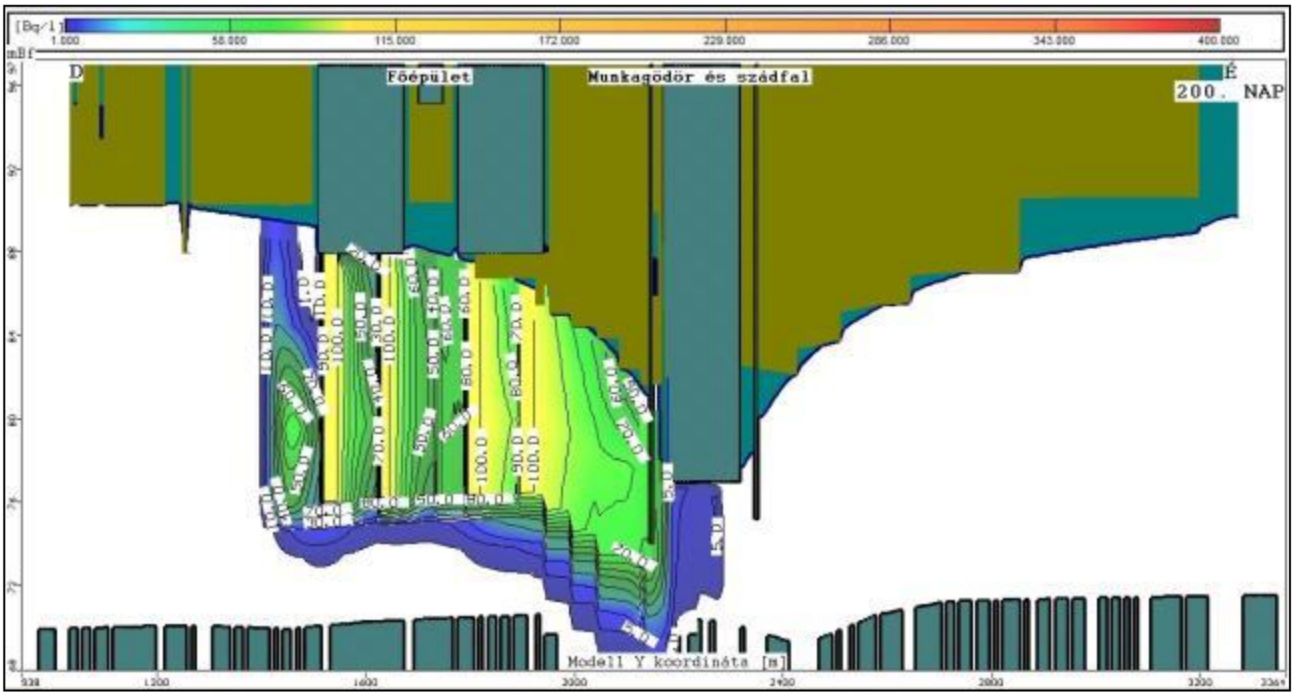
Főépület-Main building
Munkagödör és szádfal-Working pit and sheeting wall
Modell Y koordináta [m]-Model Y co-ordinate [m]
50. nap – 50th day

Figure 13.5.1-29: Vertical spread of the tritium plume (50th day).



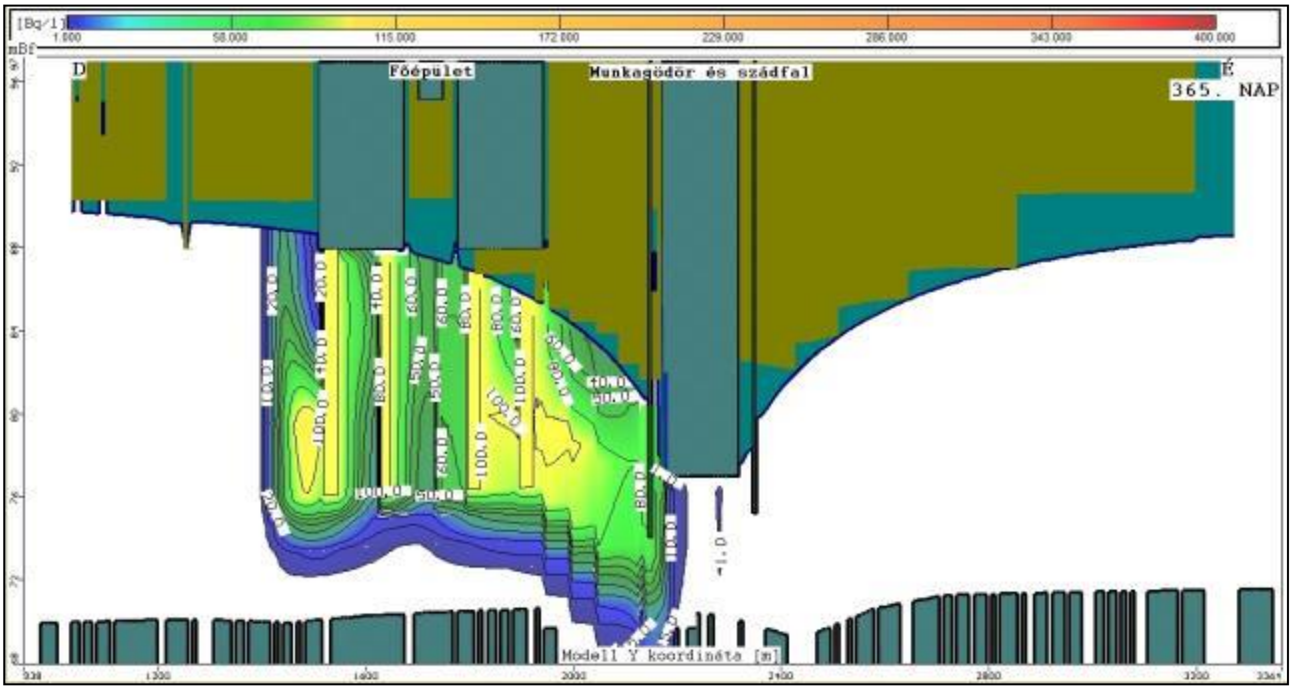
Főépület-Main building
Munkagödör és szádfal-Working pit and sheeting wall
Modell Y koordináta [m]-Model Y co-ordinate [m]
100. nap – 100th day

Figure 13.5.1-30: Vertical spread of the tritium plume (100th day).



Főépület-Main building
Munkagödör és szádfal-Working pit and sheeting wall
Modell Y koordináta [m]-Model Y co-ordinate [m]
200. nap – 200th day

Figure 13.5.1-31: Vertical spread of the tritium plume (200th day).



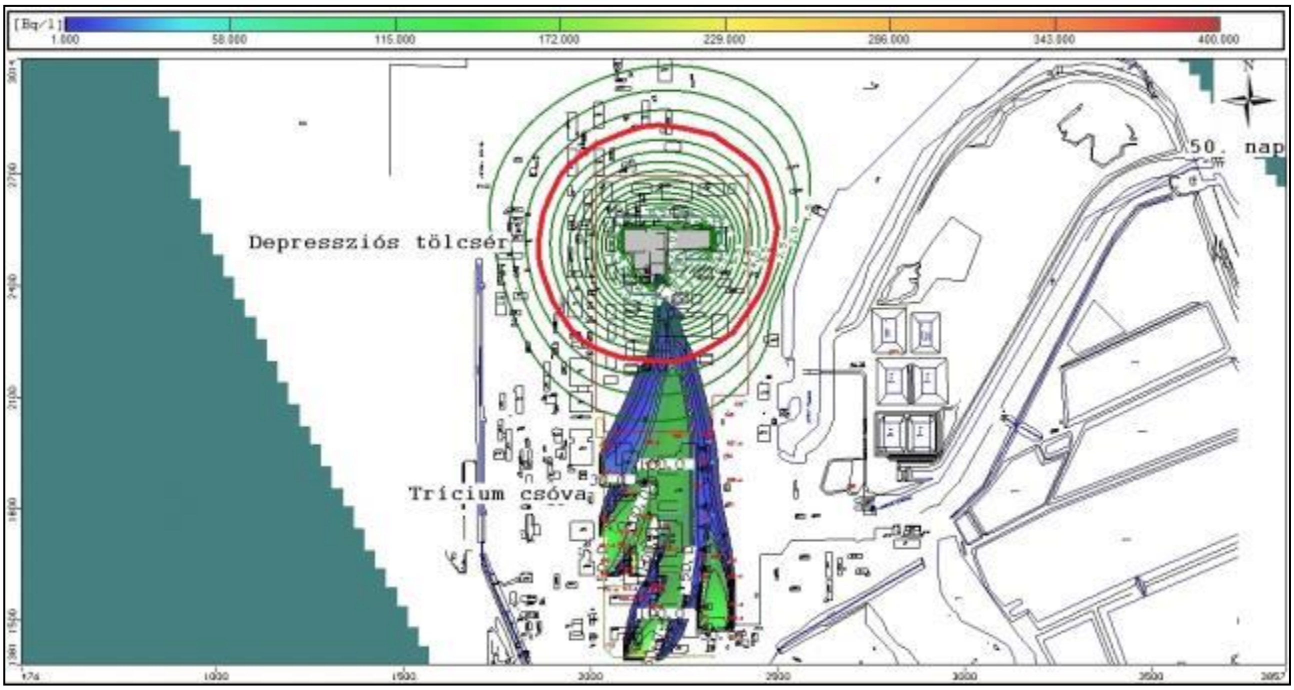
Főépület-Main building
Munkagödör és szádfal-Working pit and sheeting wall
Modell Y koordináta [m]-Model Y co-ordinate [m]
365. nap – 365th day

Figure 13.5.1-32: Vertical spread of the tritium plume (365th day).

To simulate the impact of the second working pit dewatering step, the initial values are provided by the results of the last days of the model run simulating the impact of the previous working pit dewatering step. Since we have no exact information on the progress of foundation, we have not taken into account the backfilling effect on the spread of the tritium plume. At the same time, tritium concentration values around the working pits are likely to decrease as a result of dilution and leaching, i. e. the present approach can be considered as a pessimistic estimate of the tritium quantity to be removed as a result of dewatering.

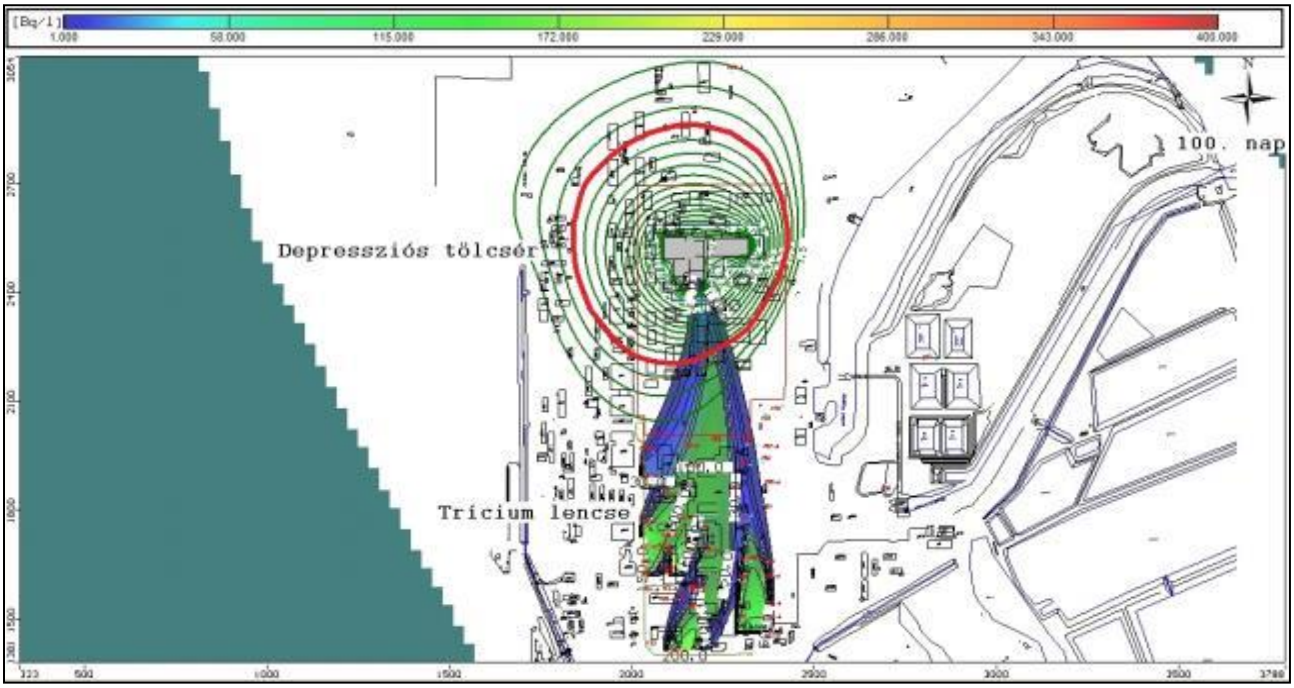
Depressziós tölcsér-Depression cone
Trícium csóva-Tritium plume
1. nap-1st day

Figure 13.5.1-33: Impact of the depression cone on the flow direction of the tritium plume (1st day)



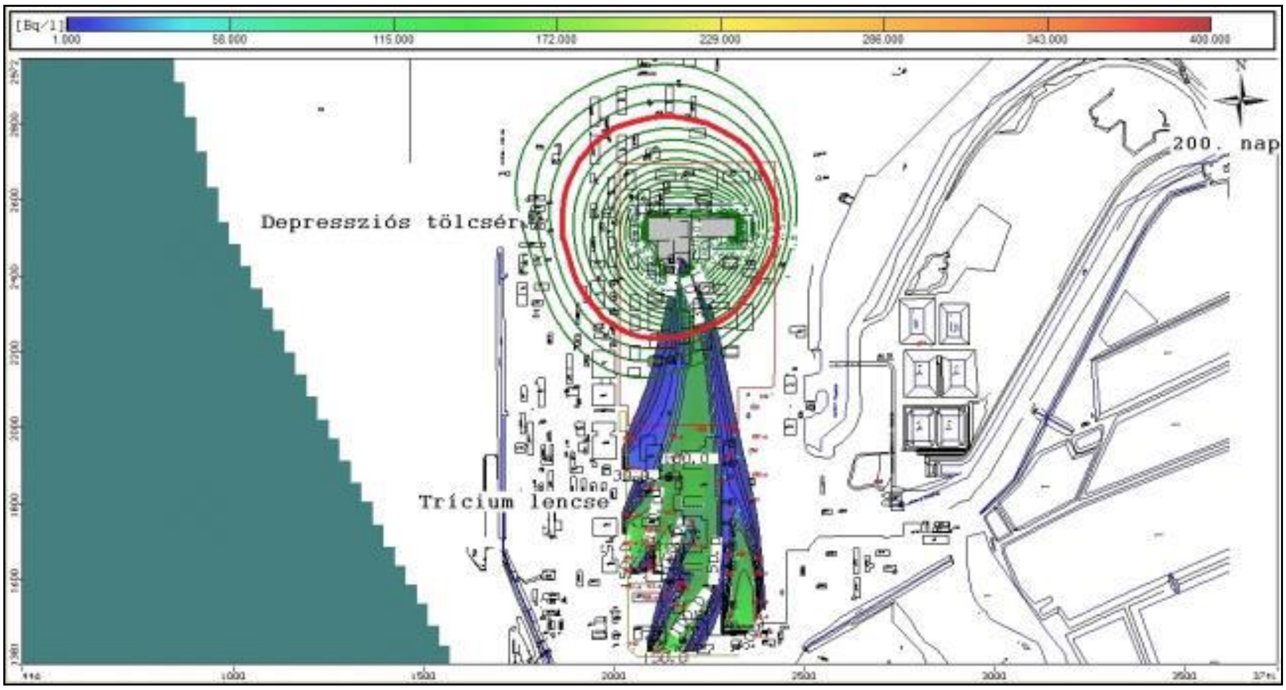
Depressziós tölcsér-Depression cone
Trícium csóva-Tritium plume
50. nap-50th day

Figure 13.5.1-34: Impact of the depression cone on the flow direction of the tritium plume (50th day)



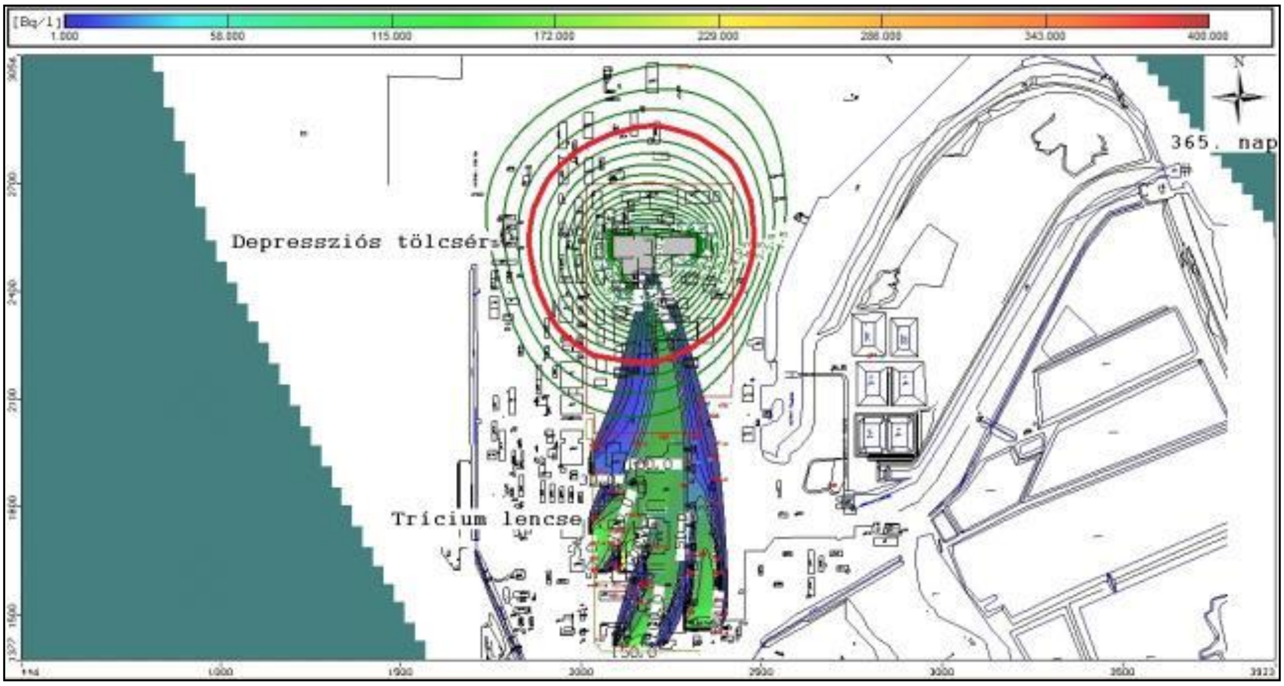
Depressziós tölcsér-Depression cone
Trícium csóva-Tritium plume
100. nap-100th day

Figure 13.5.1-35: Impact of the depression cone on the flow direction of the tritium plume (100th day)



Depressziós tölcsér-Depression cone
Trícium csóva-Tritium plume
200. nap-200th day

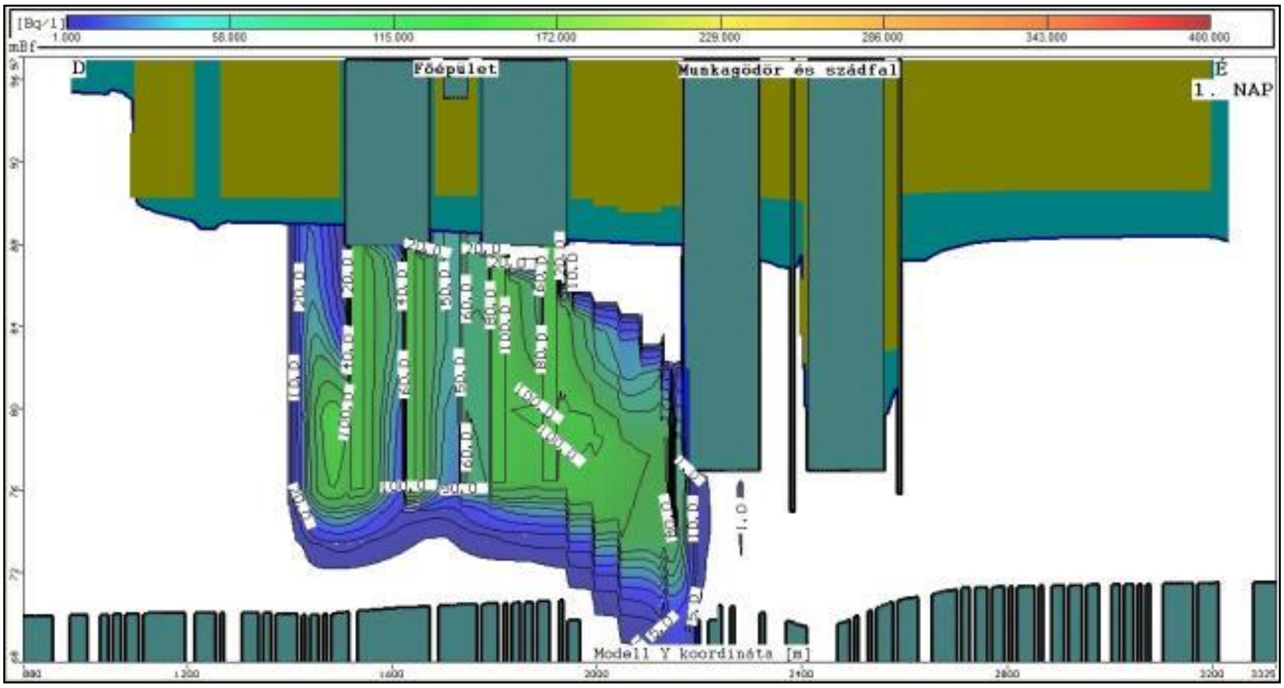
Figure 13.5.1-36: Impact of the depression cone on the flow direction of the tritium plume (200th day)



Depressziós tölcsér-Depression cone
Trícium csóva-Tritium plume
365. nap-365th day

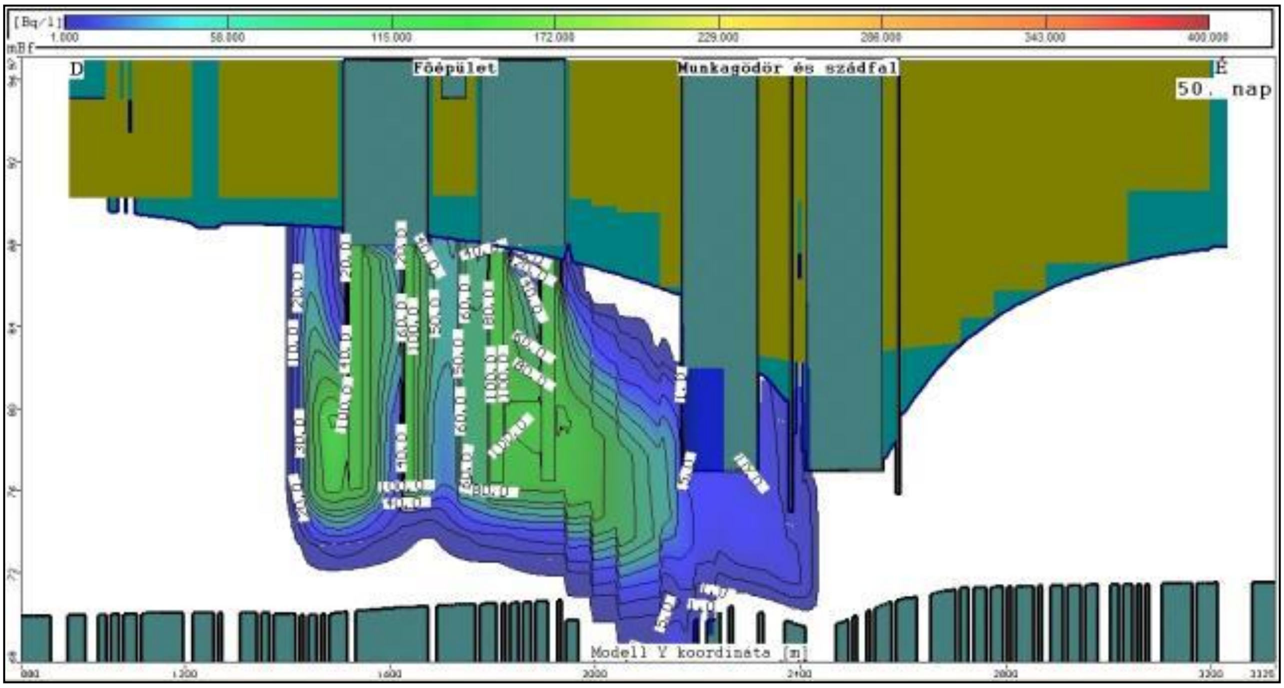
Figure 13.5.1-37: Impact of the depression cone on the flow direction of the tritium plume (365th day)

To monitor the changes as a function of depth, we have also depicted the tritium plum movement along the north-south section.



