CONSORTIUM

"DICON – ACCIONA ING."

ENVIRONMENTAL IMPACT ASSESSMENT REPORT

for Investment Proposal:

BUILDING A NEW NUCLEAR UNIT OF THE LATEST GENERATION AT THE KOZLODUY NPP SITE

CHAPTER 4: DESCRIPTION, ANALYSIS AND EVALUATION OF THE POTENTIAL SIGNIFICANT RADIATION AND NON-RADIATION IMPACT ON THE POPULATION AND THE ENVIRONMENT RESULTING FROM THE IMPLEMENTATION OF THE INVESTMENT PROPOSAL, THE USE OF NATURAL RESOURCES, THE EMISSIONS OF HARMFUL SUBSTANCES DURING NORMAL OPERATION AND IN EMERGENCY SITUATIONS, THE GENERATION OF WASTE AND THE CREATION OF DISCOMFORT

4.1. CLIMATE AND ATMOSPHERIC AIR

4.2. WATER

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A general approach will be implemented in order to establish the impact – one reflecting both the Bulgarian statutory requirements and good international practices related to the assessment of environmental impact and the risk for human health, based on:

1. **Probability for the manifestation** of the impact – expected, not expected;
2. **Territorial scope** of the impact within the boundaries of: the construction site of the IP, the Kozloduy NPP site, the 30 km Urgent Protective Action Planning Zone (UPAPZ);
3. **Type of the impact** – positive/negative and direct/indirect, primary and secondary;
4. **Level (significance) of the impact** out of 5 levels: 1 – very low, 2 – low, 3 – moderate, 4 – high, 5 – very high level;
5. **Characteristics of the impact**:
6. **Frequency** – permanent, temporary;
7. **Duration** – short-term, long-term;
8. **Cumulative effect** – impacts that occur simultaneously and affect the same environmental component/factor,
9. **Reversibility of the impact –** reversible, irreversible.

A 5-level scale is applied for the assessment of the impact: **1** – very low, **2** – low, **3** – moderate, **4** – high, **5** – very high level;

4.1 CLIMATE AND ATMOSPHERIC AIR

The alternative sites in the area of the Kozloduy NPP which considered as potentially suitable for the deployment of the NNU are shown on **Figure 4.1-1**.

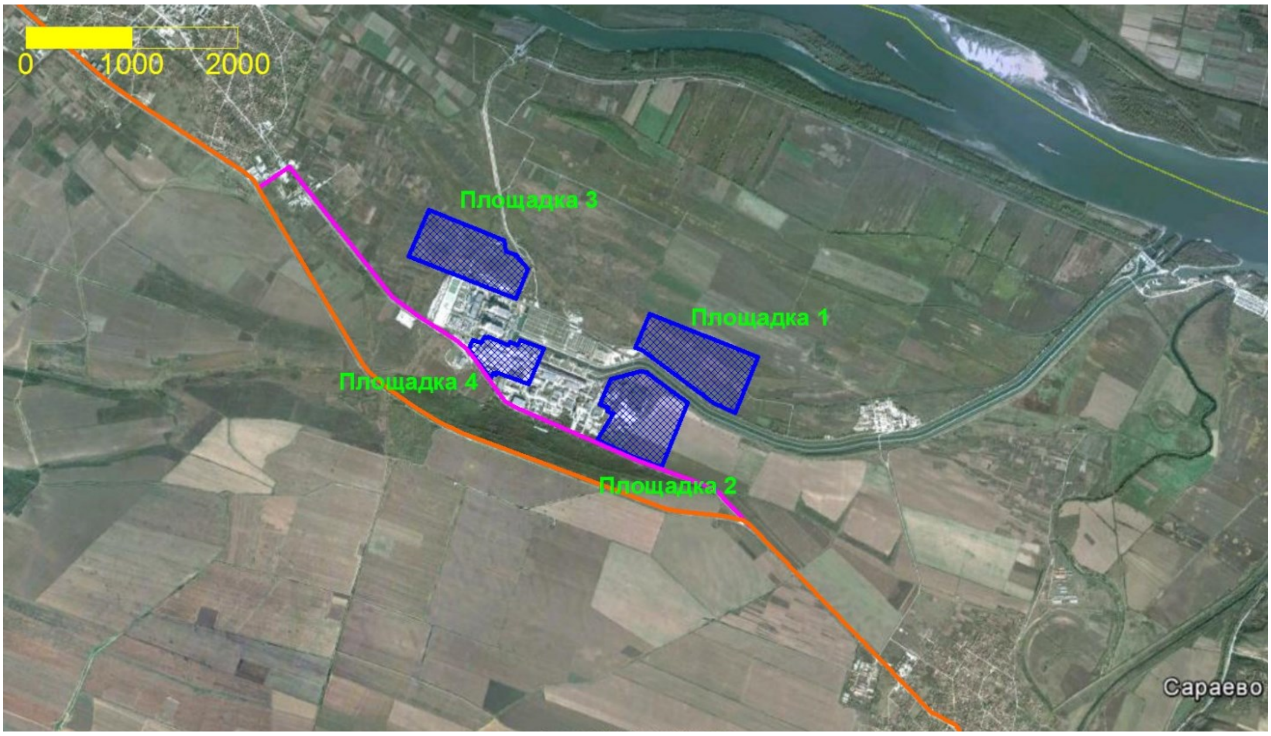


FIGURE 4.1-1: LOCATION OF THE POTENTIAL SITES FOR THE DEPLOYMENT OF THE NNU

On the figure Road II-11 from the national road network (the Harlets-Kozloduy section), 11.6 km in length, is shown in orange / ▬ /, and the internal south road of the power plant between the west and east checkpoints is shown in pink / ▬ /.