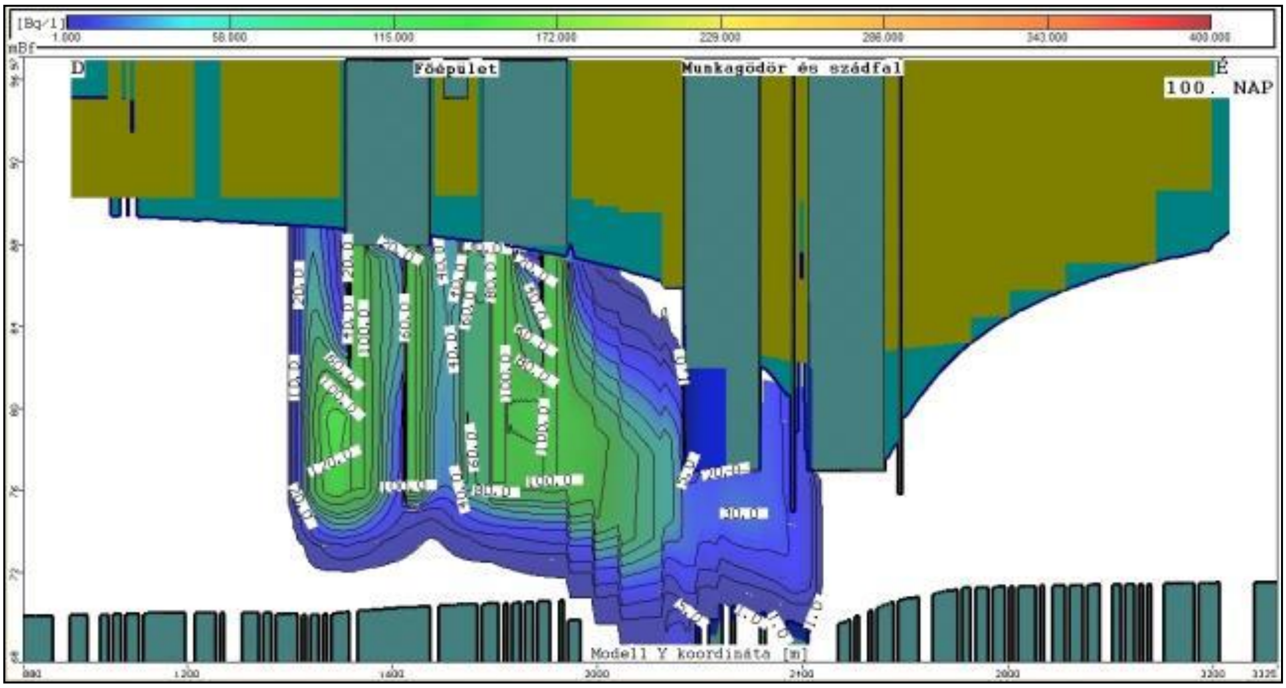
Főépület-Main building
Munkagödör és szádfal-Working pit and sheeting wall
Modell Y koordináta [m]-Model Y co-ordinate [m]
1. nap – 1st day

Figure 13.5.1-38: Vertical spread of the tritium plume (1st day).



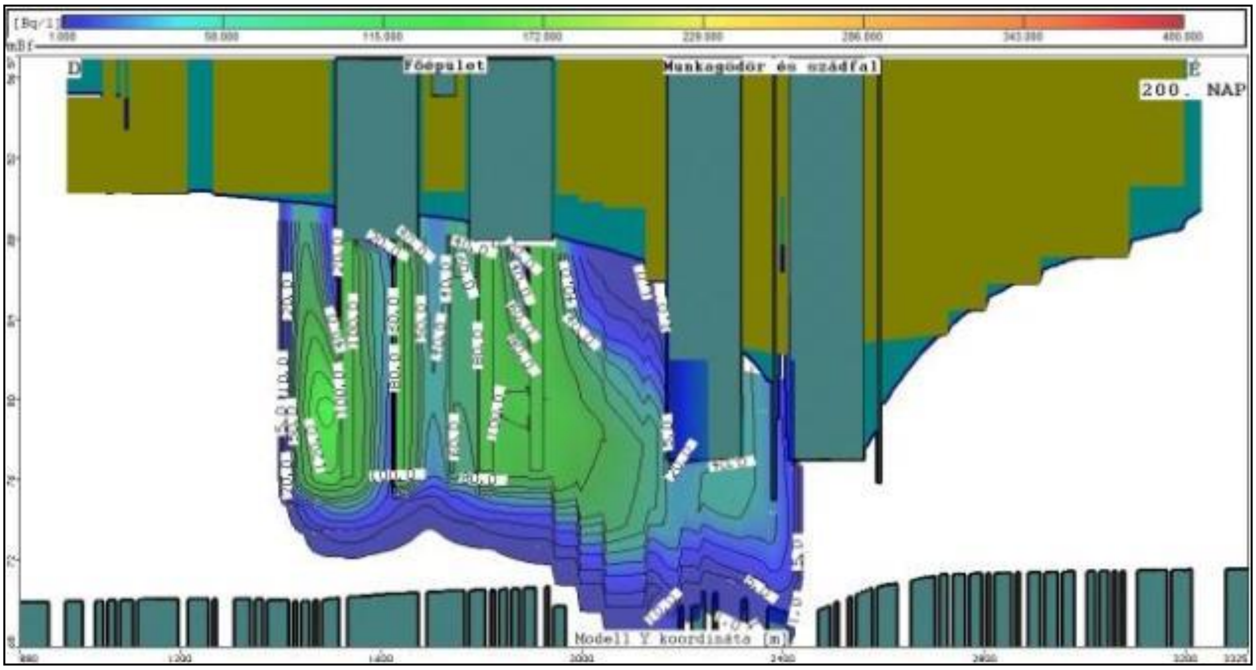
Főépület-Main building
Munkagödör és szádfal-Working pit and sheeting wall
Modell Y koordináta [m]-Model Y co-ordinate [m]
50. nap – 50th day

Figure 13.5.1-39: Vertical spread of the tritium plume (50th day).



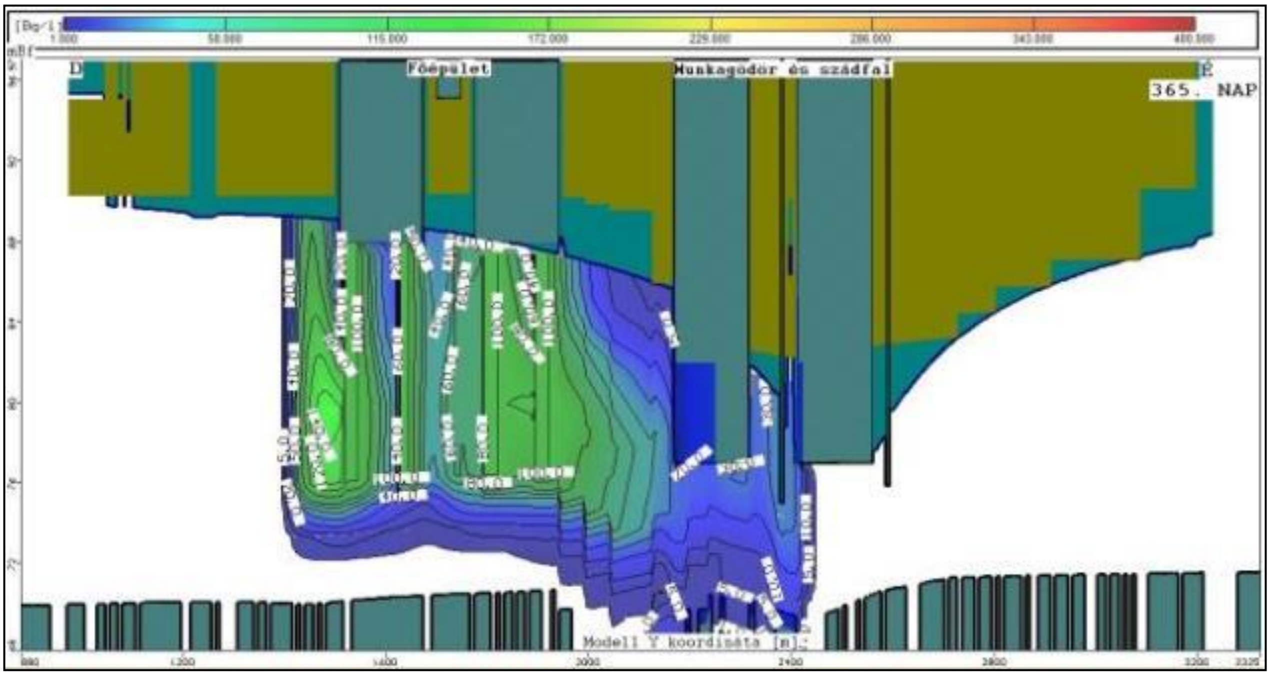
Főépület-Main building
Munkagödör és szádfal-Working pit and sheeting wall
Modell Y koordináta [m]-Model Y co-ordinate [m]
100. nap – 100th day

Figure 13.5.1-40: Vertical spread of the tritium plume (100th day).



Főépület-Main building
Munkagödör és szádfal-Working pit and sheeting wall
Modell Y koordináta [m]-Model Y co-ordinate [m]
200. nap – 200th day

Figure 13.5.1-41: Vertical spread of the tritium plume (200th day).



Főépület-Main building
Munkagödör és szádfal-Working pit and sheeting wall
Modell Y koordináta [m]-Model Y co-ordinate [m]
365. nap – 365th day

Figure 13.5.1-42: Vertical spread of the tritium plume (365th day).

13.5.1.2.2 Impact of construction on the geological medium

The investment project significantly affects geological formations in large areas with regard to landscaping and the construction of working pits. Their dimensions are defined, in addition to those of the structures, by the status of the traffic and transports roads and the conditions of dewatering. Preliminary calculations show that the maximum quantity of earth to be excavated is approx. 800 000 m^3. The estimated maximum foundation depth is 20 metres.

Terrain preparation, terrain correction, utility relocations:

The investment area in the northern vicinity of the 4th unit of the operational power plant occupies approximately a 400 m x 700 m rectangular area. The area has been previously filled up to the design level of 97.15 mBf.

Currently there are no buildings in this part of the area, only the residues of the concrete foundations have remained here. The whole area is flat, with a part covered with large concrete slabs, the rest is covered with herbaceous vegetation (local seedlings), vegetation is mowed regularly. The underground service utilities (drain, fire water network) are still existing.

The temporary construction site of the planned investment project (76.2 ha) is connected to the construction area directly to the north. This section has already been filled up to the design level. Currently, the single-storey, lightweight halls of companies serving the nuclear power plant and industrial railway tracks are situated in the western part. The eastern and northern part of the future temporary construction site has a vacant, grassy, wooded parkland character. A bank filtered battery of wells is located at the cold water canal.

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.

Stripping of soil layers with humus content:

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. The humus containing topsoil must be separately managed and deposited for further uses in compliance with Act LIII of 1995 on the general rules concerning environmental protection and Act CXXIX of 2007 on the protection of arable land, respectively. A preliminary humus removal plan must be prepared for handling humus layers, which should be compiled by consultation with the competent professional authority (Tolna County Government Office Plant and Soil Conservation Directorate).

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.

Humus-containing soils can be excavated when making working pits, thus at present, their quantities can not be estimated

Soil dusting:

By construction of working pits 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.

Watering the area is one possible mode of protection against dust generation. Even a 3-4% water content is capable of reducing the level of dust generation to a fraction of the original value. Another, cheaper option is spraying the transport routes with sandy gravel.

Erosion of the slopes of working pits as a result of precipitation (shroud erosion).

The stability of working pits for foundations - above the groundwater table - is mostly endangered by intense precipitation. Sandy soil 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).

Effect of foundations on the subsoil:

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.

With regard to the currently operating reactor units, experience has shown that the majority compaction under the foundations (thus, subsidence due to volume decrease) took place relatively quickly, in a few years. Up to the end of the 1980s, the degree of subsidence was 55.5 mm under the 1st and 2nd units, 58.1 mm under the 3rd unit and 72.6 mm under the 4th unit. The subsidence rate is greatly reduced after the initial period (a few years), but total consolidation only occurred a few decades later. The depth limit of tensions giving rise to subsidence and arising from the weight of the relevant facilities can be specified to be 47 m according to calculations.

13.5.2 IMPACT AREAS OF CONSTRUCTION

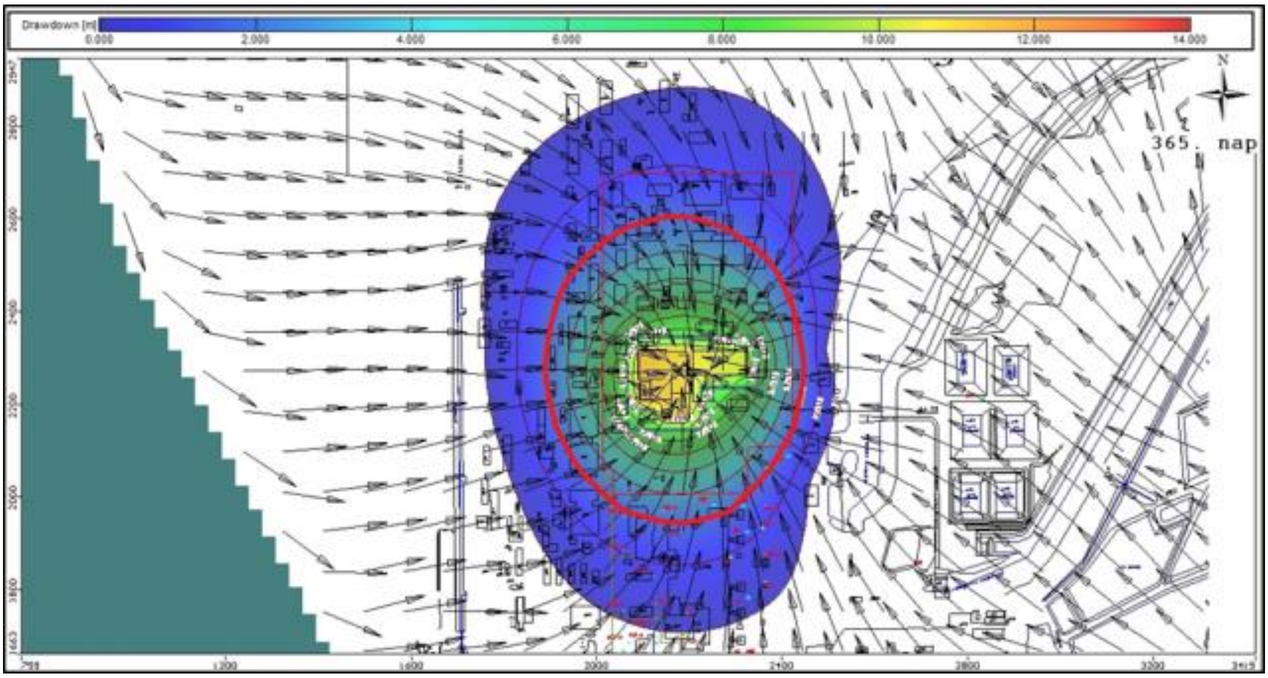
The impact of preparatory works is neutral. During construction, the effect of extraction of humus-containing soils occurs on a one-off basis, it can be properly demarcated in time. The humus-containing soils currently in a buried state are utilized, so this can be regarded as an improving effect.

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 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.

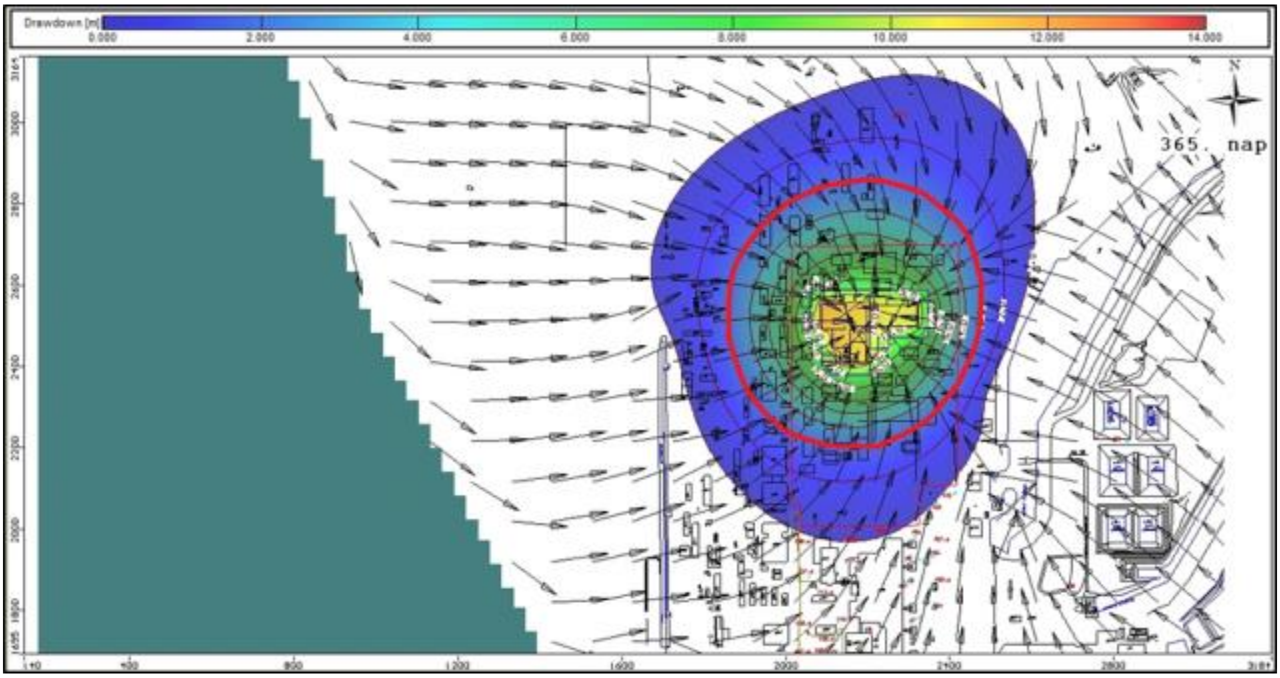
13.5.2.1 Direct effects

We have defined the impact of dewatering of working pits with the average value of annual water level fluctuations in all monitoring wells of the site (~3.12 m = 3 m). The impact area extends to the line of 3-meter water level reduction (marked by red contour).



365. nap – 365th day

Figure 13.5.2-1: Impact area of dewatering the first working pit



365. nap – 365th day

Figure 13.5.2-2: Impact area of dewatering the second working pit

13.5.2.2 Indirect effects

In this chapter, we will assess the amount of radioactive activity concentration increase caused by the power plant under pessimistic conditions (conservative estimate) in the Danube and thus, indirectly in a bank filtrated water base. As a conservative estimate, we have used the smallest discharge rate, not considering the fact that bank filtrated water bases have only partially received water from the Danube (20-40%). We have assumed full mixing in the calculation because water bases are located far from the estuarine zone, and we did not want to distinguish between the two bank sections.

From Table 13.5.2-1 and Table 13.5.2-3 it is apparent that there is a single isotope which increases in a meaningful way the radionuclide concentration of the Danube, and this is tritium. Not only do the others involve no radiation health risk, but in most cases, their detection is not even possible even with the most sensitive measurement techniques. The other potentially detectable radionuclide could be ^{14}C, but only if using a very special measurement technique. However, we have to note that due to the characteristics of water treatment in the primary circuit (usually acidic), it is unlikely to be regarded as a dominant radionuclide from the aspect of activity concentration of liquid discharge. However, since ^{14}C is very easily integrated in certain elements of the living world and its dose contribution to atmospheric emissions is dominant, we will approximate it by using an estimation.

PAKS							
Nuclide	**Emission [Bq/year]**	**Nuclide**	**Emission [Bq/year]**	**Nuclide**	**Emission [Bq/year]**	**Nuclide**	**Emission [Bq/year]**
H-3	2.24E+13	**Fe-59**	2.71E+07	**Pu-238**	9.08E+05	**Ag-110m**	2.97E+07
***C-14**	2.10E+09	**Co-60**	1.02E+08	**Pu-239/240**	6.84E+05	**Cs-134**	1.14E+07
Cr-51	7.50E+07	**Sr-89**	2.54E+06	**Am-241**	1.67E+05	**Cs-137**	9.07E+07
Mn-54	4.52E+07	**Y-90+Sr-90**	5.79E+06	**Cm-242**	5.37E+03	**I-131**	2.15E+07
Co-58	1.63E+07	**Tc-99**	4.03E+07	**Cm-244**	8.92E+03		

Note: *Value amended by a safety factor (10%).

Table 13.5.2-1: Normal, operating and controlled liquid radioactive emissions of the Paks Nuclear Power Plant in 2013

	Q [m³/s]	**Q [m³/year]**	**Q [l/year]**
NV	5500	1.73E+11	1.73E+14
KÖV	2600	8.20E+10	8.20E+13
KV	600	1.89E+10	1.89E+13

Table 13.5.2-2: Danube discharge rate at Paks as a function of characteristic water levels

PAKS							
Nuclide	**NV, KÖV, KV [Bq/dm³]**	**Nuclide**	**NV, KÖV, KV [Bq/dm³]**	**Nuclide**	**NV, KÖV, KV [Bq/dm³]**	**Nuclide**	**NV, KÖV, KV [Bq/dm³]**
H-3	1.29E-01	**Fe-59**	1.56E-07	**Pu-238**	5.23E-09	**Ag-110m**	1.71E-07
	2.73E-01		3.31E-07		1.11E-08		3.62E-07
	1.18E+00		1.43E-06		4.80E-08		1.57E-06
C-14	1.22E-05	**Co-60**	5.88E-07	**Pu-239/240**	3.94E-09	**Cs-134**	6.57E-08
	2.56E-05		1.24E-06		8.34E-09		1.39E-07
	1.11E-04		5.39E-06		3.61E-08		6.02E-07
Cr-51	4.32E-07	**Sr-89**	1.46E-08	**Am-241**	9.63E-10	**Cs-137**	5.23E-07
	9.15E-07		3.10E-08		2.04E-09		1.11E-06
	3.96E-06		1.34E-07		8.83E-09		4.79E-06
Mn-54	2.61E-07	**Y-90+Sr-90**	3.34E-08	**Cm-242**	3.10E-11	**I-131**	1.24E-07
	5.51E-07		7.06E-08		6.55E-11		2.62E-07
	2.39E-06		3.06E-07		2.84E-10		1.14E-06
Co-58	9.40E-08	**Tc-99**	2.32E-07	**Cm-244**	5.14E-11		
	1.99E-07		4.92E-07		1.09E-10		
	8.61E-07		2.13E-06		4.71E-10		

Table 13.5.2-3: Activity concentration values calculated with the characteristic discharge rates of the Danube in 2013

In Chapter 13.5.1 of the KHV, we discussed the distribution of tritium entering the groundwater from previous malfunctions and its spread in the vicinity of the power plant. The amount of assumed daily output can be calculated from the model. Even according to a pessimistic estimate, this may be maximum 160 MBq/day [13-5]. Since the characteristic flow direction of groundwater points towards the cold water canal, the final receiving medium of this release will also be the Danube. As regards its extent, this is 2,6‰ of liquid release for tritium, i. e. it will not modify the release within the margin of error. Its amount is further reduced by the factor that the access time (main building-Danube) may even be 10-20 years, which is comparable to the half-life of tritium (12-32 years). We could provide a pessimistic estimate for the other radionuclides by considering them as spreading in the same way as tritium (no sorption in the soil) and the level of release would be taken into account to the same extent as measurable or calculable for tritium. This is a very pessimistic estimate in itself, but nevertheless, it represents no excess burden for the Danube (because even here, 2.6‰ is within the margin of error). However since the commissioning of the groundwater monitoring system surrounding the power plant in 2000, and despite its nuclide specific detection limit of 1E-06–1E-03 Bq/dm^3, this groundwater monitoring system did not detect any clearly identifiable radionuclide from the power plant apart from tritium and ^{14}C, we have not taken their effects into account at all.

During construction and operation of the new power plant named Paks II, tritium has two ways to enter the Danube. Along with the natural groundwater flow and with water removed in the course of dewatering. In the case of groundwater flow, the maximum daily amount of tritium is 160 MBq, and as a result of dewatering, it is 53 MBq. In the Danube, this results in a maximum tritium activity concentration increase of 0.003 Bq/dm^3 and/or 0.001 Bq/dm^3 in the case of low water, which is negligible compared to liquid release.

No measurement data are available concerning the amount of radiocarbon released in an organic form. The probable reason for the latter's unavailability is that its quantity is likely to be much less compared to the carbonate form (acidic water plant) and even the related measurement technique is complicated. The activity of radiocarbon present in a carbonate form is estimated from the activity concentrations of quarterly average samples of released wastewater. On this basis,, the release value in 2013 was 1.9E+09 Bq. This value was the highest in the past 10 years and this is increased by an additional 10% to take into account release in an organic phase. Thus, we can estimate the amount of ^{14}C released by the Paks Nuclear Power Plant to be 2.1E+09 Bq. Since the ^{14}C activity is not specified for the planned liquid release of the two units to be established, but tritium release for the two new units shows good agreement with the current release levels of Paks, this is considered to be 1,05E+09 Bq per unit. This value will be taken into consideration in the impact of Paks II.

Government decree 201/2001 (X. 25.) restricts the radioactivity of drinking water as per two criteria. The activity concentration of tritium must not be higher than 100 Bq/dm^3, and the total indicative dose (tritium, potassium-40, radon and radon without its decay products may not be higher than 0.1mSv/year. "No drinking water must be tested in terms of tritium or radioactivity in order to define the total indicative dose in that case, if an other analysis shows that the tritium level of the calculated indicative dose is far below the threshold value." In order to meet this criterion the WHO recommendation for drinking water quality may provide more information [13-8], since the reference level is also 0.1mSv/year in their case. They have calculated the possible radionuclide concentrations pertaining to the said dose, and also declare that if the total alpha activity concentration is 0.5 Bq/dm^3 and the total beta one is below 1 Bq/dm^3, then the above mentioned condition can be met. When values are higher than this (total alpha, total beta activity concentration) it is practical to make isotope specific calculations and to clarify the dose accordingly.

Since in normal operation, as a result of the dilutive effect of the Danube, the ^{14}C concentration of the Danube does not even approach the above mentioned limits (and those of the other radioisotopes are 6-10 orders of magnitude below the latter), tritium remains the only isotope with a measurable impact. The power plant is only capable of increasing the tritium activity concentration of the Danube by 1.18 Bq/dm^3 in the case of law water when assuming uniform mixing. 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 from this aspect.

13.5.2.3 Transboundary environmental impacts

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.

13.6 IMPACT OF OPERATION OF PAKS II ON THE GEOLOGICAL MEDIUM AND UNDERGROUND WATER OF THE SITE

13.6.1 NORMAL OPERATION

The operational periods following the establishment are shown in Table 13.6.1-1.

Activity	Time interval
Simultaneous operation of Units 1-4 of the Paks Nuclear Power Plant and Paks II. Unit 1	2025-2030
Simultaneous operation of Units 1-4 of the Paks Nuclear Power Plant and Units 1-2 of Paks II	2030-2032
Final shut down of Units 1-4 of the Paks Nuclear Power Plant, reaching the end of the extended operating time of the Power Plant	2032-2037
Following the shut down of Units 1-4 of the Paks Nuclear Power Plant, independent and simultaneous operation of Units 1 and 2 of Paks II	2037-2085
Expiry of the operating period of Unit 1 of Paks II.	2085
Following the shut down of Unit 1 of Paks II, independent operation of Unit 2 of Paks II	2085-2090
Expiry of the operating period of Unit 2 of Paks II	2090

Table 13.6.1-1: Operating periods of the Paks II units and their joint operation with the existing units of the Paks Nuclear Power Plant.

Impact of operation of new units

During the operation of new reactor units, no significant additional effects are likely in comparison with the present situation. During the operation of new reactor units, while the technological requirements are fully observed, no soil contamination should be expected. Only failure events can cause soil contamination.

Loading impact of the facilities on the subsoil

After completion of constructions, in the operating period, consolidation of the load-bearing soil under the foundation is continued even if at an increasingly slower pace. Soil compaction as a result of load is an irreversible process. The effect of consolidation processes is similar to those in the construction phase, but the duration of the effect is longer.

Turbine bases (machine bases) with a vibration effect on the soil

Soils are further compacted under the relevant bases, moreover, in extreme cases, the phenomenon of earth flow may occur, as well. Therefore, very thorough geotechnical investigations are needed before foundation works. In an adverse event, soil consolidation or soil stabilization must be done. Although vibration effects may improve certain properties, but potentially uneven soil subsidence may be harmful to the relevant facilities.

13.6.1.1 Impact areas of operation of Paks II

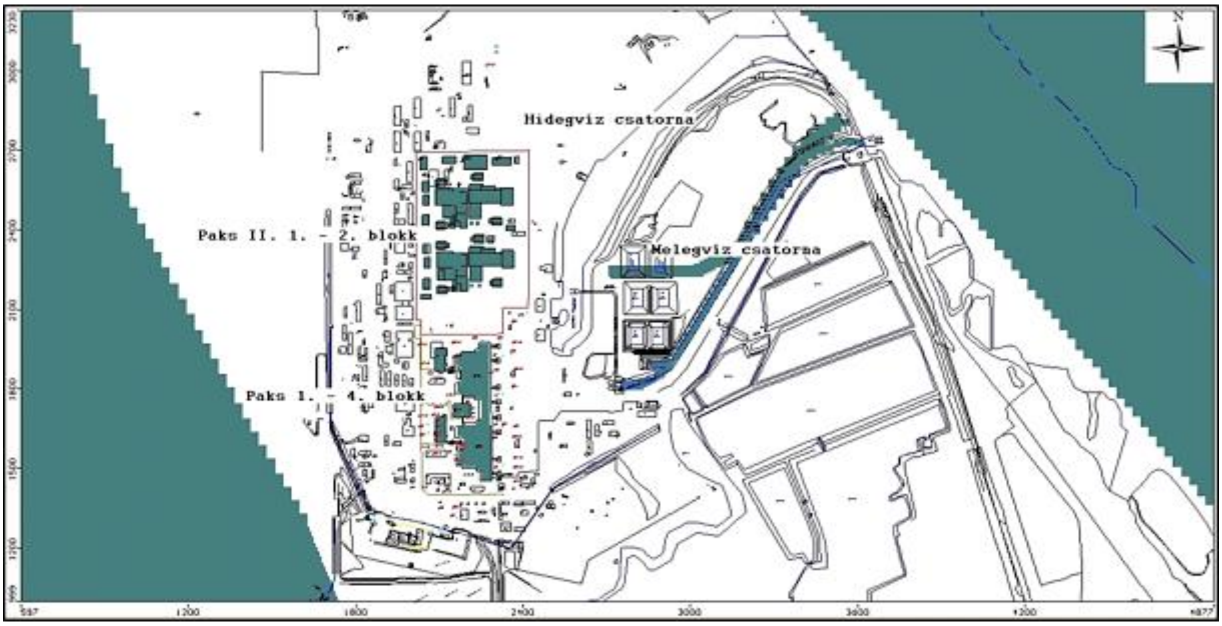
13.6.1.1.1 Direct effects

Flow paths and access times derived from the modified hydrological model of the site (with the addition of the locations of new units, 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.

At the end of the operating period of the Paks Nuclear Power Plant, tritium replenishment will be discontinued and as a result, the tritium plume will gradually shrink, which effect is also reinforced by the tritium decay process. The tritium half-life is 12.32 years, which is taken into account by the model with the decay constant of tritium. The decay constant is as follows:

$$\lambda = \frac{ln2}{t_{1/2}} = \frac{ln2}{4500} = 0{,}00015403/day$$

Where:
λ: decay constant
$t_{1/2}$:half-life.



Note:
Deep foundation buildings extend down to a depth of 20 m, all other buildings to a depth of 5 m from the surface.

Paks II. 1.– 2. blokk - Paks II Units 1-2
Paks I. 1.– 4. blokk - Paks I Units 1-4
Hidegvíz csatorna-Cold water canal
Melegvíz csatorna-Hot water canal

Figure 13.6.1-1: Site image modified with the new power plant and the hot water canal branch

RESULTS OF THE MODEL RUN UNDER LOW WATER CONDITIONS

The cold water canal and the Danube level has been set to 85.14 mBf at the site. Applying an annual precipitation infiltration of 40 mm, the maximum velocities can be estimated to be 1.5E-5 m/s.

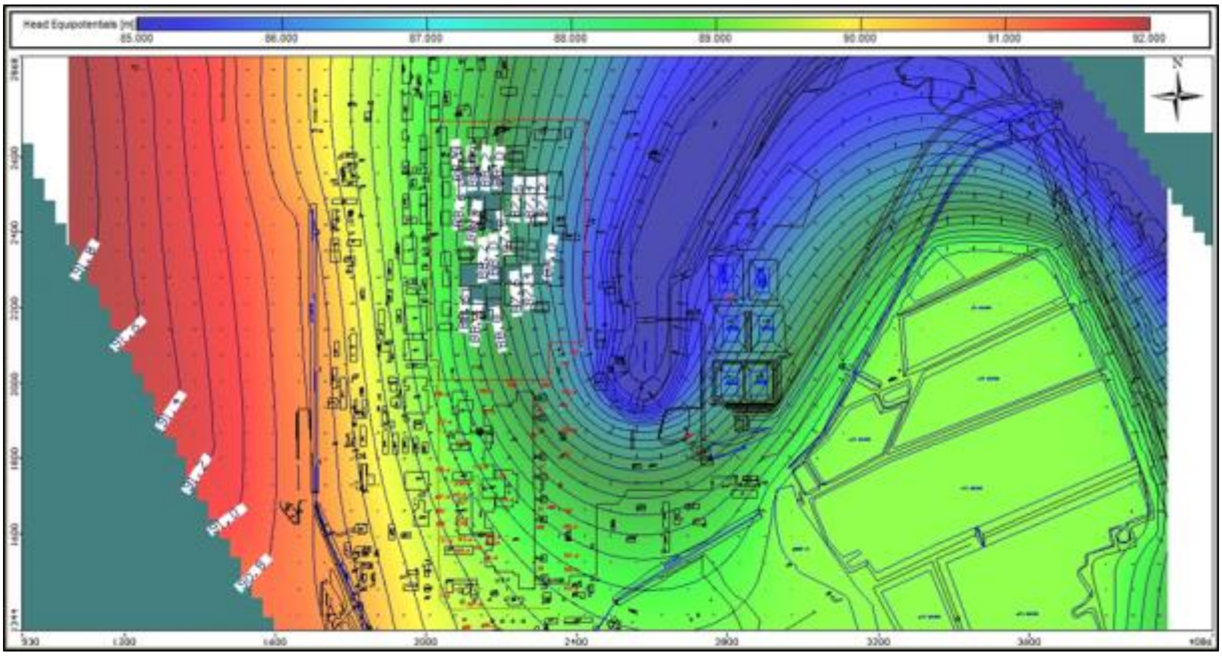
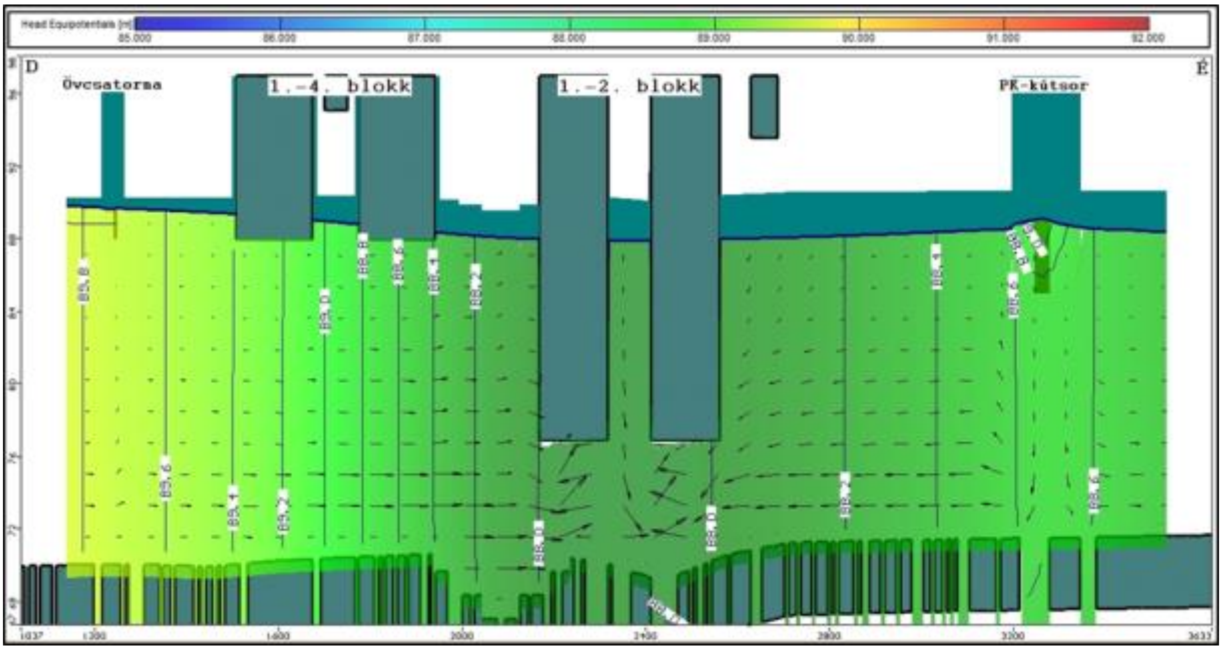


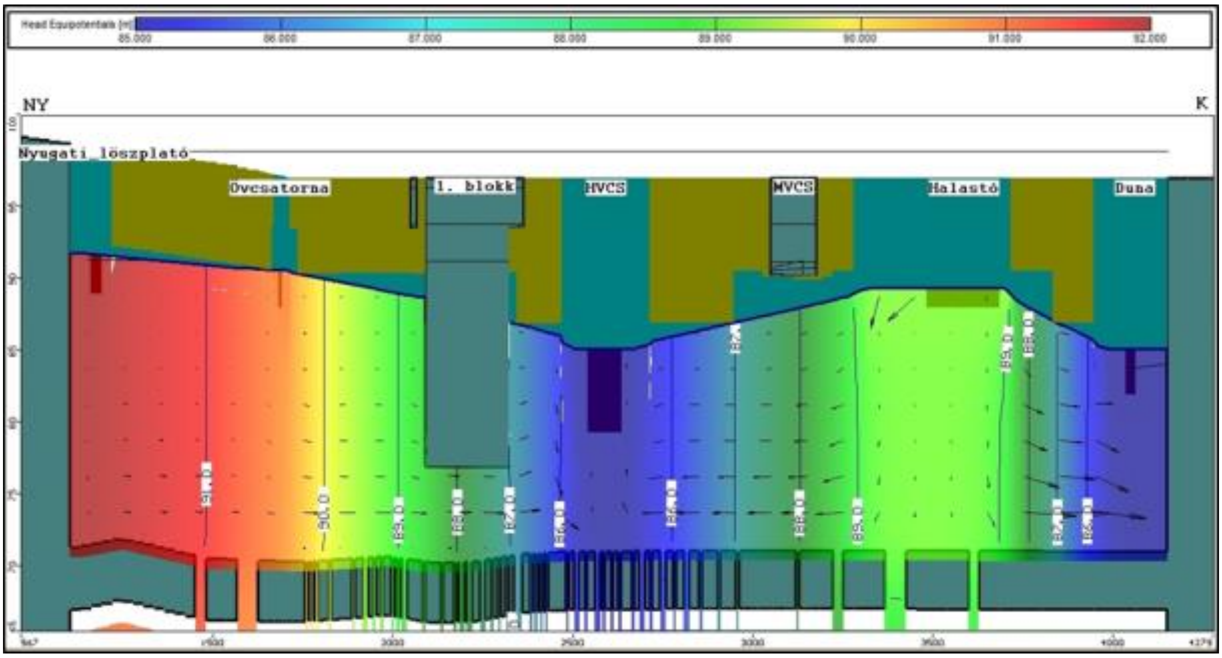
Figure 13.6.1-2: Contour map of the groundwater table and the velocity space in case of low water level in the Danube (85.14 mBf)



Note:
The flow rate will increase in the volume under the relevant buildings because water flows through the smaller volume between the clay layer and the foundations.

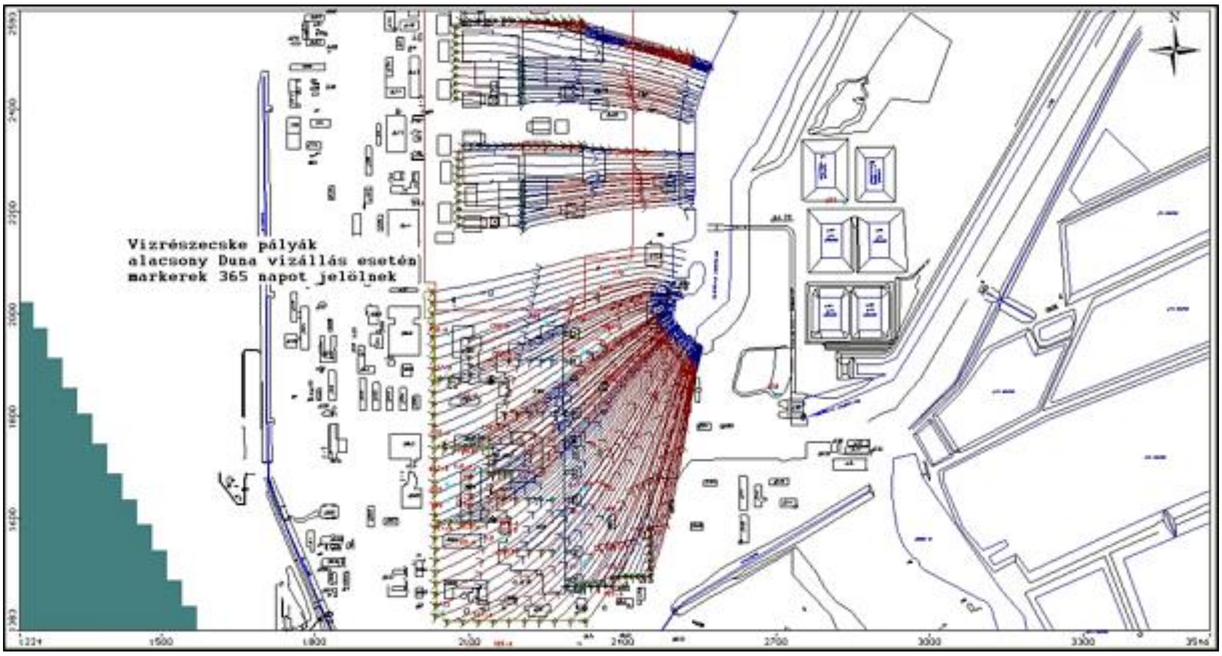
Övcsatorna - Diversion ditch
1.-4. blokk - Units 1-4
1.-2. blokk - Units 1-2
PK-kútsor-PK battery of wells

Figure 13.6.1-3: Vertical image of the groundwater table and the velocity space along a N - S section



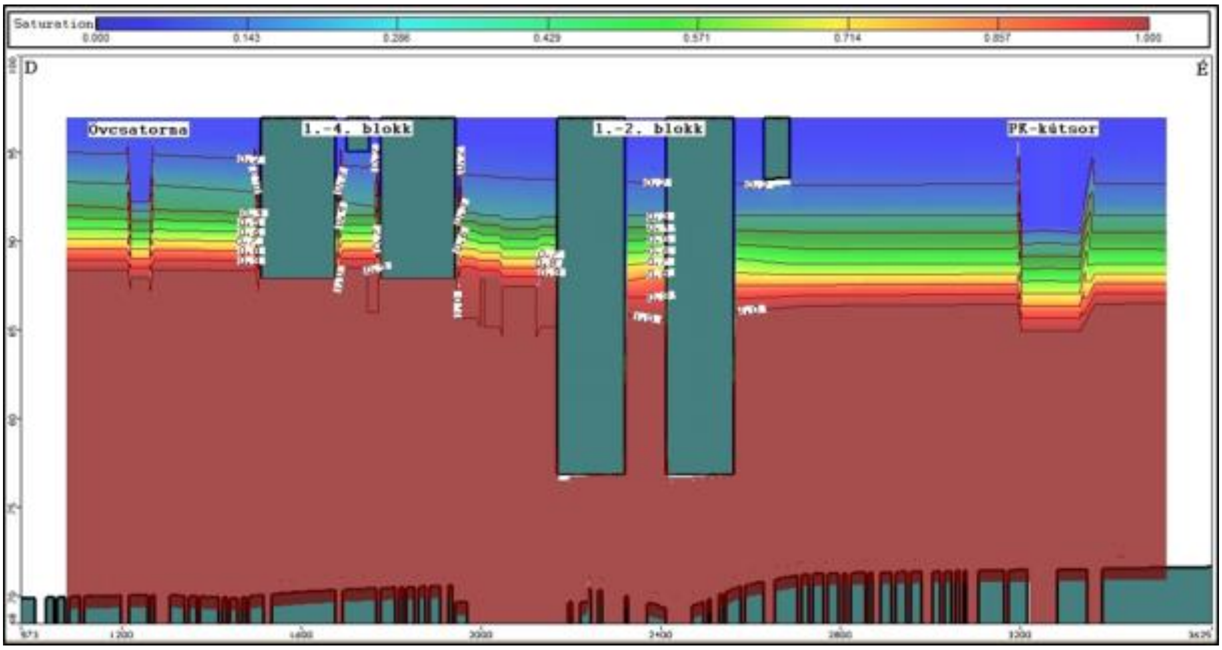
Nyugati löszplató-Western loess plateau
Övcsatorna-Diversion ditch
1. blokk-Unit 1
HVCS-Cold water canal
MVCS-Hot water canal
Halastó-Fish pond
Duna-River Danube

Figure 13.6.1-4: Vertical image of the groundwater table and the velocity space along a W-E section



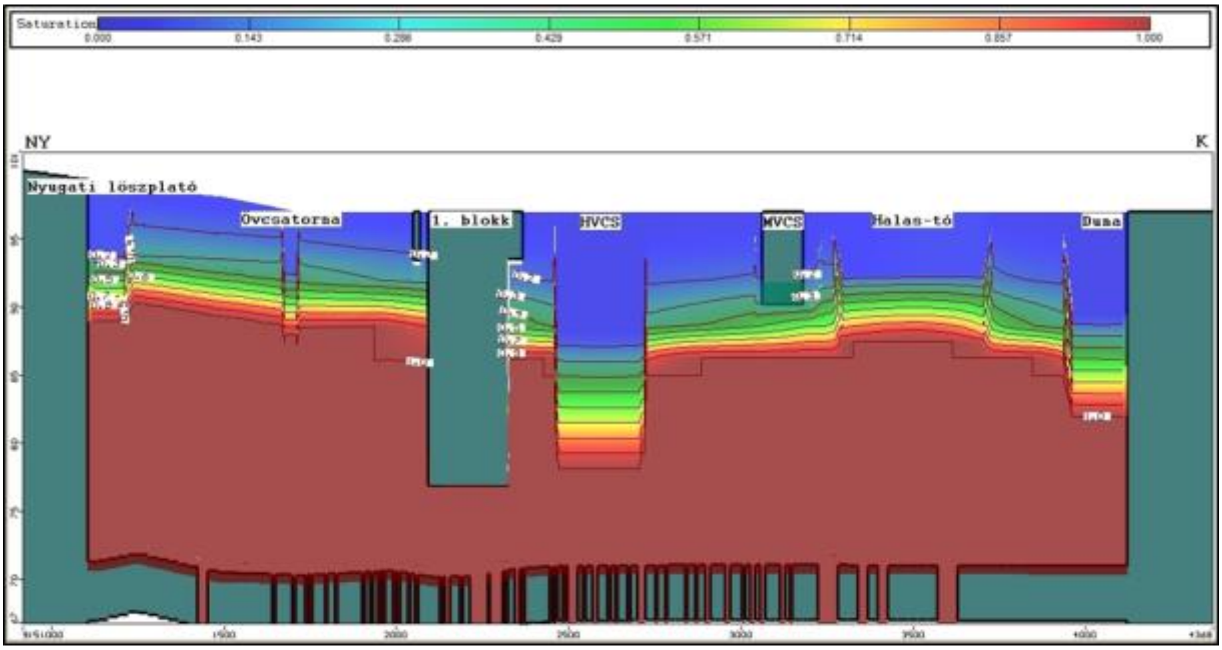
Vízrészecske pályák alacsony Duna vízállás esetén - Water particle paths in case of low Danube water level
markerek 365 napot jelölnek - markers indicate 365 days

Figure 13.6.1-5: Water particle path located in the layer under the power plant for low Danube water level



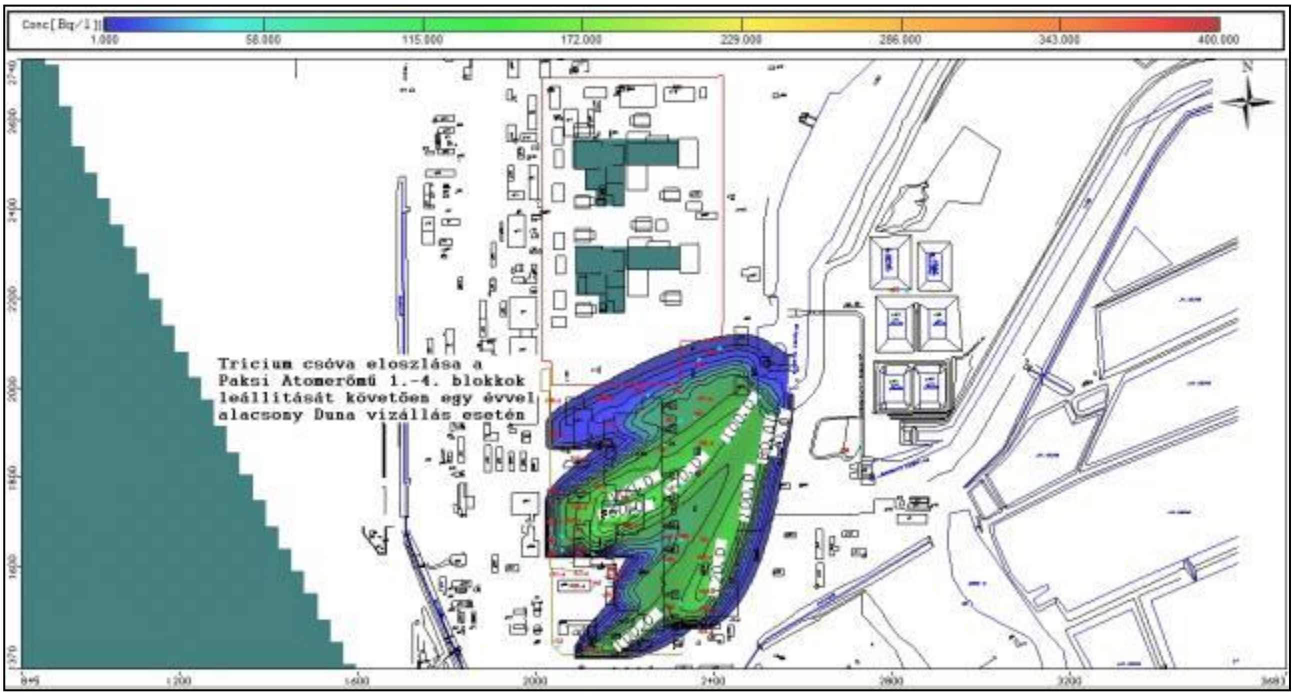
Övcsatorna-Diversion ditch
1.– 4. blokk-Units 1-4
1.– 2. blokk-Units 1-2
PK-kútsor-PK battery of wells

Figure 13.6.1-6: Image of the three-phase zone in case of constantly low Danube water level along a N - S section



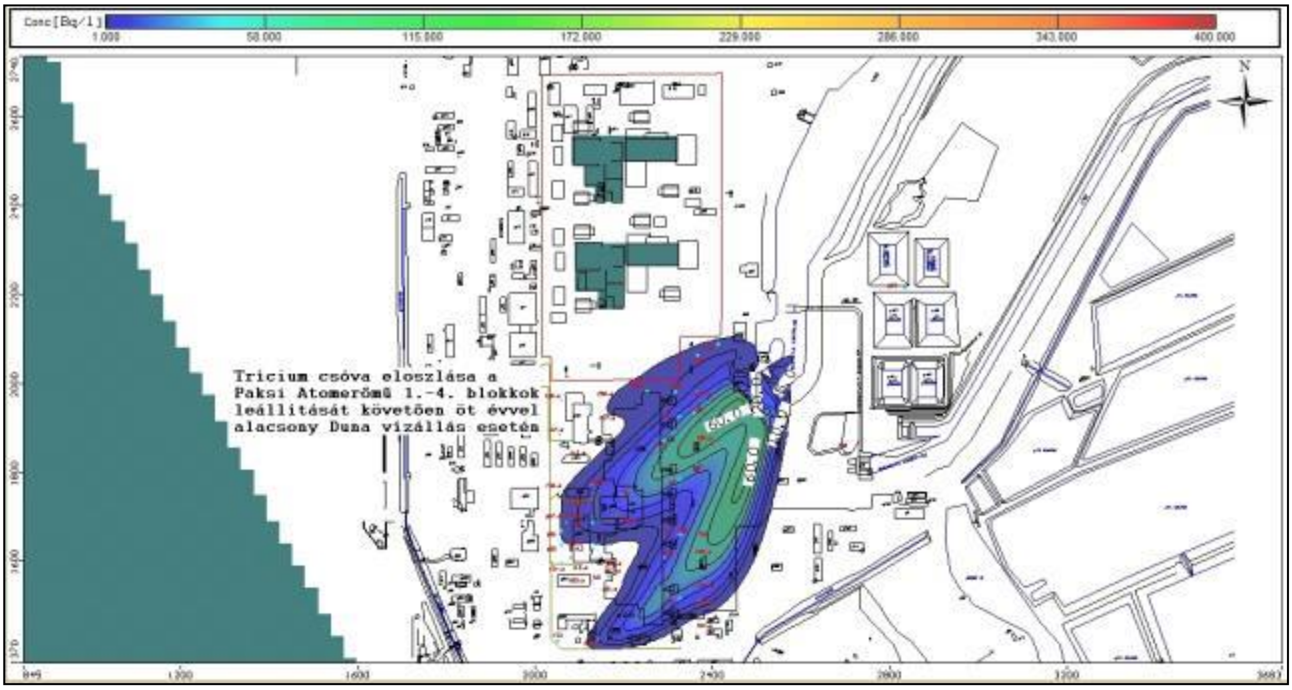
Nyugati löszplató-Western loess plateau
Övcsatorna-Diversion ditch
1. blokk-Unit 1
HVCS-Cold water canal
MVCS-Hot water canal
Halas-tó-Fish pond
Duna-River Danube

Figure 13.6.1-7: Image of the three-phase zone in case of constantly low Danube water level along a W - E section



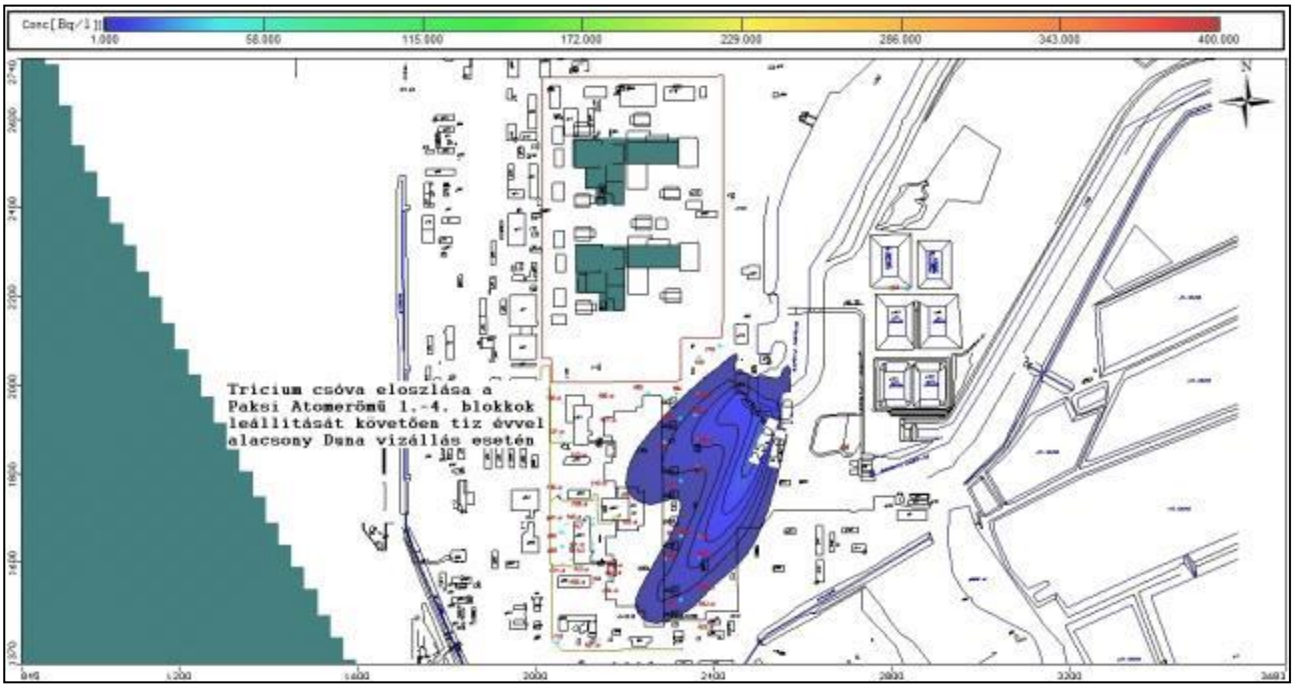
Trícium csóva eloszlása a Paksi Atomerőmű 1.-4. blokkok leállítását követően egy évvel alacsony Duna vízállás esetén - Distribution of the tritium plume one year after shut down of Units 1-4 of Paks Nuclear Power Plant in case of low Danube water level

Figure 13.6.1-8: Distribution of the tritium plume one year after shut down of Units 1-4 of Paks Nuclear Power Plant in case of low Danube water level



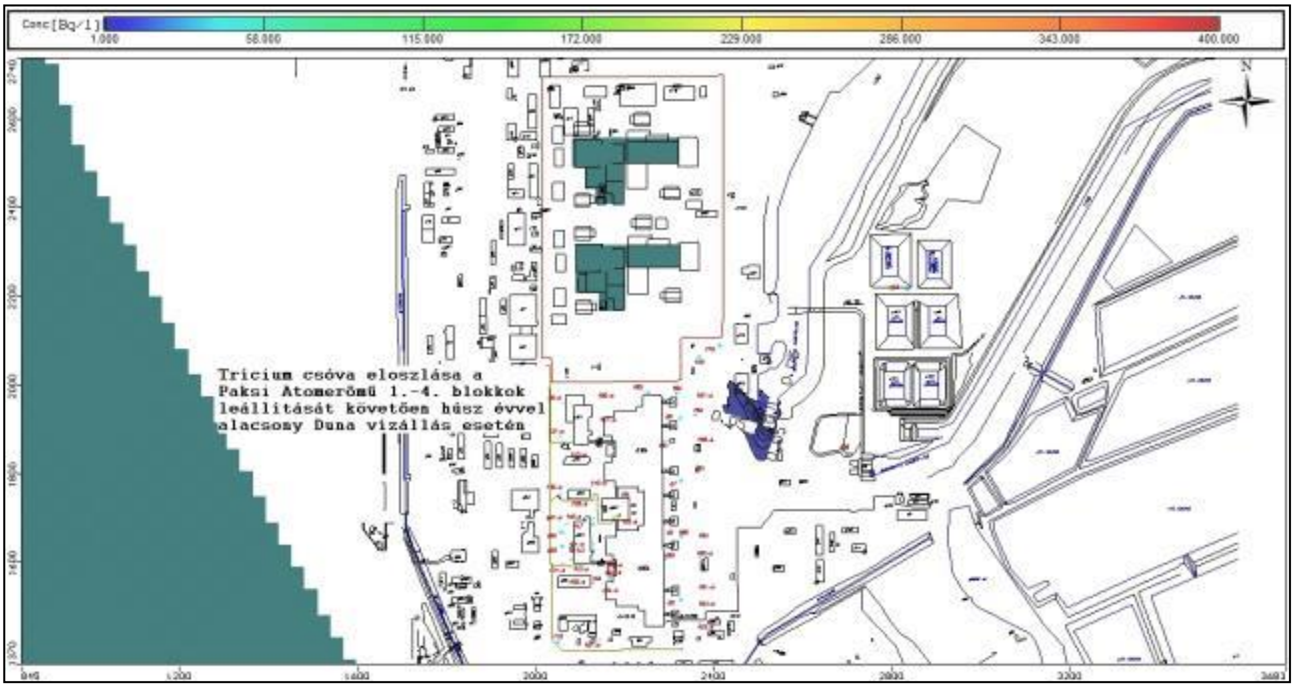
Trícium csóva eloszlása a Paksi Atomerőmű 1.-4. blokkok leállítását követően öt évvel alacsony Duna vízállás esetén - Distribution of the tritium plume five years after shut down of Units 1-4 of Paks Nuclear Power Plant in case of low Danube water level

Figure 13.6.1-9: Distribution of the tritium plume five years after shut down of Units 1-4 of Paks Nuclear Power Plant in case of low Danube water level



Trícium csóva eloszlása a Paksi Atomerőmű 1.-4. blokkok leállítását követően tíz évvel alacsony Duna vízállás esetén - Distribution of the tritium plume ten years after shut down of Units 1-4 of Paks Nuclear Power Plant in case of low Danube water level

Figure 13.6.1-10: Distribution of the tritium plume ten years after shut down of Units 1-4 of Paks Nuclear Power Plant in case of low Danube water level



Trícium csóva eloszlása a Paksi Atomerőmű 1.-4. blokkok leállítását követően húsz évvel alacsony Duna vízállás esetén - Distribution of the tritium plume twenty years after shut down of Units 1-4 of Paks Nuclear Power Plant in case of low Danube water level

Figure 13.6.1-11: Distribution of the tritium plume twenty years after shut down of Units 1-4 of Paks Nuclear Power Plant in case of low Danube water level

RESULTS OF THE MODEL RUN UNDER MEDIUM WATER CONDITIONS

The cold water canal and the Danube level has been set to 87.73 mBf at the site. Applying an annual precipitation infiltration of 40 mm, the maximum velocities can be estimated to be 3.8E-6 m/s.

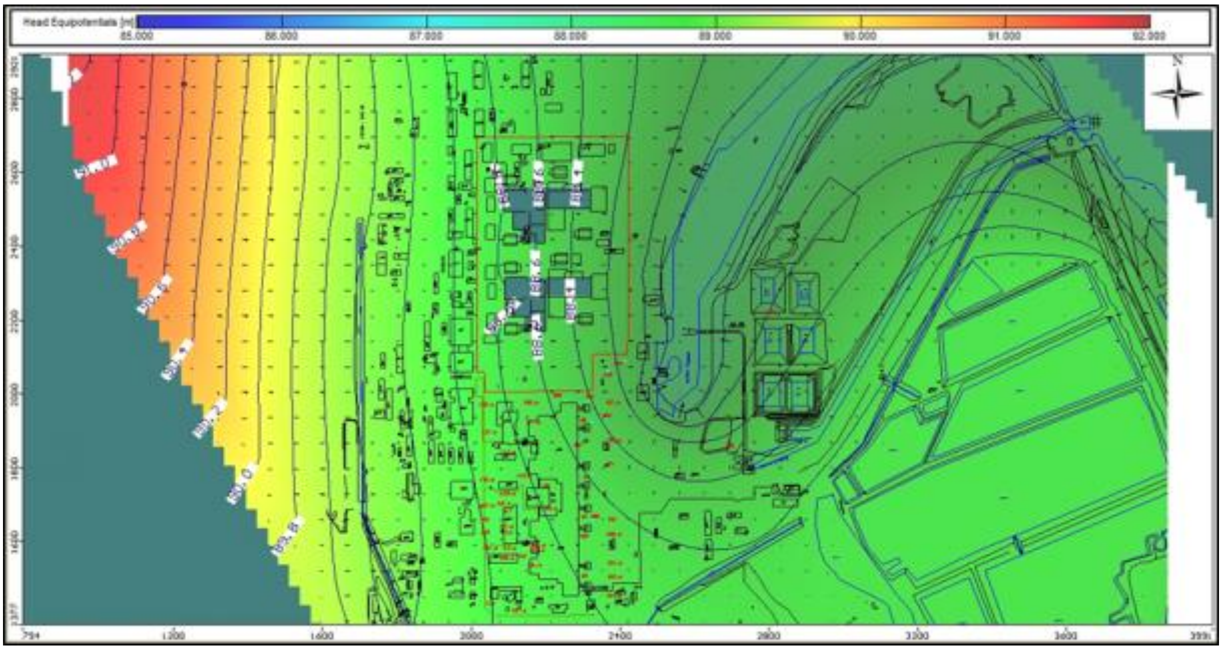
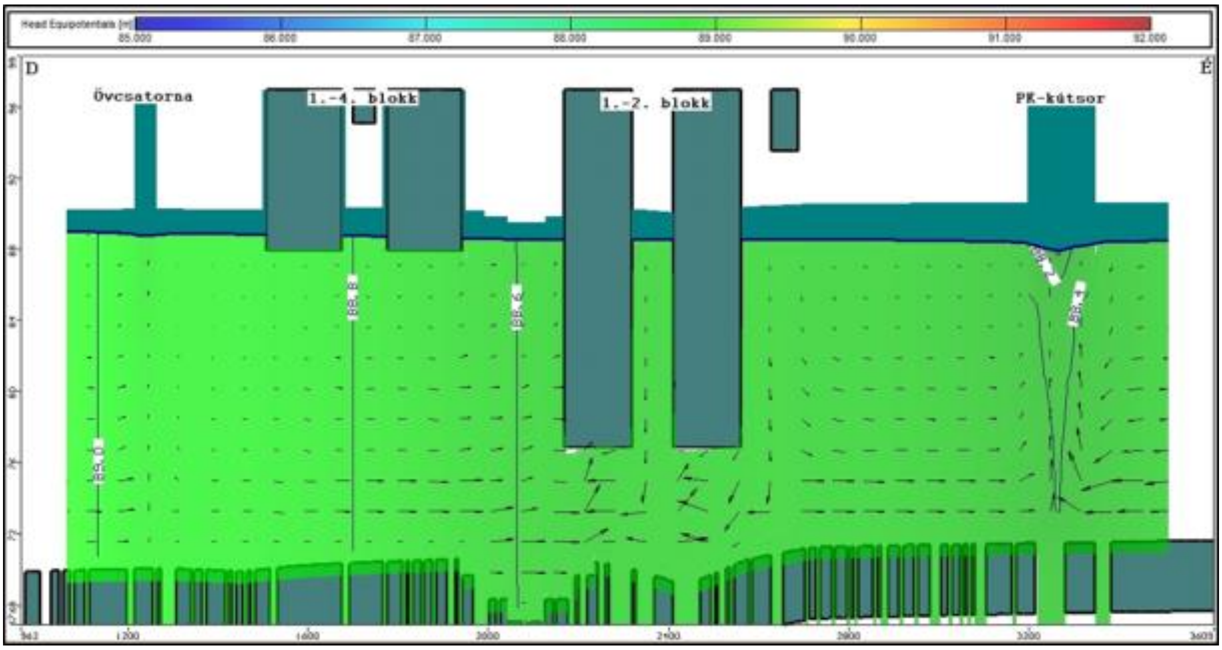
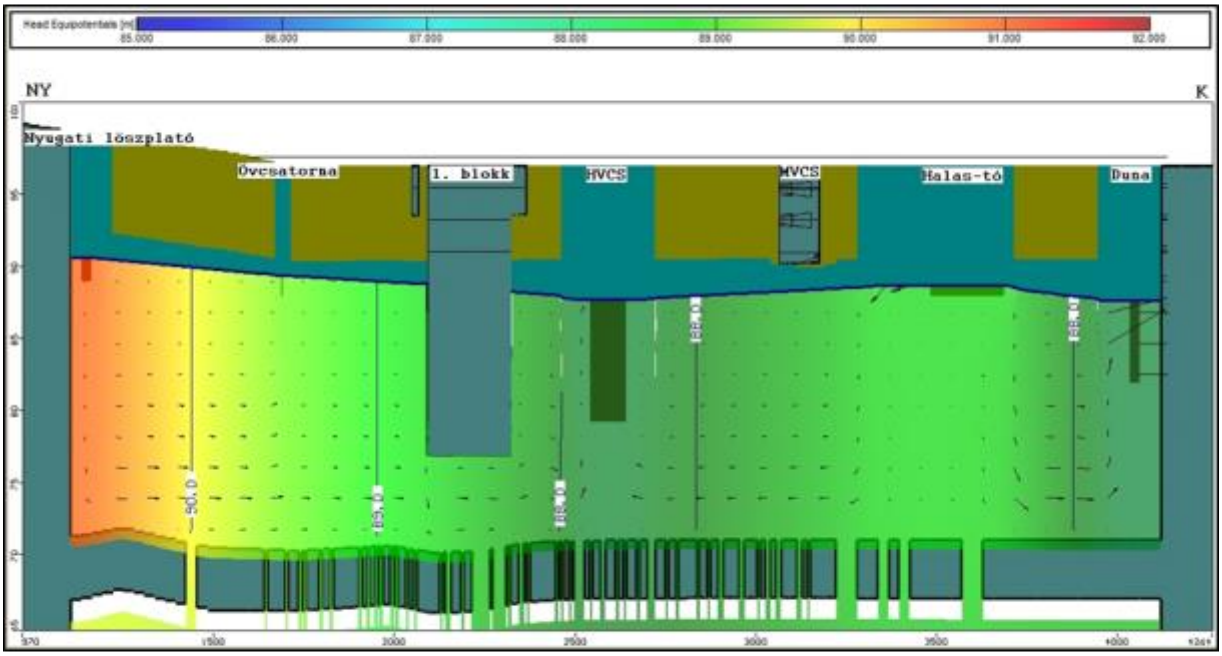


Figure 13.6.1-12: Contour map of the groundwater table and the velocity space in case of medium water level in the Danube (87.73 mBf)



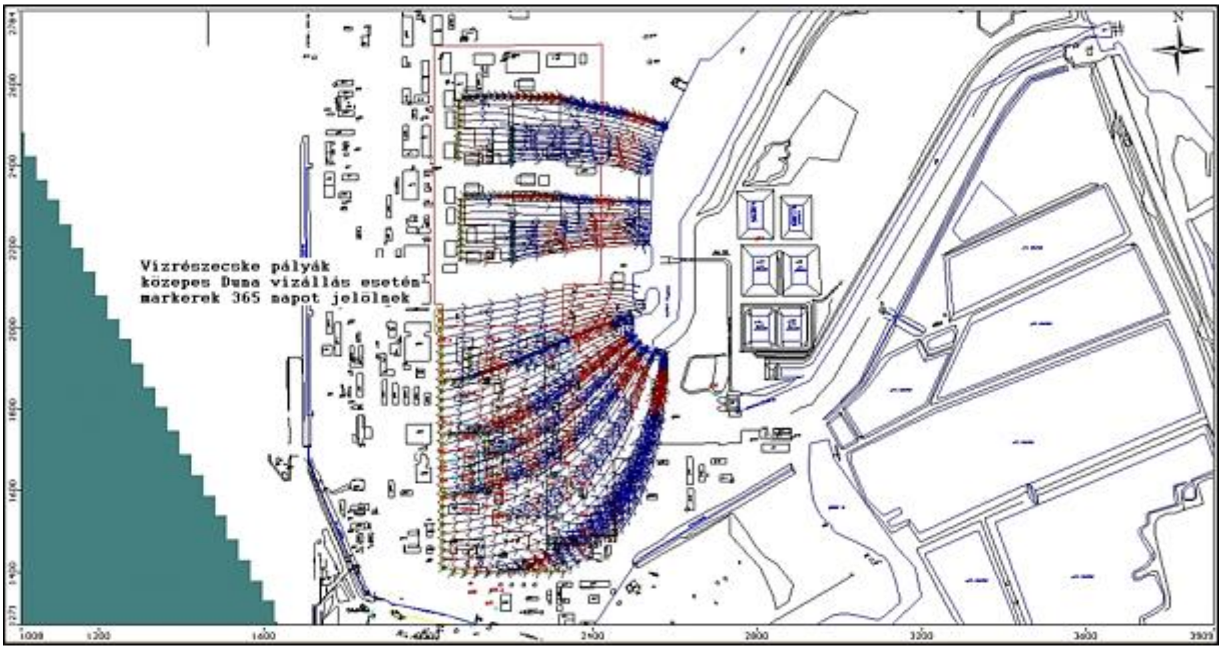
Övcsatorna-Diversion ditch
1.– 4. blokk-Units 1-4
1.– 2. blokk-Units 1-2
PK-kútsor-PK battery of wells

Figure 13.6.1-13: Vertical image of the groundwater table and the velocity space along a N - S section



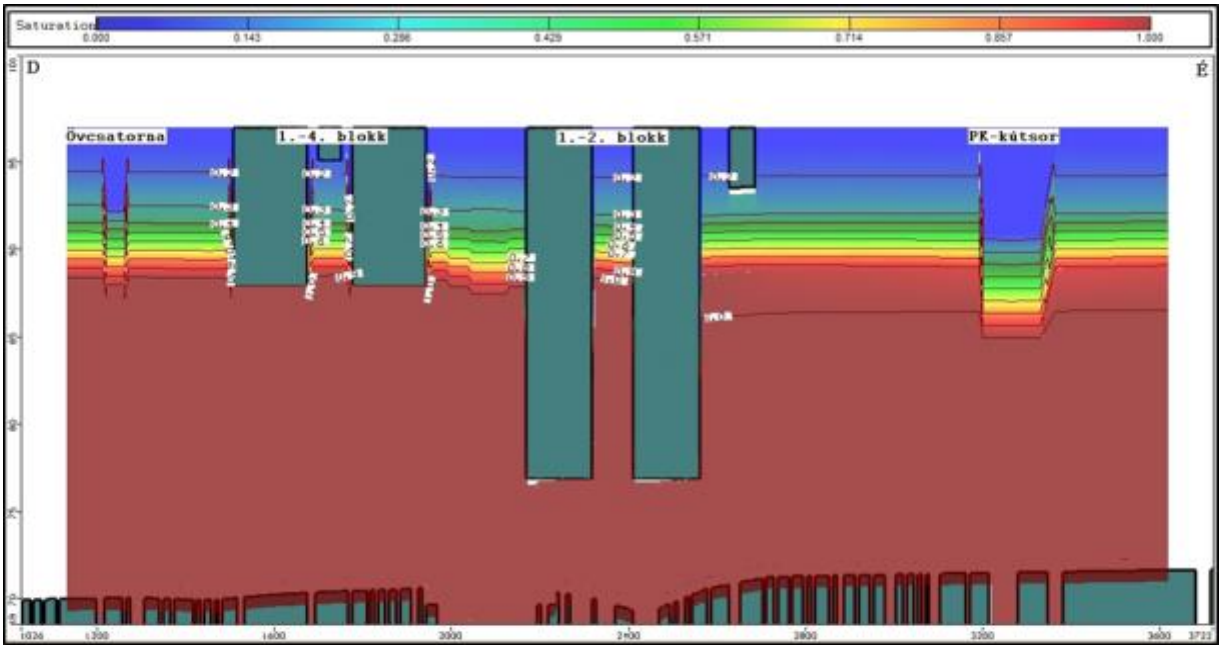
Nyugati löszplató-Western loess plateau
Övcsatorna-Diversion ditch
1. blokk-Unit 1
HVCS-Cold water canal
MVCS-Hot water canal
Halas-tó-Fish pond
Duna-River Danube

Figure 13.6.1-14: Vertical image of the groundwater table and the velocity space along a W-E section



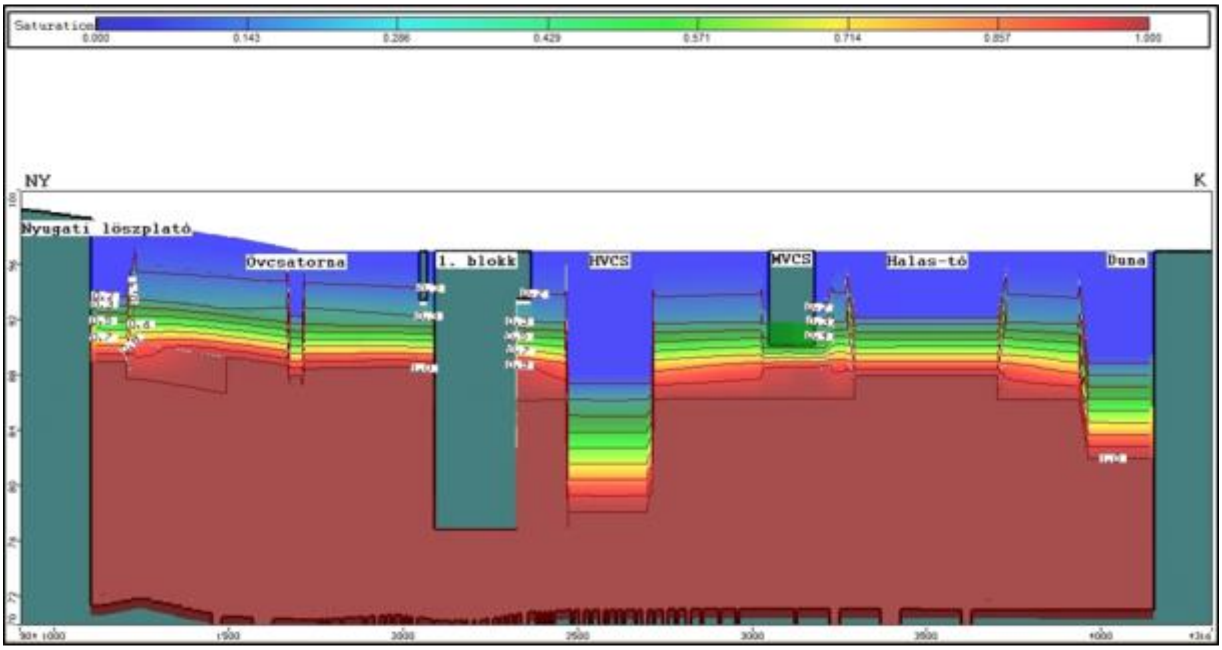
Vízrészecske pályák közepes Duna vízállás esetén-Water particle paths in case of medium Danube water level
markerek 365 napot jelölnek-markers indicate 365 days

Figure 13.6.1-15: Water particle path located in the layer under the power plant for medium Danube water level



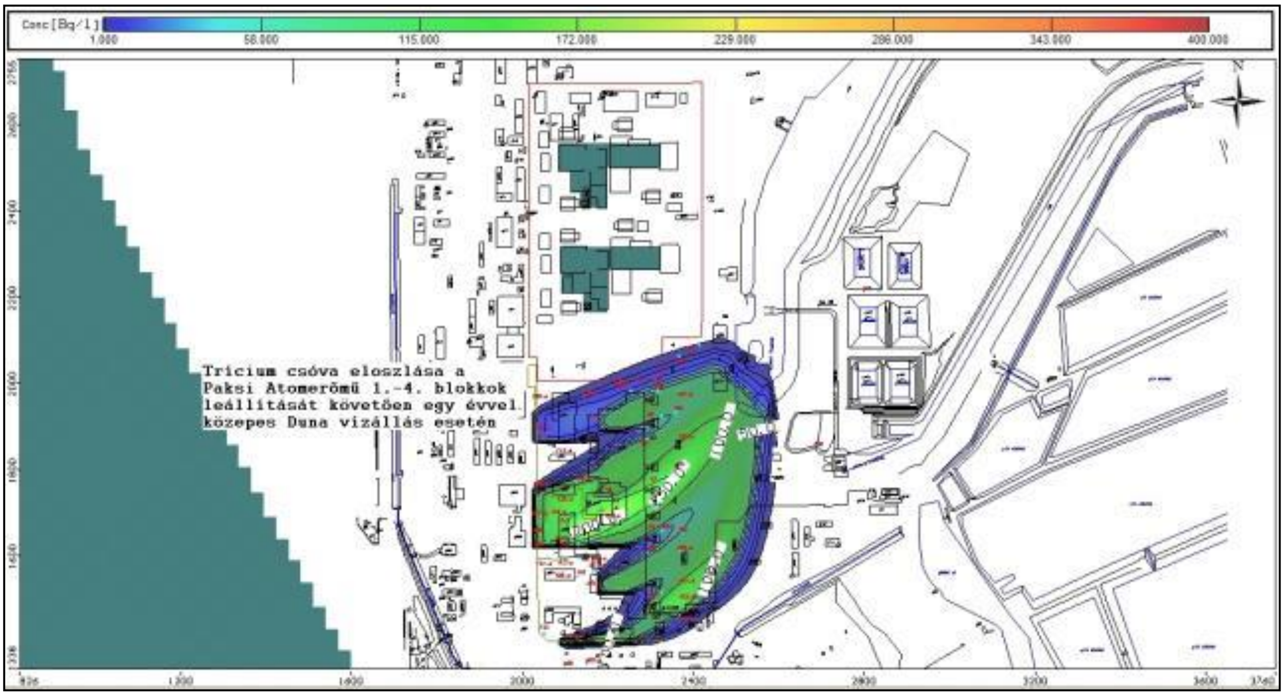
Övcsatorna-Diversion ditch
1.– 4. blokk-Units 1-4
1.– 2. blokk-Units 1-2
PK-kútsor-PK battery of wells

Figure 13.6.1-16: Image of the three-phase zone in case of constantly medium Danube water level along a N - S section



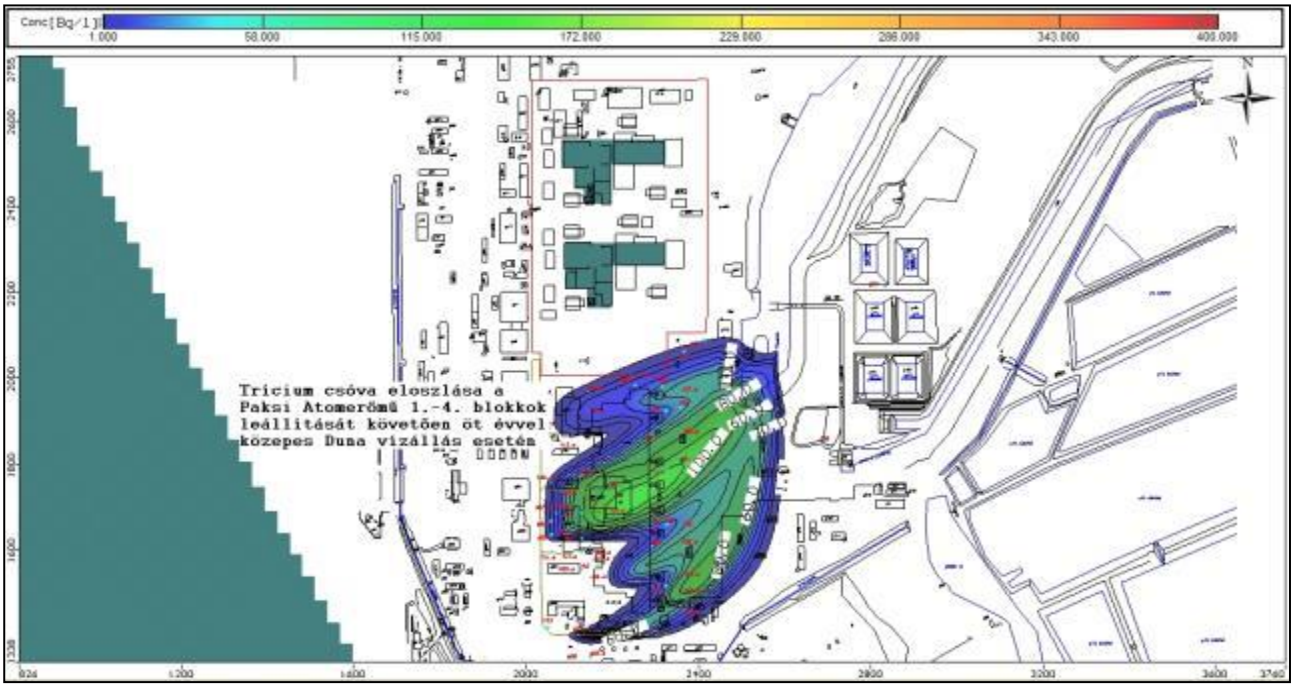
Nyugati löszplató-Western loess plateau
Övcsatorna-Diversion ditch
1. blokk-Unit 1
HVCS-Cold water canal
MVCS-Hot water canal
Halas-tó-Fish pond
Duna-River Danube

Figure 13.6.1-17: Image of the three-phase zone in case of constantly medium Danube water level along a W - E section



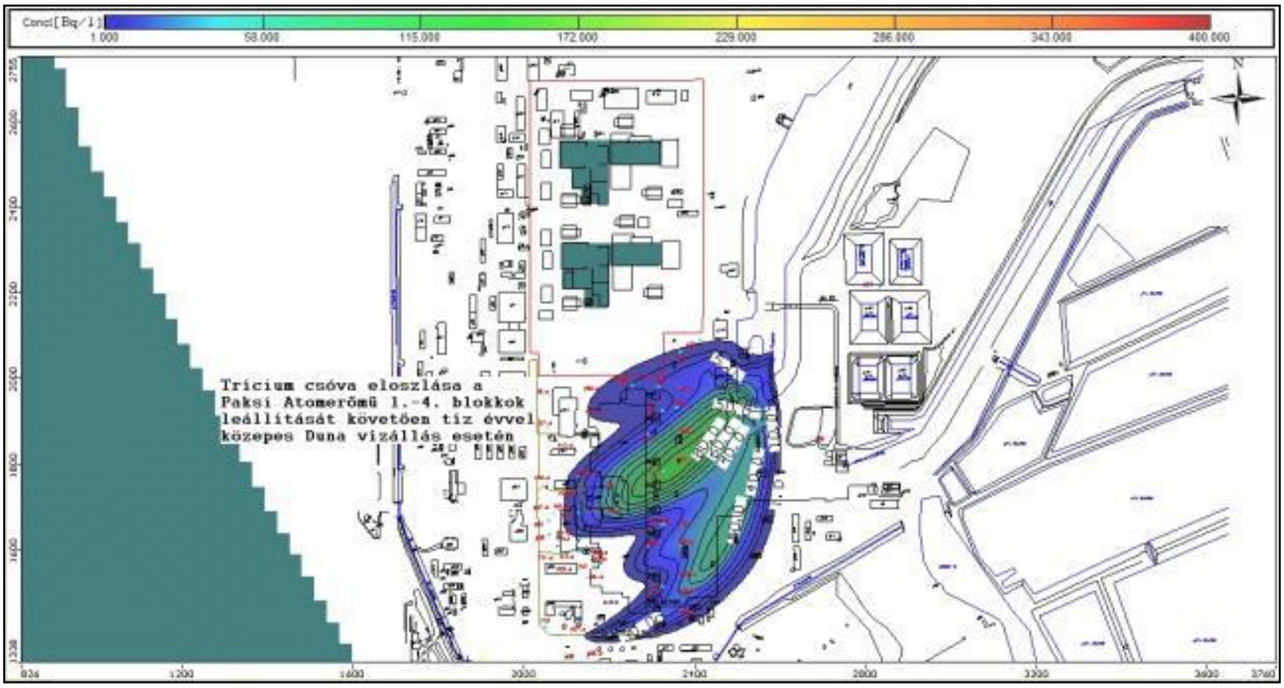
Trícium csóva eloszlása a Paksi Atomerőmű 1.-4. blokkok leállítását követően egy évvel közepes Duna vízállás esetén - Distribution of the tritium plume one year after shut down of Units 1-4 of Paks Nuclear Power Plant in case of medium Danube water level

Figure 13.6.1-18: Distribution of the tritium plume one year after shut down of Units 1-4 of Paks Nuclear Power Plant in case of medium Danube water level



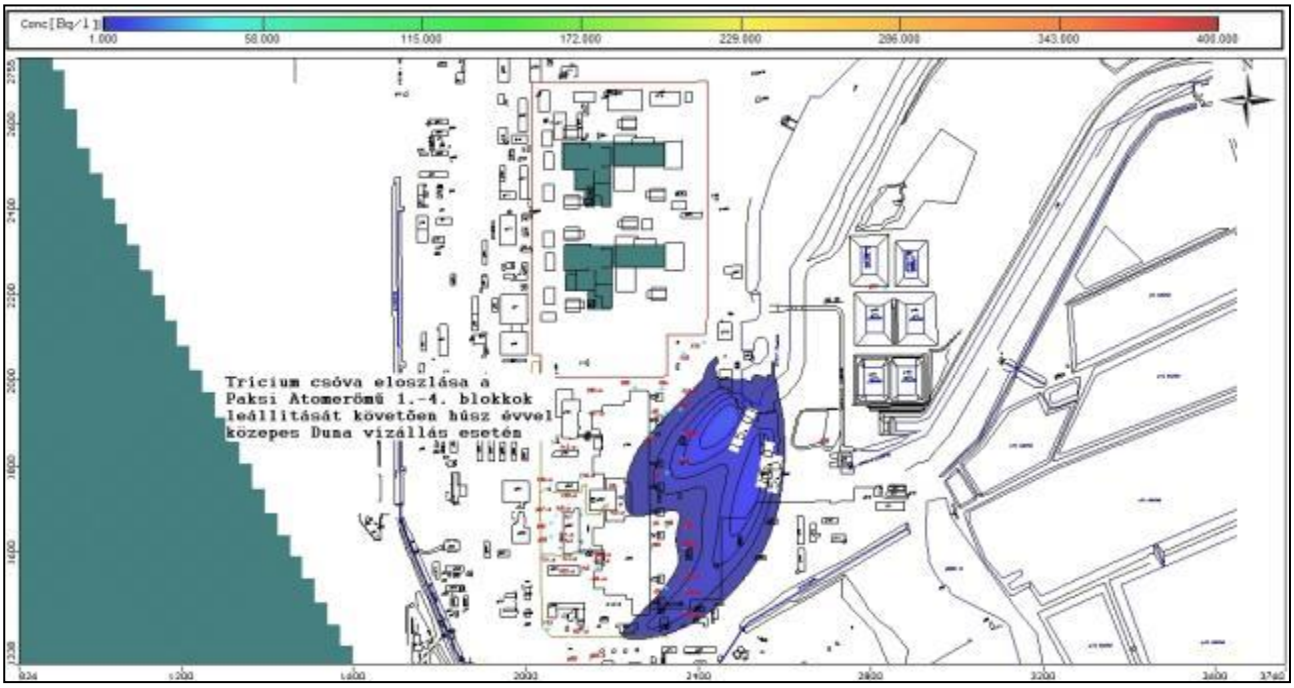
Trícium csóva eloszlása a Paksi Atomerőmű 1.-4. blokkok leállítását követően öt évvel közepes Duna vízállás esetén - Distribution of the tritium plume five years after shut down of Units 1-4 of Paks Nuclear Power Plant in case of medium Danube water level

Figure 13.6.1-19: Distribution of the tritium plume five years after shut down of the Units 1-4 of Paks Nuclear Power Plant in case of medium Danube water level



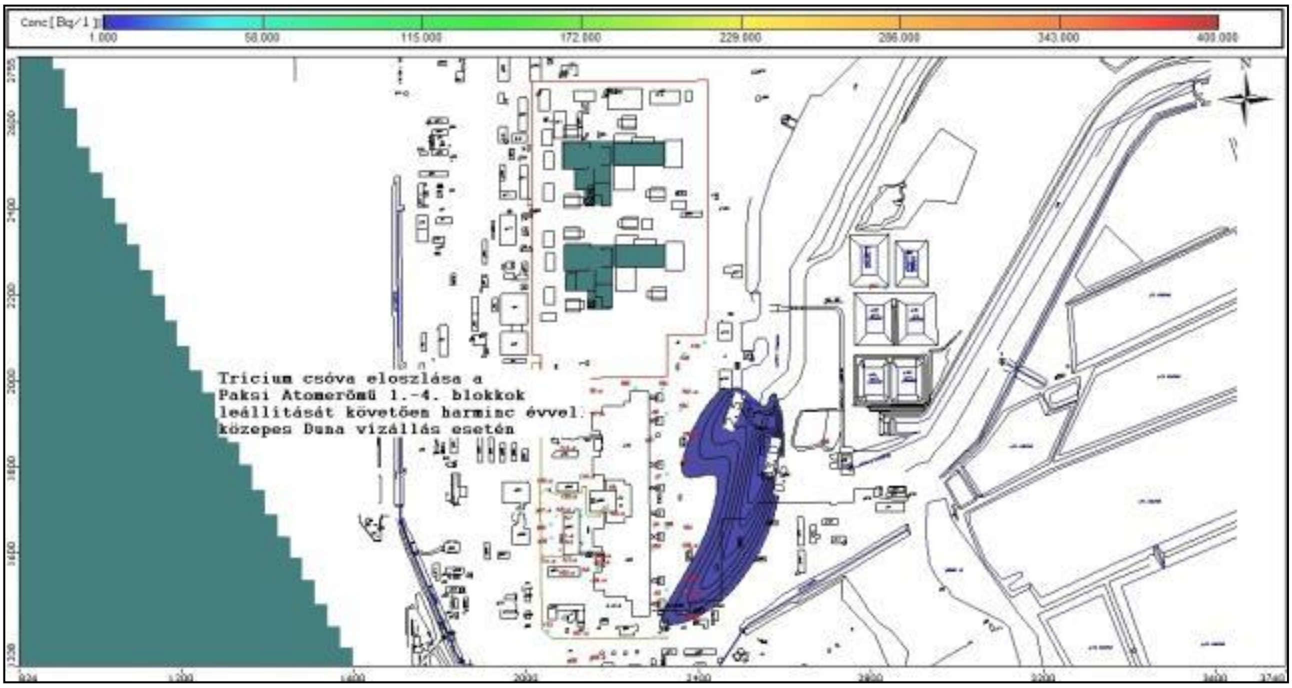
Trícium csóva eloszlása a Paksi Atomerőmű 1.-4. blokkok leállítását követően tíz évvel közepes Duna vízállás esetén - Distribution of the tritium plume ten years after shut down of Units 1-4 of Paks Nuclear Power Plant in case of medium Danube water level

Figure 13.6.1-20: Distribution of the tritium plume ten years after shut down of Units 1-4 of Paks Nuclear Power Plant in case of medium Danube water level



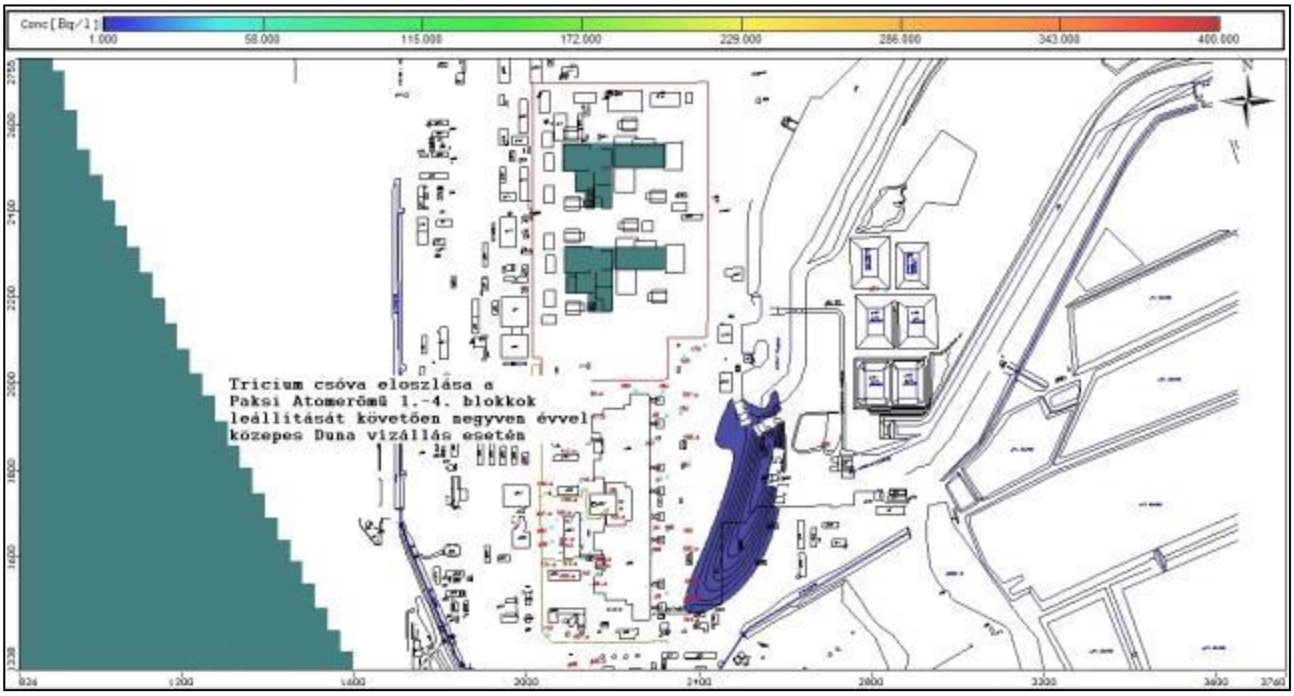
Trícium csóva eloszlása a Paksi Atomerőmű 1.-4. blokkok leállítását követően húsz évvel közepes Duna vízállás esetén - Distribution of the tritium plume twenty years after shut down of Units 1-4 of Paks Nuclear Power Plant in case of medium Danube water level

Figure 13.6.1-21: Distribution of the tritium plume twenty years after shut down of Units 1-4 of Paks Nuclear Power Plant in case of medium Danube water level



Trícium csóva eloszlása a Paksi Atomerőmű 1.-4. blokkok leállítását követően harminc évvel közepes Duna vízállás esetén - Distribution of the tritium plume thirty years after shut down of Units 1-4 of Paks Nuclear Power Plant in case of medium Danube water level

Figure 13.6.1-22: Distribution of the tritium plume thirty years after shut down of Units 1-4 of Paks Nuclear Power Plant in case of medium Danube water level



Trícium csóva eloszlása a Paksi Atomerőmű 1.-4. blokkok leállítását követően negyven évvel közepes Duna vízállás esetén - Distribution of the tritium plume forty years after shut down of Units 1-4 of Paks Nuclear Power Plant in case of medium Danube water level

Figure 13.6.1-23: Distribution of the tritium plume forty years after shut down of Units 1-4 of Paks Nuclear Power Plant in case of medium Danube water level

<u>RESULTS OF THE MODEL RUN UNDER HIGH WATER CONDITIONS</u>

The cold water canal and the Danube level has been set to 94.01 mBf at the site. Applying an annual precipitation infiltration of 40 mm, the maximum velocities can be estimated to be 9.2E-6 m/s.

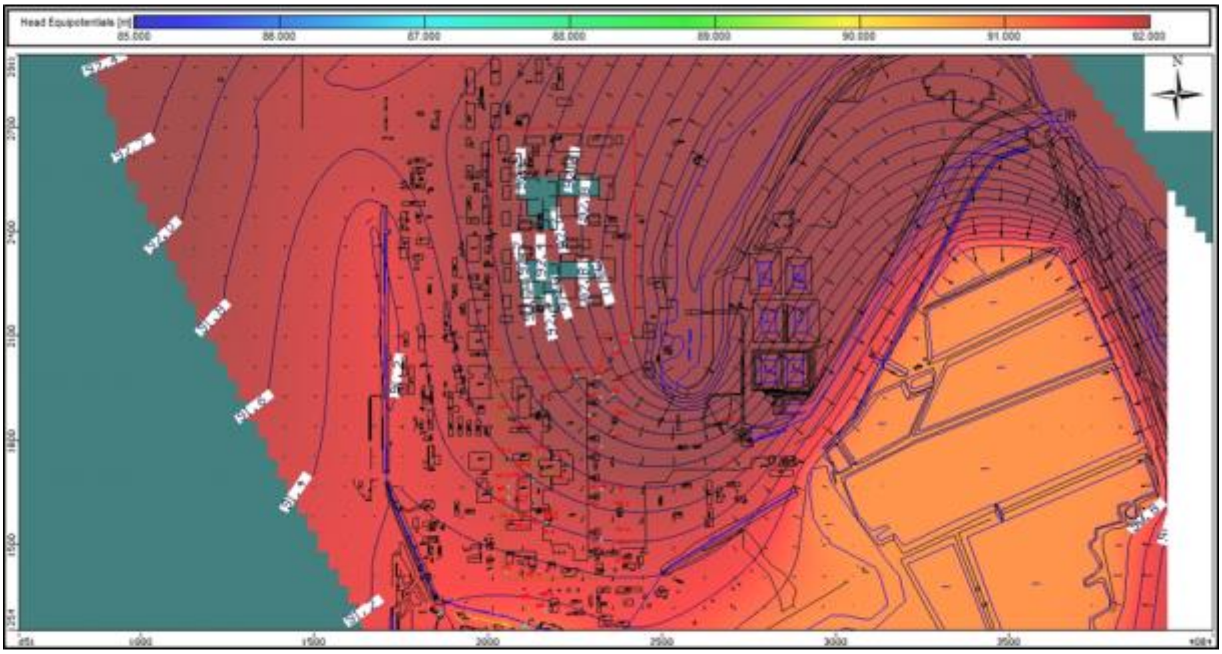
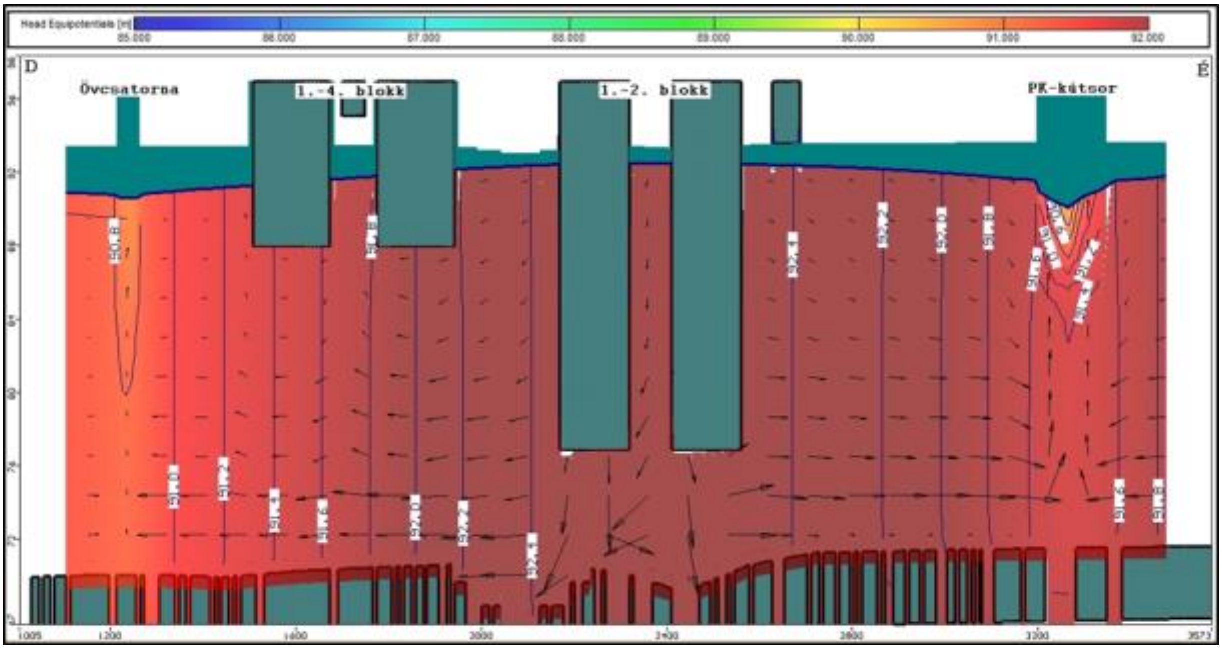
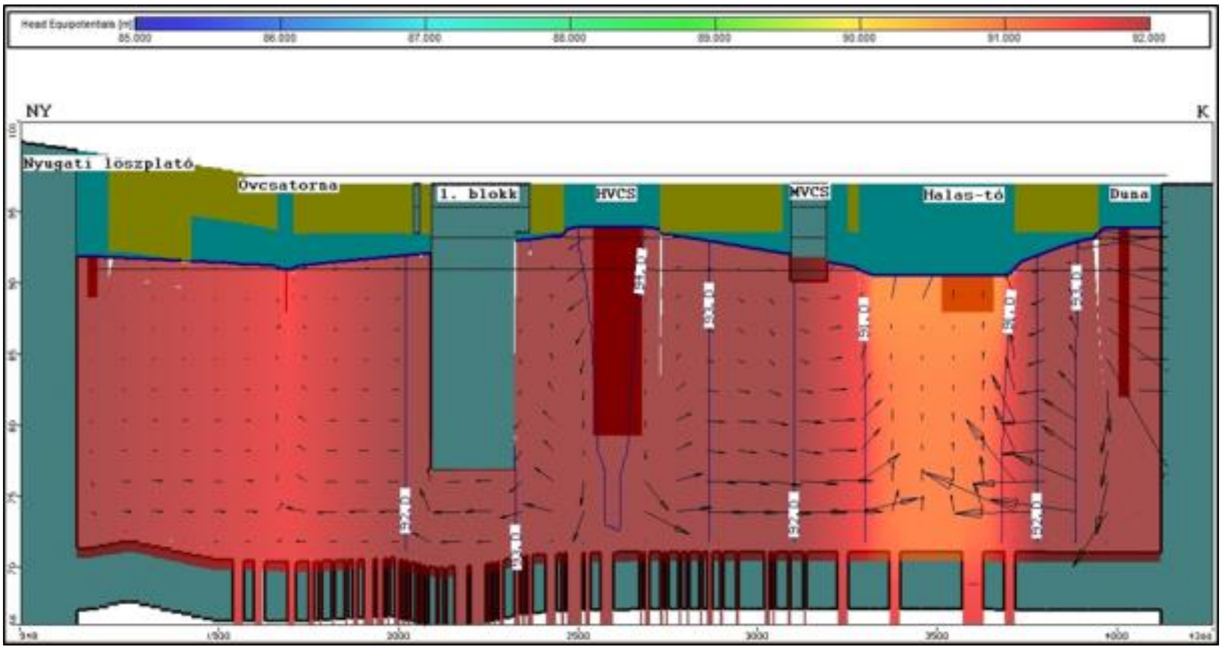


Figure 13.6.1-24: Contour map of the groundwater table and the velocity space in case of high water level in the Danube (94.01 mBf)



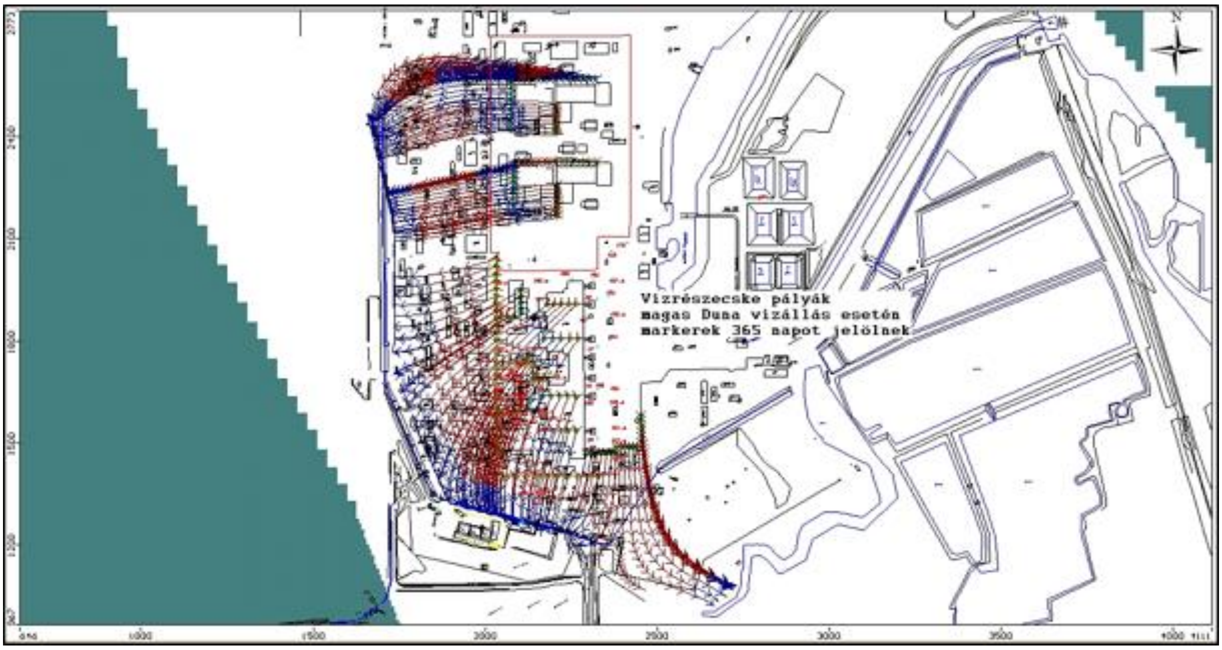
Övcsatorna-Diversion ditch
1.– 4. blokk-Units 1-4
1.– 2. blokk-Units 1-2
PK-kútsor-PK battery of wells

Figure 13.6.1-25: Vertical image of the groundwater table and the velocity space along a N - S section



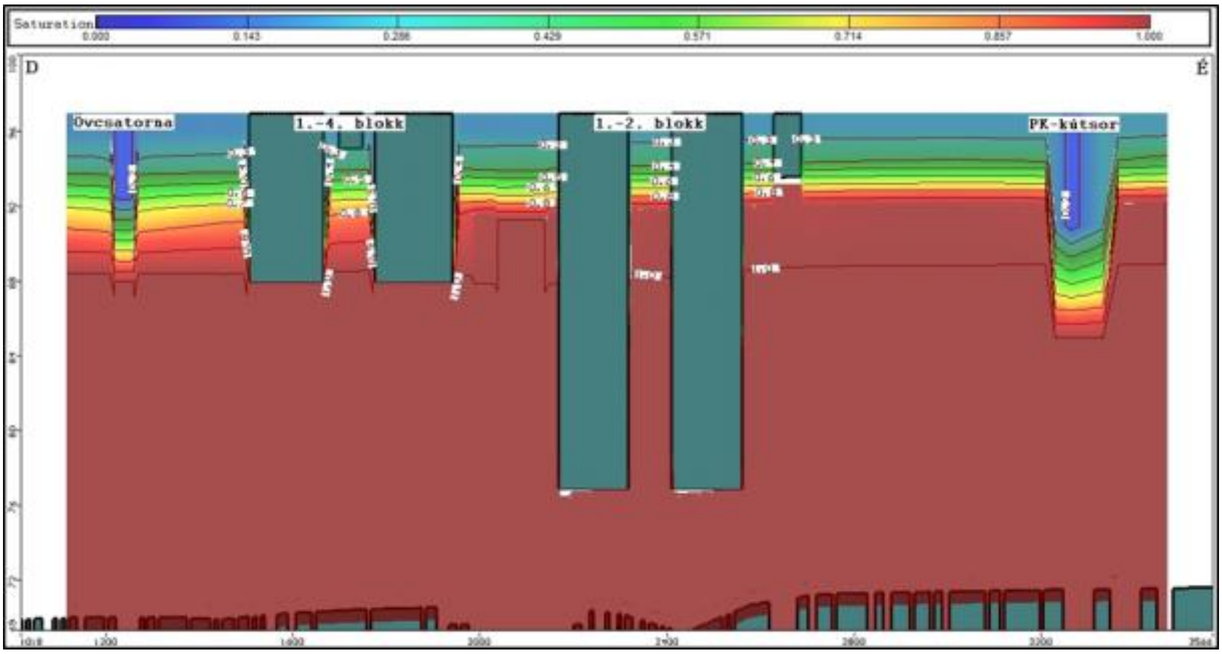
Nyugati löszplató-Western loess plateau
Övcsatorna-Diversion ditch
1. blokk-Unit 1
HVCS-Cold water canal
MVCS-Hot water canal
Halas-tó-Fish pond
Duna-River Danube

Figure 13.6.1-26: Vertical image of the groundwater table and the velocity space along a W-E section



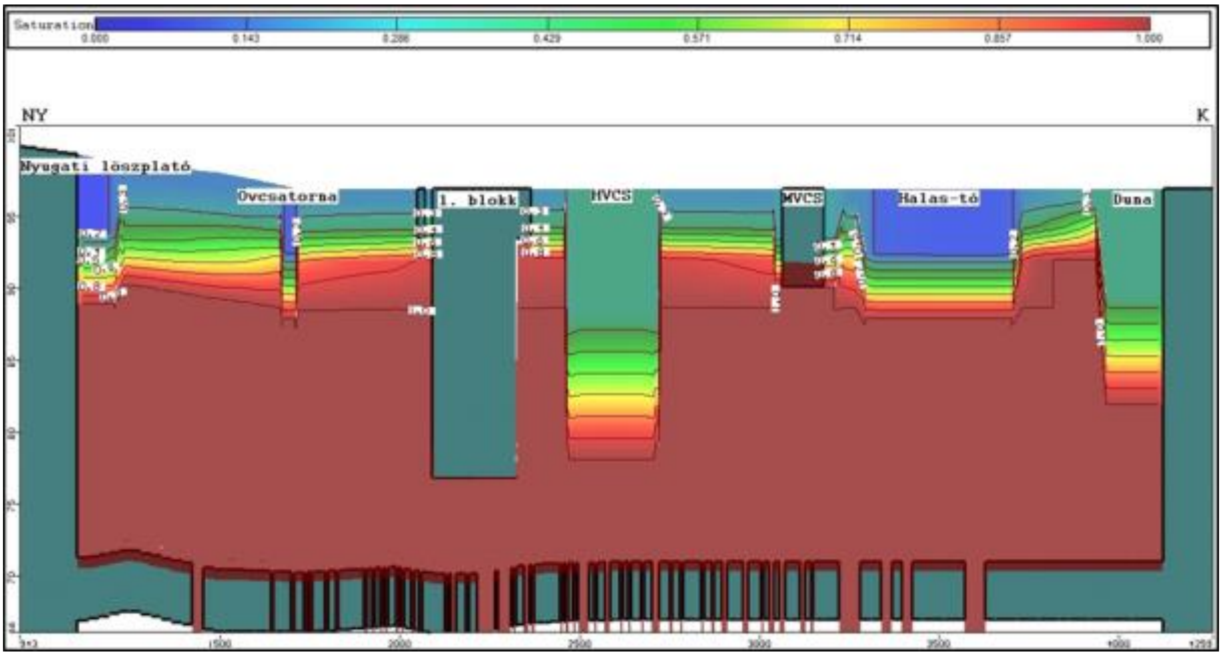
Vízrészecske pályák magas Duna vízállás esetén-Water particle paths in case of high Danube water level
markerek 365 napot jelölnek-markers indicate 365 days

Figure 13.6.1-27: Water particle path located in the layer under the power plant for high Danube water level



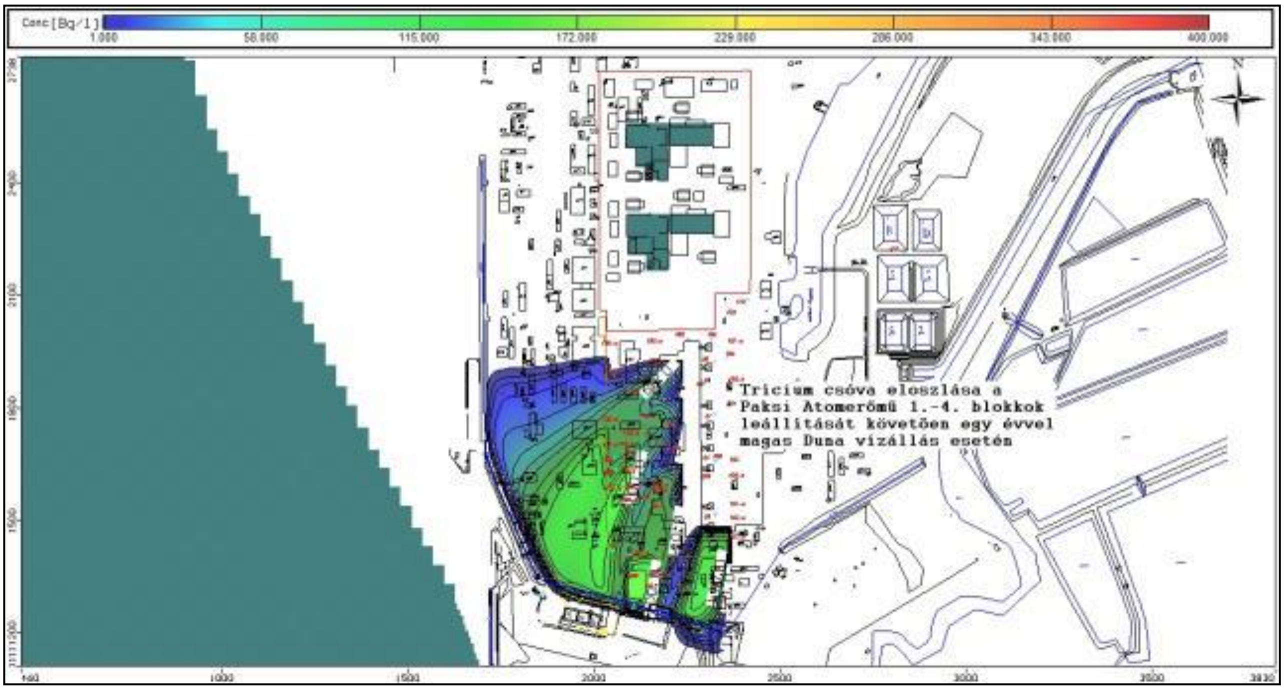
Övcsatorna-Diversion ditch
1.– 4. blokk-Units 1-4
1.– 2. blokk-Units 1-2
PK-kútsor-PK battery of wells

Figure 13.6.1-28: Image of the three-phase zone in case of constantly high Danube water level along a N - S section



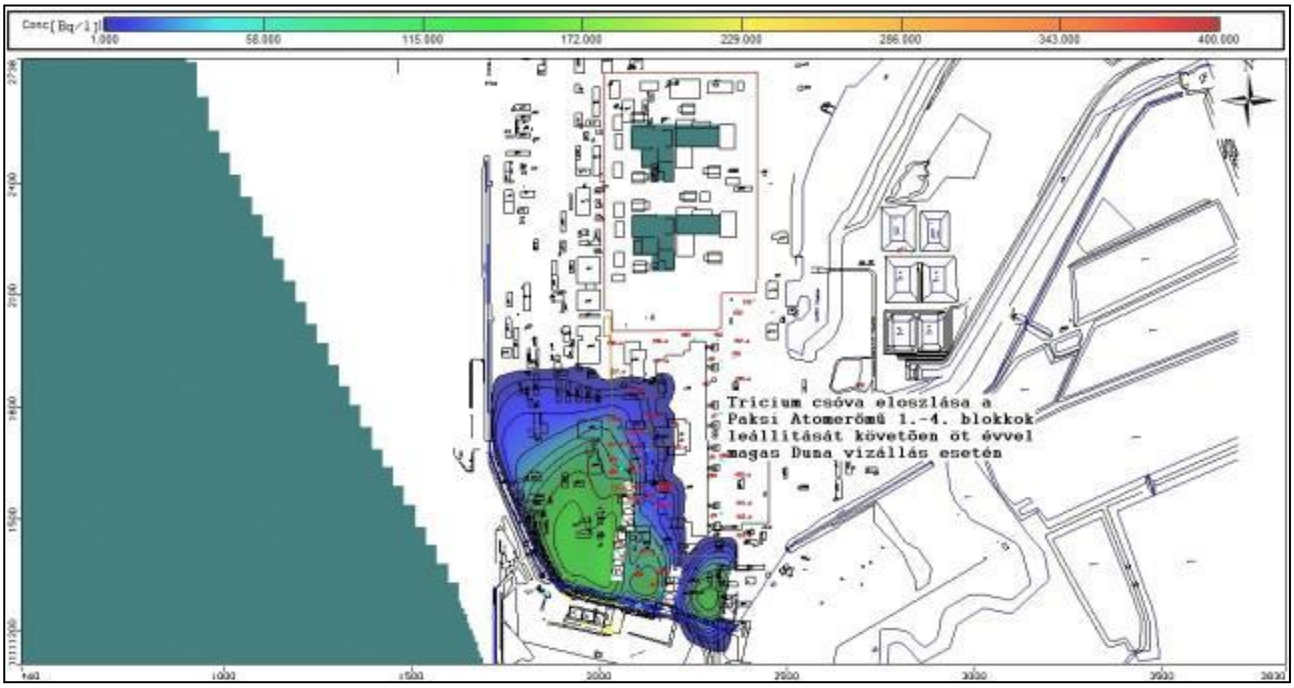
Nyugati löszplató-Western loess plateau
Övcsatorna-Diversion ditch
1. blokk-Unit 1
HVCS-Cold water canal
MVCS-Hot water canal
Halas-tó-Fish pond
Duna-River Danube

Figure 13.6.1-29: Image of the three-phase zone in case of constantly high Danube water level along a W - E section



Trícium csóva eloszlása a Paksi Atomerőmű 1.-4. blokkok leállítását követően egy évvel magas Duna vízállás esetén - Distribution of the tritium plume one year after shut down of Units 1-4 of Paks Nuclear Power Plant in case of high Danube water level

Figure 13.6.1-30: Distribution of the tritium plume one year after shut down of Units 1-4 of the Paks Nuclear Power Plant in case of high Danube water level



Trícium csóva eloszlása a Paksi Atomerőmű 1.-4. blokkok leállítását követően öt évvel magas Duna vízállás esetén - Distribution of the tritium plume five years after shut down of Units 1-4 of Paks Nuclear Power Plant in case of high Danube water level

Figure 13.6.1-31: Distribution of the tritium plume five years after shut down of Units 1-4 of the Paks Nuclear Power Plant in case of high Danube water level

Trícium csóva eloszlása a Paksi Atomerőmű 1.-4. blokkok leállítását követően tíz évvel magas Duna vízállás esetén - Distribution of the tritium plume ten years after shut down of Units 1-4 of Paks Nuclear Power Plant in case of high Danube water level

Figure 13.6.1-32: Distribution of the tritium plume ten years after shut down of Units 1-4 of the Paks Nuclear Power Plant in case of high Danube water level

Trícium csóva eloszlása a Paksi Atomerőmű 1.-4. blokkok leállítását követően húsz évvel magas Duna vízállás esetén - Distribution of the tritium plume twenty years after shut down of Units 1-4 of Paks Nuclear Power Plant in case of high Danube water level

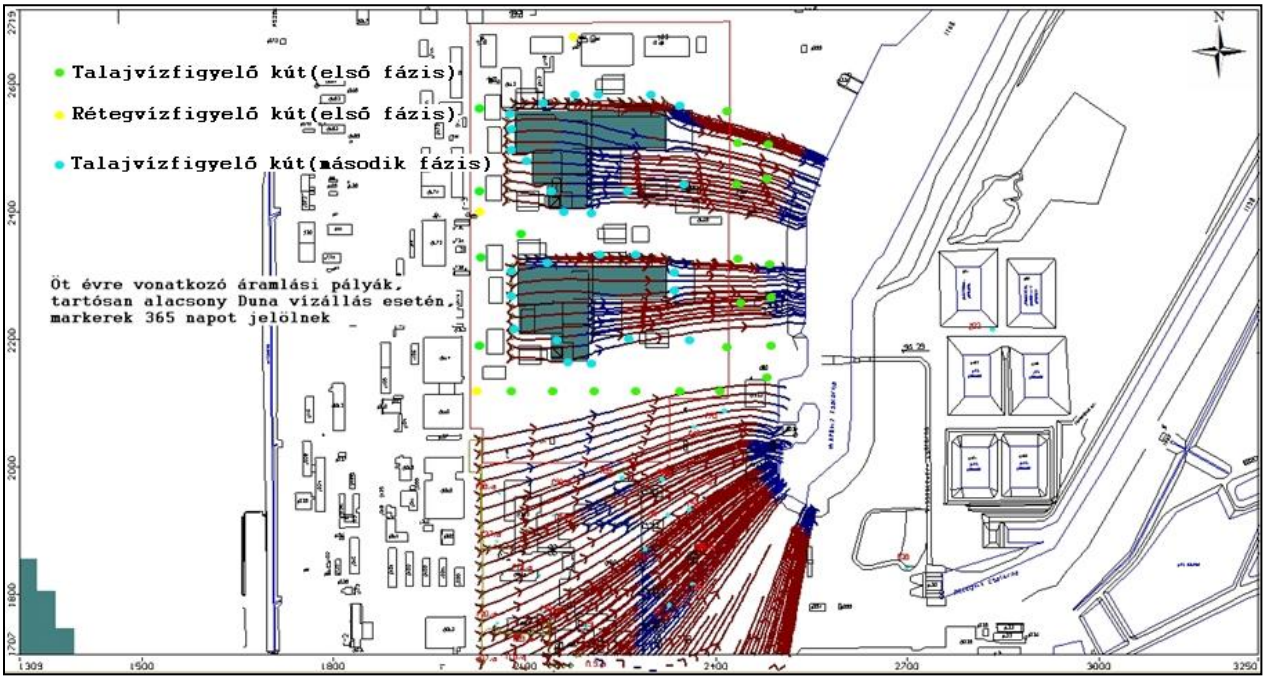
Figure 13.6.1-33: Distribution of the tritium plume twenty years after shut down of Units 1-4 of the Paks Nuclear Power Plant in case of high Danube water level

Trícium csóva eloszlása a Paksi Atomerőmű 1.-4. blokkok leállítását követően harminc évvel magas Duna vízállás esetén - Distribution of the tritium plume thirty years after shut down of Units 1-4 of Paks Nuclear Power Plant in case of high Danube water level

Figure 13.6.1-34: Distribution of the tritium plume thirty years after shut down of Units 1-4 the Paks Nuclear Power Plant in case of high Danube water level

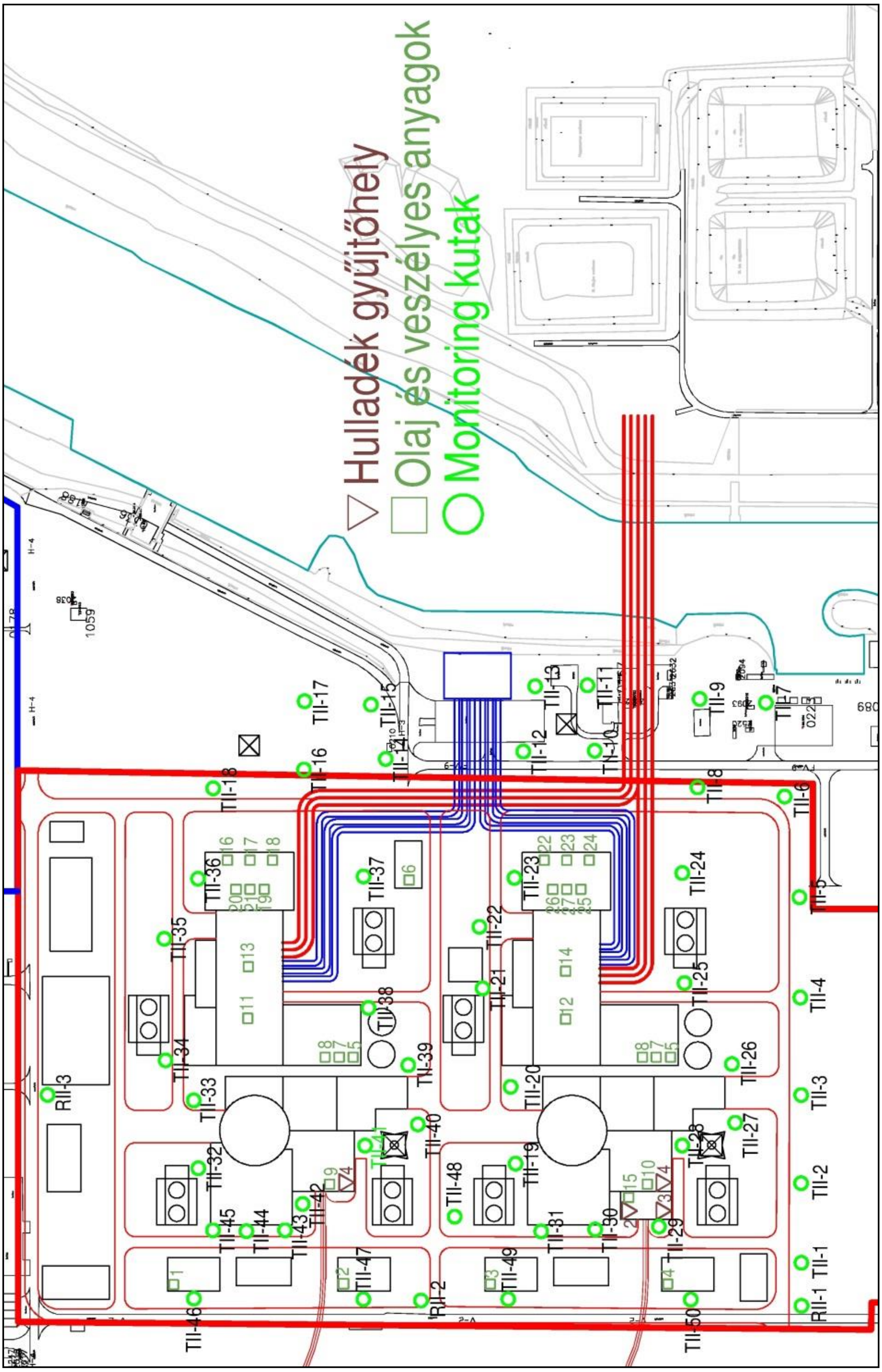
13.6.1.1.2 Conceptual design of the groundwater monitoring system

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 unit 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.



Talajvíz figyelő kút (első fázis)-Groundwater monitoring well (Phase 1)
Rétegvíz figyelő kút (első fázis)-Confined groundwater monitoring well (Phase 1)
Talajvíz figyelő kút (második fázis)-Groundwater monitoring well (Phase 2)
Öt évre vonatkozó áramlási pályák tartósan alacsony Duna vízállás esetén-Flow paths for five years in case of permanently low Danube water level
markerek 365 napot jelölnek-markers indicate 365 days

Figure 13.6.1-1: Installation phases of the monitoring system wells and flow paths



∇ Hulladék gyűjtőhely-Hazardous waste collection site
☐ Olaj és veszélyes anyagok-Oil and hazardous materials
○ Monitoring kutak -Monitoring wells

Figure 13.6.1-2: Waste disposal sites, storage sites for oily and hazardous materials and locations of monitoring wells

Sequential number	Denomination	Quantity
1, 2, 3, 4	Diesel generator (2 units/each building)	325 m^3 / Diesel generator
5	Hydrazine and és ammonia store	Ammonia hydroxide 1 m^3 Hydrazine 3 t
6	Hydrogen store	13 m^3
7	Chemicals store	Nitric acid 51 m^3 Sulphuric acid 80 m^3
8	Water treatment plant	Hydrochloric acid 53 m^3 Sodium hydroxide 40 m^3
9, 10	Boric acid storage	2 x 3 t
11, 12	Steam turbine oil system	2 x 120 m^3
13, 14	Generator hydrogen cooling	8 m^3
15	Strategic motor fuel charge	225.6 t
16, 17, 18; 22, 23, 24	Single phase main transformer	2 x 3 x 90 t
19, 20; 25, 26	Three phase utility transformer	2 x 2x 33 t
21; 27	Backup/Starter grid transformer	2 x 33 t

Table 13.6.1-1: Storage of oil and chemical compounds in the operating period

We propose to install the following wells for monitoring of the area.

Name of well	EOV Y	EOV X	Name of well	EOV Y	EOV X
TII-1	634943	137042	TII-28	635030	137131
TII-2	635003	137042	TII-29	634970	137149
TII-3	635067	137042	TII-30	634968	137196
TII-4	635140	137044	TII-31	634967	137236
TII-5	635214	137044	TII-32	635013	137492
TII-6	635289	137054	TII-33	635063	137495
TII-7	635358	137068	TII-34	635093	137516
TII-8	635295	137120	TII-35	635183	137517
TII-9	635361	137118	TII-36	635228	137492
TII-10	635322	137196	TII-37	635229	137368
TII-11	635371	137201	TII-38	635132	137365
TII-12	635321	137250	TII-39	635089	137335
TII-13	635370	137240	TII-40	635046	137328
TII-14	635316	137351	TII-41	635030	137367
TII-15	635357	137363	TII-42	634987	137414
TII-16	635308	137413	TII-43	634967	137427
TII-17	635359	137413	TII-44	634966	137456
TII-18	635295	137481	TII-45	634967	137481
TII-19	635017	137255	TII-46	634917	137495
TII-20	635074	137259	TII-47	634916	137369
TII-21	635147	137280	TII-48	634977	137300
TII-22	635192	137282	TII-49	634916	137261
TII-23	635228	137256	TII-50	634916	137125
TII-24	635232	137131	RII-1	634911	137043
TII-25	635150	137130	RII-2	634915	137326
TII-26	635090	137094	RII-3	635067	137604
TII-27	635047	137092			

	Confined groundwater monitoring well (phase 1)
	Groundwater monitoring well (phase 1)
	Groundwater monitoring well (phase 2)

Table 13.6.1-2: Names and EOV coordinates of monitoring wells

Groundwater monitoring wells

The base depth of proposed groundwater monitoring wells is 20 m, the top of filters is located 7.5 meters their bottom is positioned 15 meters from the surface. The piping diameter is 175 mm.

From groundwater monitoring wells TII-1, TII-4, TII-6, TII-8, TII-10, TII-12, TII-14, TII-16, TII-18, TII-19, TII-20, TII-21, TII-22, TII-23, TII-25, TII-26, TII-28,TII-30, TII-31, TII-32, TII-33, TII-34, TII-35, TII-38, TII-39, TII-41, TII-45, TII-46, TII-50:

tritium activity concentration by LSC measuring technique, without enrichment, on a ***monthly*** basis.

gamma-spectrometry (in case of tritium indication), from ***average samples taken in two months***

^{14}C, ***average samples taken in four months***

^{90}Sr and alfaspectrometry (in case of tritium indication), ***average samples taken in six months***

From groundwater monitoring wells TII-10, TII-12, TII-18, TII-23, TII-24, TII-25, TII-28, TII-29, TII-30, TII-31, TII-33, TII-36, TII-38, TII-41, TII-45, TII-46,TII-47, TII-48, TII-49, TII-50:

semi-annually: pH, conductivity, PO_43^-, F^-, NH_4+, NO_2^-, NO_3^-, Cl^-, SO_42^-, Cr, Co, Ni, Cu, Zn, Mo, Se, Cd, Sn, Ba, Pb, Ag, As, Hg;

annually: pH, conductivity, m-alkalinity, total dissolved material content, Na, K, Ca, Mg, Mn, Fe, PO_43^-, F^-, NH_4+, NO_2^-, NO_3^-, Cl^-, SO_42^-, CO_32^-, HCO_3^-, total hardness, total organic carbon, KOIps, Ag, Al, As, B, Ba, Be, Cd, Co, Cr, Cu, Hg, Li, Mo, Ni, Pb, Sb, Se, Sn, Te, Ti, Tl, U, V, Zn, PAH, TPH, BTEX

In wells located in the vicinity of potential sources, after measurement of the baseline level for the whole set of components, we only consider necessary to measure components corresponding to the chemicals used, on a quarterly basis.

Confined groundwater monitoring wells

From the RII-1, RII-2, RII-3 confined groundwater monitoring wells, tritium activity concentration ***on an annual basis*** using the T/^{3}He method, to check the absence of tritium (current status).

13.6.1.1.3 Indirect effects

The ^{14}C activity is not specified for the planned liquid release of the two new units to be established, but T release for the two new units shows good agreement with the current release levels of Paks, this is considered to be 1.05E+9 Bq per unit.

PAKS II Unit 1		**PAKS II Units 1 2**	
Nuclide	**Emission [Bq/year]**	**Nuclide**	**Emission [Bq/year]**
H-3	9.10E+12	**H-3**	1.82E+13
I-131	3.50E+07	**I-131**	7.00E+07
I-132	2.30E+06	**I-132**	4.60E+06
I-133	1.20E+07	**I-133**	2.40E+07
I-134	1.40E+06	**I-134**	2.80E+06
I-135	3.90E+06	**I-135**	7.80E+06
Sr-89	8.10E+05	**Sr-89**	1.62E+06
Sr-90	2.30E+03	**Sr-90**	4.60E+03
Cs-134	8.00E+07	**Cs-134**	1.60E+08
Cs-137	1.20E+08	**Cs-137**	2.40E+08
Co-58	5.60E+05	**Co-58**	1.12E+06
Mn-54	6.10E+05	**Mn-54**	1.22E+06
Co-60	2.50E+06	**Co-60**	5.00E+06
Cr-51	5.50E+05	**Cr-51**	1.10E+06
***C-14**	1.05E+09	***C-14**	2.10E+09

Note: * Estimated value

Table 13.6.1-1: Normal, operating and controlled liquid radioactive emissions of the Paks Nuclear Power Plant

	Q [m^3/s]	Q [m^3/év]	Q [l/év]
NV	5500	1.73E+11	1.73E+14
KÖV	2600	8.20E+10	8.20E+13
KV	600	1.89E+10	1.89E+13

Table 13.6.1-2: Danube discharge rate at Paks as a function of characteristic water levels

PAKSII Unit 1					
Nuclide	**NV, KÖV, KV [Bq/dm^3]**	**Nuclide**	**NV, KÖV, KV [Bq/dm^3]**	**Nuclide**	**NV, KÖV, KV [Bq/dm^3]**
H-3	5.25E-02	**I-135**	2.25E-08	**Co-58**	3.23E-09
	1.11E-01		4.76E-08		6.83E-09
	4.81E-01		2.06E-07		2.96E-08
I-131	2.02E-07	**Sr-89**	4.67E-09	**Mn-54**	3.52E-09
	4.27E-07		9.88E-09		7.44E-09
	1.22E-07		4.28E-08		3.22E-08
I-132	1.33E-08	**Sr-90**	1.33E-11	**Co-60**	1.44E-08
	2.81E-08		2.81E-11		3.05E-08
	1.22E-07		1.22E-10		1.32E-07
I-133	6.92E-08	**Cs-134**	4.61E-07	**Cr-51**	3.17E-09
	1.46E-07		9.76E-07		6.71E-09
	6.34E-07		4.23E-06		2.91E-08
I-134	8.07E-09	**Cs-137**	6.92E-07	***C-14**	6.07E-06
	1.71E-08		1.46E-06		1.28E-05
	7.40E-08		6.34E-06		5.56 E-5

Note: * Estimated value.

Table 13.6.1-3: Activity concentration values calculated with the characteristic discharge rates of the Danube. Paks Unit II.1

PAKSII Units 1 and 2					
Nuclide	**NV, KÖV, KV [Bq/dm^3]**	**Nuclide**	**NV, KÖV, KV [Bq/dm^3]**	**Nuclide**	**NV, KÖV, KV [Bq/dm^3]**
H-3	1.05E-01	**I-135**	4.50E-08	**Co-58**	6.46E-09
	2.22E-01		9.51E-08		1.37E-08
	9.62E-01		4.12E-07		5.92E-08
I-131	4.04E-07	**Sr-89**	9.34E-09	**Mn-54**	7.03E-09
	8.54E-07		1.98E-08		1.49E-08
	3.70E-06		8.56E-08		6.45E-08
I-132	2.65E-08	**Sr-90**	2.65E-11	**Co-60**	2.88E-08
	5.61E-08		5.61E-11		6.10E-08
	2.43E-07		2.43E-10		2.64E-07
I-133	1.38E-07	**Cs-134**	9.22E-07	**Cr-51**	6.34E-09
	2.93E-07		1.95E-06		1.34E-08
	1.27E-06		8.46E-06		5.81E-08
I-134	1.61E-08	**Cs-137**	1.38E-06	***C-14**	6.07E-06
	3.41E-08		2.93E-06		1.28E-05
	1.48E-07		1.27E-05		5.56 E-5

Note: * Estimated values.

Table 13.6.1-4: Activity concentration values calculated with the characteristic discharge rates of the Danube, Paks Units II 1 and 2

Since in the event of normal operation, the radionuclides released from the two new units 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 units 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.

13.6.1.2 Effects of joint operation of Paks II and the Paks Nuclear Power Plant

As a result of elimination of the depression cone around the units built and as a result of simultaneous operation, the spread of the tritium plume will gradually return to its original direction. The groundwater will begin to flow again to the cold water canal.

13.6.1.3 Impact areas of joint operation of Paks II and the Paks Nuclear Power Plant

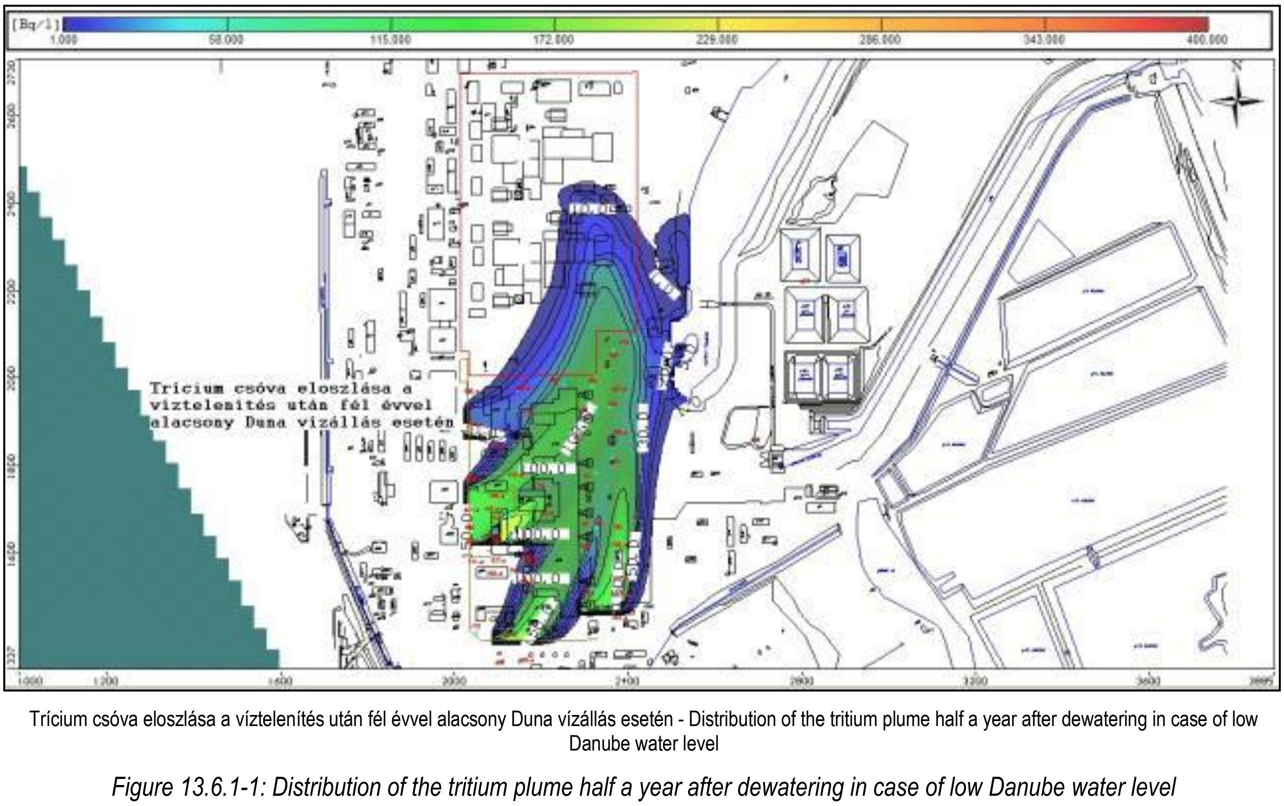
During simultaneous operation of the old and the new power plant units, new effects on the geological medium should not be expected. During simultaneous operation of old and new units, the geological medium is subject to similar effects (load effects of the facilities on the subsoil, vibration effects of turbine bases), but these effects are completely separate in time and space. Soil contamination will only occur in failure events.

13.6.1.3.1 Direct effects

Progressive elimination of the depression cone following the construction period will impact the direction of spread of the tritium plume. The direction of spread of the tritium plume will gradually return to the original east-northeast direction towards the cold water canal. To assess this process, we have performed permanent model runs for a seventeen-year period as a function of characteristic Danube water levels.

RESULTS OF THE MODEL RUN UNDER LOW WATER CONDITIONS

In case of low water conditions, the original E-NE flow direction can be restored roughly in half a year and in five years, the tritium plume spread since the maximum flow rate towards the Danube and the cold water canal is manifest in case of low Danube water level.

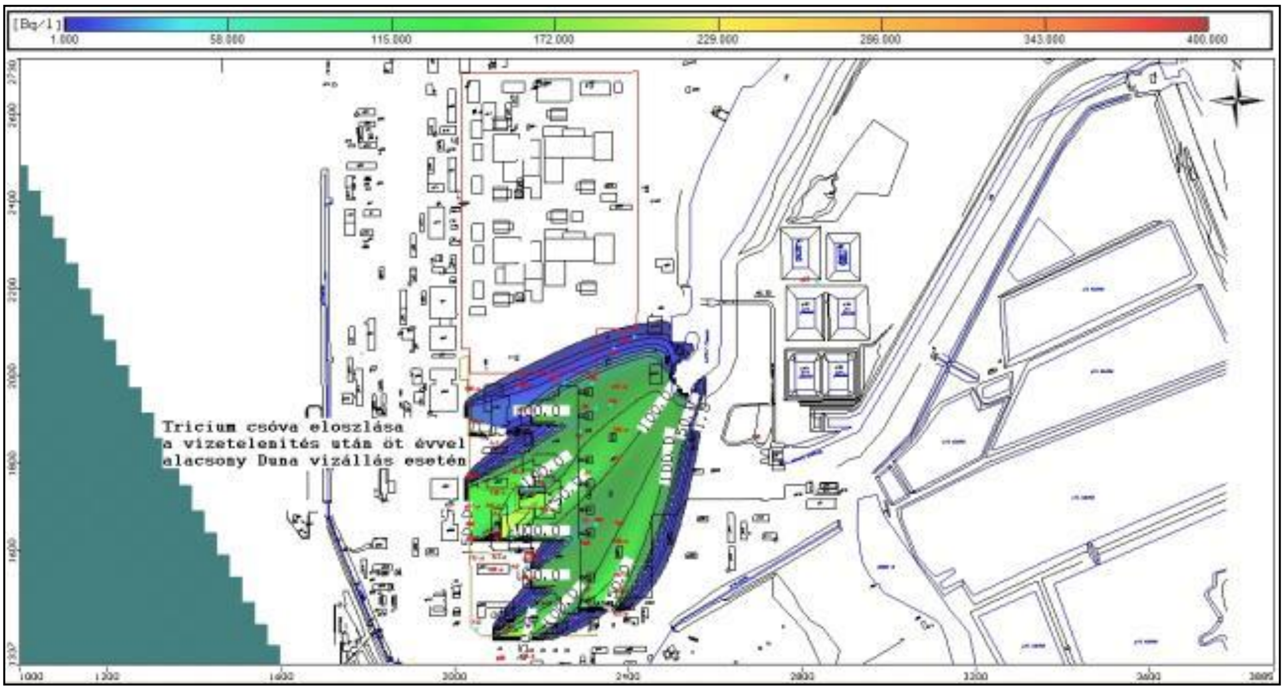


Trícium csóva eloszlása a víztelenítés után fél évvel alacsony Duna vízállás esetén - Distribution of the tritium plume half a year after dewatering in case of low Danube water level

Figure 13.6.1-1: Distribution of the tritium plume half a year after dewatering in case of low Danube water level

Trícium csóva eloszlása a víztelenítés után egy évvel alacsony Duna vízállás esetén - Distribution of the tritium plume one year after dewatering in case of low Danube water level

Figure 13.6.1-2: Distribution of the tritium plume one year after dewatering in case of low Danube water level

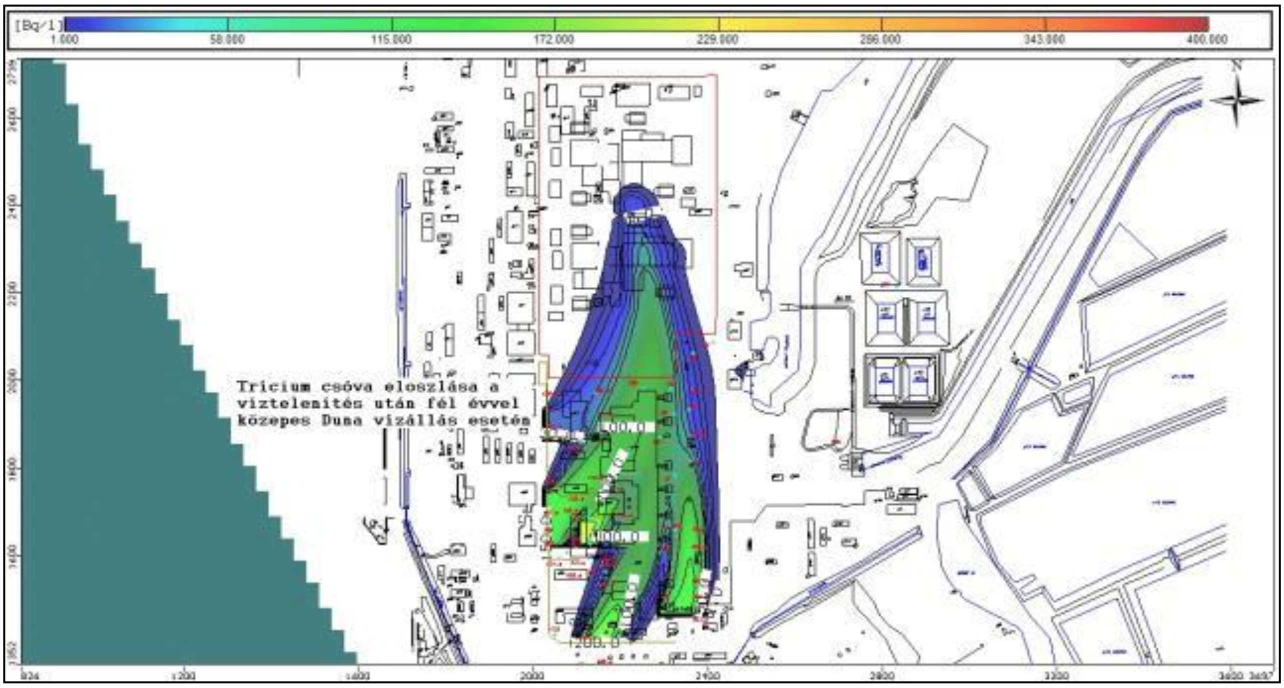


Trícium csóva eloszlása a víztelenítés után öt évvel alacsony Duna vízállás esetén - Distribution of the tritium plume five years after dewatering in case of low Danube water level

Figure 13.6.1-3: Distribution of the tritium plume five years after dewatering in case of low Danube water level

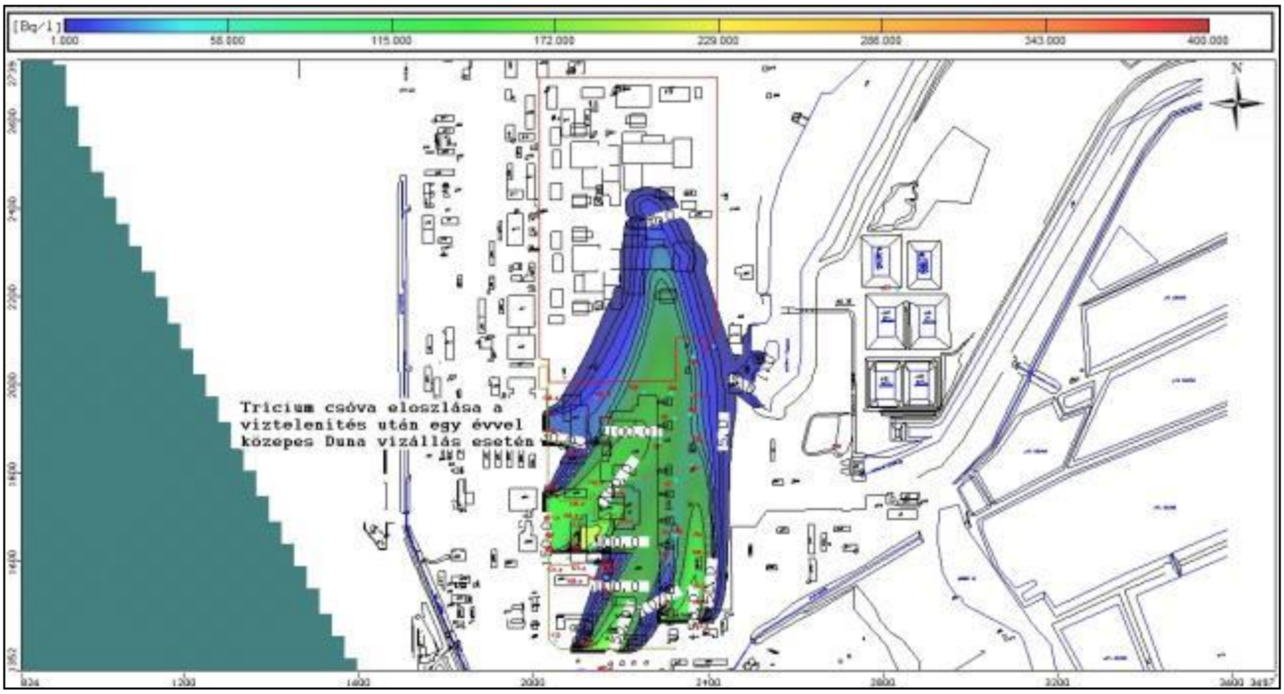
RESULTS OF THE MODEL RUN UNDER MEDIUM WATER CONDITIONS

In case of medium water conditions, the original E-NE flow direction can be restored roughly in one year and in ten years, the tritium plume spread since the flow rate towards the Danube and the cold water canal is decelerated in case of medium Danube water level.



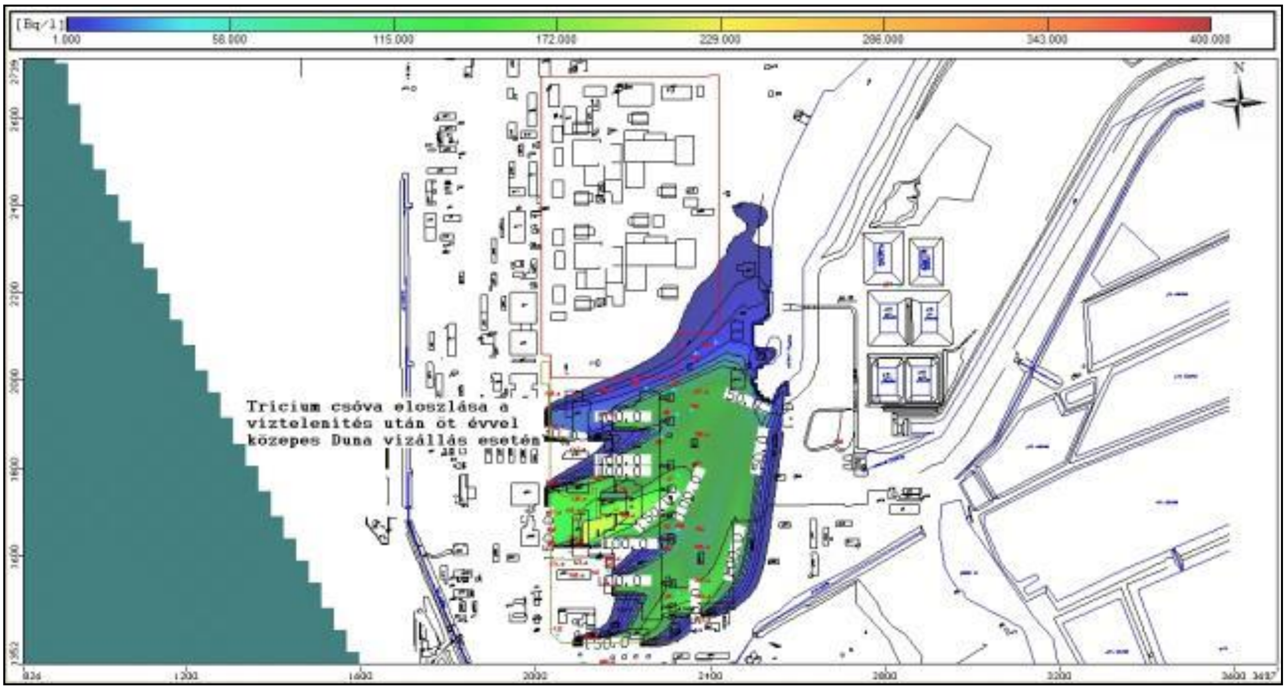
Trícium csóva eloszlása a víztelenítés után fél évvel közepes Duna vízállás esetén - Distribution of the tritium plume half a year after dewatering in case of medium Danube water level

Figure 13.6.1-4: Distribution of the tritium plume half a year after dewatering in case of medium Danube water level



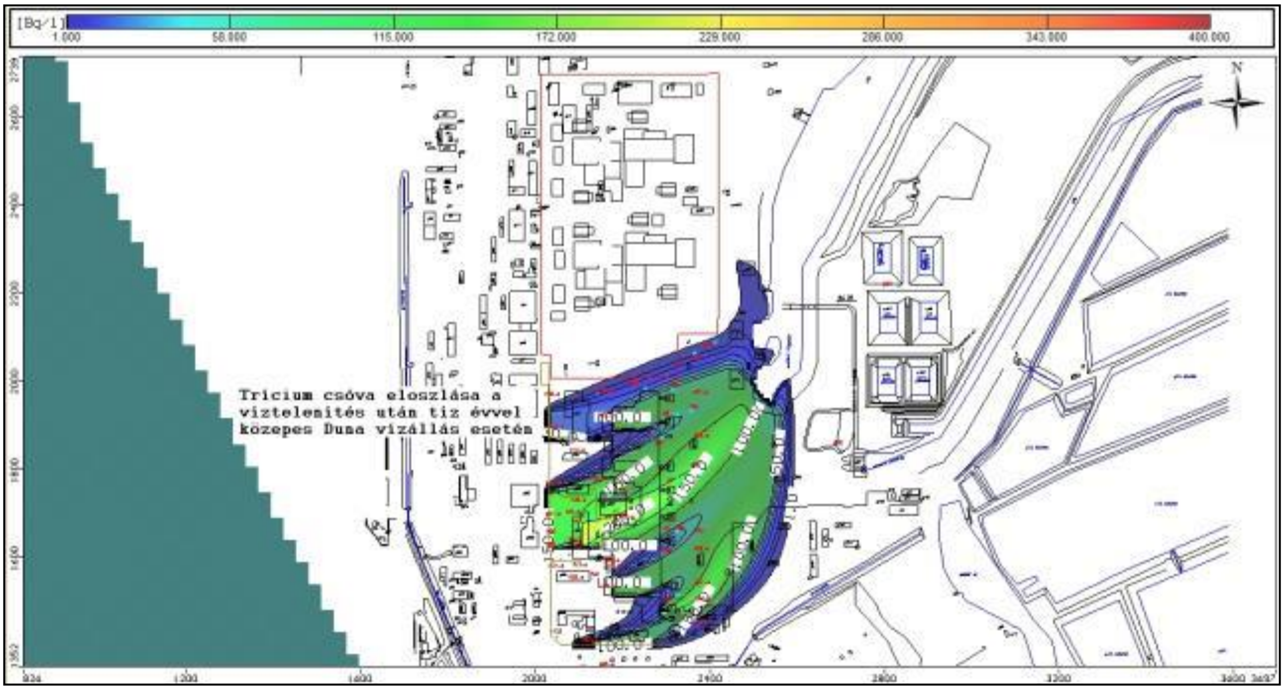
Trícium csóva eloszlása a víztelenítés után egy évvel közepes Duna vízállás esetén - Distribution of the tritium plume one year after dewatering in case of medium Danube water level

Figure 13.6.1-5: Distribution of the tritium plume one year after dewatering in case of medium Danube water level



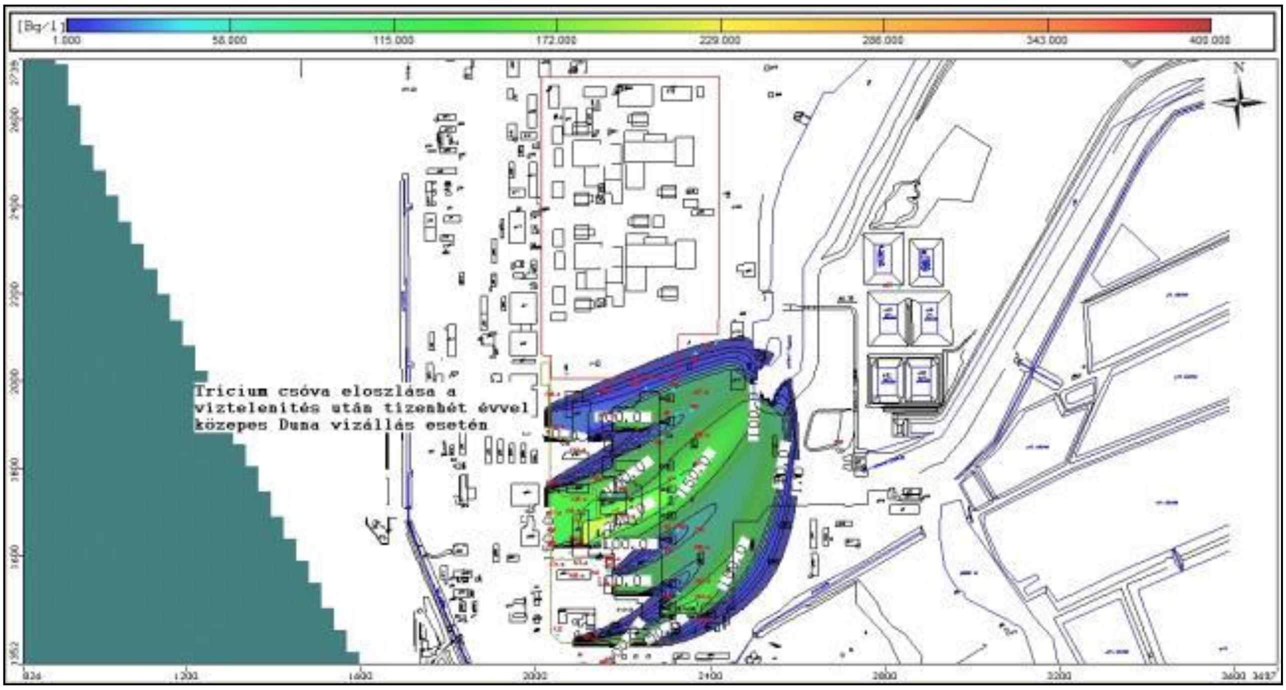
Trícium csóva eloszlása a víztelenítés után öt évvel közepes Duna vízállás esetén - Distribution of the tritium plume five years after dewatering in case of medium Danube water level

Figure 13.6.1-6: Distribution of the tritium plume five years after dewatering in case of medium Danube water level



Trícium csóva eloszlása a víztelenítés után tíz évvel közepes Duna vízállás esetén - Distribution of the tritium plume ten years after dewatering in case of medium Danube water level

Figure 13.6.1-7: Distribution of the tritium plume ten years after dewatering in case of medium Danube water level

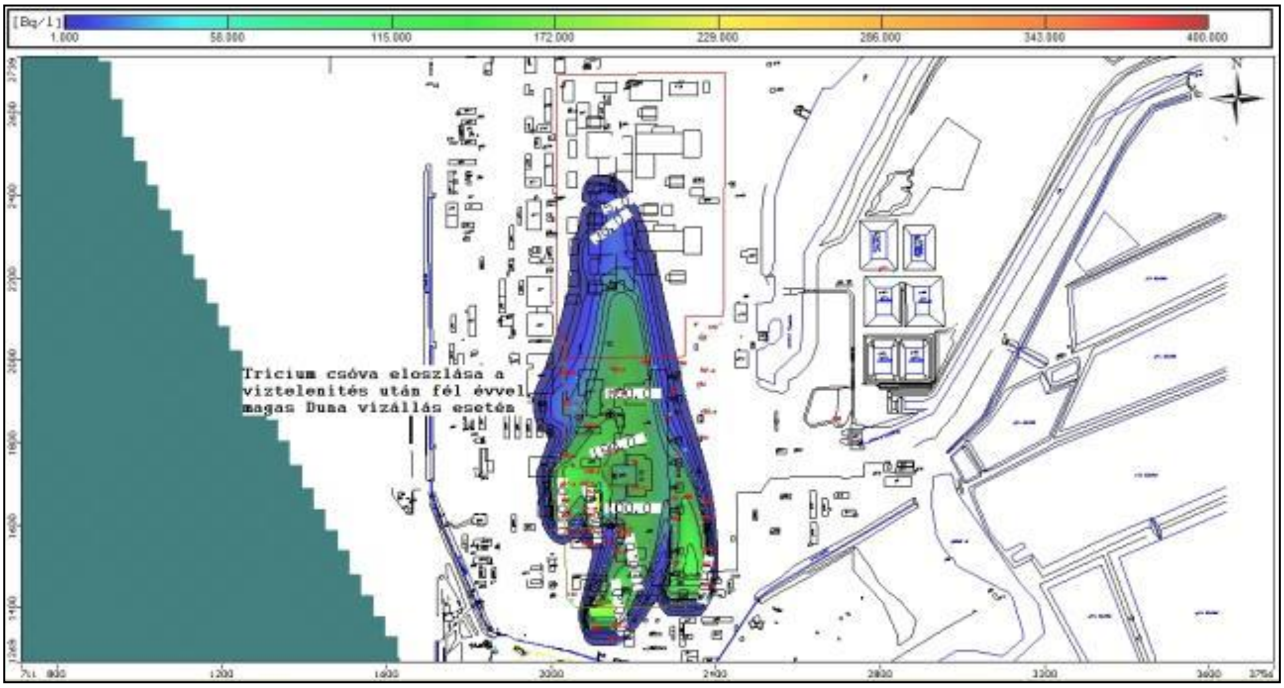


Trícium csóva eloszlása a víztelenítés után tizenhét évvel közepes Duna vízállás esetén - Distribution of the tritium plume seventeen years after dewatering in case of medium Danube water level

Figure 13.6.1-8: Distribution of the tritium plume seventeen years after dewatering in case of medium Danube water level

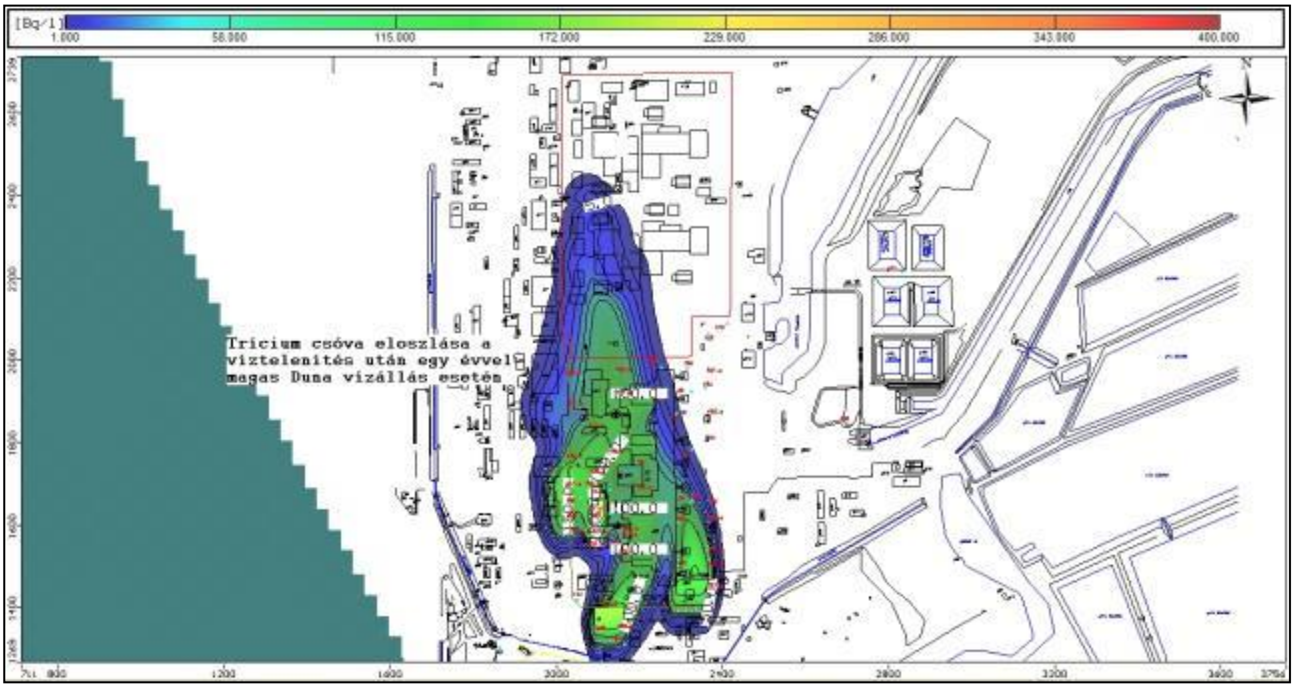
<u>**RESULTS OF THE MODEL RUN UNDER HIGH WATER CONDITIONS**</u>

In case of high water conditions, the original E-NE direction changes to W-SW and the plume starts to spread towards the diversion ditch. We wish to emphasize that in reality, the typical long-term water level can exist for a few months and permanent simulations have predicted extreme cases.



Trícium csóva eloszlása a víztelenítés után fél évvel magas Duna vízállás esetén - Distribution of the tritium plume half a year after dewatering in case of high Danube water level

Figure 13.6.1-9: Distribution of the tritium plume half a year after dewatering in case of high Danube water level



Trícium csóva eloszlása a víztelenítés után egy évvel magas Duna vízállás esetén - Distribution of the tritium plume one year after dewatering in case of high Danube water level

Figure 13.6.1-10: Distribution of the tritium plume one year after dewatering in case of high Danube water level

Trícium csóva eloszlása a víztelenítés után öt évvel magas Duna vízállás esetén - Distribution of the tritium plume five years after dewatering in case of high Danube water level

Figure 13.6.1-11: Distribution of the tritium plume five years after dewatering in case of high Danube water level

Trícium csóva eloszlása a víztelenítés után tíz évvel magas Duna vízállás esetén - Distribution of the tritium plume ten years after dewatering in case of high Danube water level

Figure 13.6.1-12: Distribution of the tritium plume ten years after dewatering in case of high Danube water level

13.6.1.3.2 Indirect effects

Since in the event of normal operation, the radionuclides released from the four old and two new units will 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 power plants will be only capable of increasing the tritium activity concentration of the Danube by 2.14 Bq/dm^3 in the case of low water. For comparison, the tritium activity concentration of the current precipitation is 0.52 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.

	Danube water level	Increment in activity concentration arising from total emission (except tritium)
PaksII 1 and 2 units	NV	1.51E-05
	KÖV	3.19E-05
	KV	1.38E-04
Paks 1-4 units	NV	1.37E-05
	KÖV	2.28E-04
	KV	5.52E-04
Total	NV	2.88E-05
	KÖV	6.08E-05
	KV	2.64E-04

Table 13.6.1-1: Total increase of activity concentration in the Danube caused by the emission of alpha, beta and gamma radiating isotopes.

13.6.1.3.3 Transboundary environmental impacts

From the hydrological model of the site, one can clearly draw the conclusion that contaminants 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.

13.6.2 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.

As a result of improper operation and in the event of accidents and failure events various (non-radioactive) contaminants may be released to the environment, thus to the geological medium or the underground water, as well. Due to underground pressure conditions (the pressure of confined groundwater is higher than that of groundwater) only groundwater can be involved, but confined groundwater cannot be affected by surface contamination. The degree of potential contamination is assessed in accordance with Annexes 1-4 of KvVM-EüM-FVB Decree 6/2009 (IV. 14.)

In the planned area of the new units, 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 1 E-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.

13.7 IMPACTS OF ABANDONMENT OF PAKS II ON THE GEOLOGICAL MEDIUM BENEATH THE SITE AS WELL AS THE UNDERGROUND WATER.

Currently, dismantling can be considered as the most likely among the abandonment and decommissioning scenarios. In this case, radioactive material may enter the groundwater (primarily by leaching) during dismantling of the substructure (plate base). In this case, we will not have to anticipate short-lived radionuclides. The impact of radioisotopes that may enter the groundwater is severely limited by sorption and the fact that the access time is 12-20 years between the main building and the Danube (for the most mobile tritium) as a function of location and water level. However, since the foundation of the current power plant (as a function of the Danube water level) is in the saturation zone even now, no excess load significantly different from the operating condition can be assumed, which is reported in detail in the previous chapters. Generally speaking, apart from tritium and carbon, the mobility of radioactive materials entering the groundwater is small, any potential contamination during dismantling can be controlled and eliminated in time, so there is no point in dealing with its effects under the current circumstances. Accidental spillage and thus, leaching into the soil along the waste transport route represents a further risk, but this effect can only be anticipated after completion of the specific dismantling plan.

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