4.1.1 SOURCES OF POLLUTION AND GASEOUS AND DUST EMISSIONS TO THE ATMOSPHERIC AIR

The inventory of the emissions during the stages for the implementation of the IP makes an assessment on the levels of pollution and also identifies the source type – **Table 4.1-1**.

TABLE 4.1-1: SOURCES OF NON-RADIATION EMISSIONS

STAGE	SOURCES		
	Point-based	Area-based	Linear
Construction *(Initial Stage -before the engineering and construction works)*	**There are no** organised point-based sources of non-radiation pollutants	1. **Dust emissions** during the scraping of the upper layer of soil, excavation works, loading and removal of earth masses, as well as mechanical dust generation resulting from the movement of the construction machinery over the terrain while	**Gaseous emissions** from the ICEs of road vehicles (both private cars and technological vehicles transporting personnel and supplying raw materials) along the transportation arteries providing access to the power plant

		preparing the infrastructure of the site. 2. **Gaseous emissions** from the internal combustion engines (ICEs) of the construction machinery and the technological vehicles	
Operation	**There are no** organised point-based sources of non-radiation pollutants	**none**	**Gaseous emissions** from the ICEs of road vehicles (both private cars and technological vehicles transporting personnel and supplying raw materials) along the transportation arteries providing access to the power plant
Decommissioning	**There are no** organised point-based sources of non-radiation pollutants	**Gaseous emissions** from the internal combustion engines (ICEs) of the construction machinery and the technological vehicles	**Gaseous emissions** from the ICEs of road vehicles (both private cars and technological vehicles transporting personnel and supplying raw materials) along the transportation arteries providing access to the power plant

4.1.1.1 DURING CONSTRUCTION

The extraordinary gaseous and dust emissions during the construction stage result from the earth excavation works, the dust material processing, and the wind erosion of the open earth mass embankments, as well as the gaseous emissions from the transportation vehicles and construction machinery (internal combustion engines).

The quantities of the earth material and the necessary machinery and transport vehicles for each of the potential sites for the implementation of the NNU are presented in **Table 4.1-2**[1].

TABLE 4.1-2: TYPE OF ACTIVITIES AND MACHINERY

[1] Machinery necessary for the engineering preparation of the envisaged sites, Reference data from the New Capacities management, dated 28.03.2013.

	Site 1	Site 2	Site 3	Site 4
Excavated earth masses				
Excavated humus	210 000	220 000	210 000	
Excavation	-	343 000	3 440 000	310 000
Embankment up to elevation level 0.00	4 420 000	165 000	3 650 000	
TOTAL	**4 630 000**	**728 000**	**7 300 000**	**310 000**
Machinery				
Excavator	7	2	5	5
Excavators for spreading and compacting	7	4	5	0
Vibrational steam-rollers	10	4	5	0
Skid steers (loaders)	3	5	5	15
Dumper trucks	35	10	25	25

Site 4 has its own specific characteristics, because it is filled with many sub-sites from the existing infrastructure. It involves many complicated and responsible decisions related to the dismantling of the existing facilities.

An integral part of the information presented above, the schedule for the engineering preparation of the sites within the territory of the Kozloduy NPP must be envisaged in the Feasibility Study on the construction of a new nuclear unit.

4.1.1.1.1 Gaseous emissions

4.1.1.1.1.1 Construction machinery

The area-based emissions have been established using the methodology of the **EMEP/EEA air pollutant emission inventory guidebook – 2009** on the non-road mobile construction machinery with diesel fuel internal combustion engines (**1.A.2.f ii**), and on carbon dioxide – according to **IPCC** (**NFR** code **1.A.5.b.iii**).

The annual emissions (250 working days, 14 hours per day) of exhaust gases from the ICEs are shown in **Table 4.1-3**.

TABLE 4.1-3: ANNUAL EMISSIONS FROM THE CONSTRUCTION MACHINERY FOR EACH SITE

Site	Emissions [t/y]									$tCO_{2\text{-equiv}}$
	Greenhouse gases			Primary and specific pollutants						
	CO_2	CH_4	N_2O	NO_x	SO_X	CO	NMVOC	PM10	NH_3	
Site 1	33 026.05	2.04	14.27	142.75	1.04	142.75	20.39	8.16	0.0816	**37 494.1**
Site 2	11 983.48	0.74	5.18	51.80	0.38	51.80	7.40	2.96	0.0296	**13 604.7**
Site 3	23 043.79	1.42	9.96	99.60	0.72	99.60	14.23	5.69	0.0569	**26 161.3**
Site 4	20 540.12	1.27	8.88	88.78	0.64	88.78	12.68	5.07	0.0507	**23 319.0**

The emission quantities presented above are released directly into the atmospheric air from the exhaust pipes of the ICE vehicles.

4.1.1.1.1.2 Transportation activity

Based on data provided by the Client, "Machinery necessary for the engineering preparation of the envisaged sites", Reference data from the New Capacities management, dated 28.03.13, the envisaged intensity of the transport servicing the construction works is about 3 trips per hour for 14 working hours per day for the delivery of raw materials and waste removal.

The emissions (as a linear value) from the average 24-hour intensity of the road vehicle traffic (**Table 4.1-4**) has been assessed using the European *Emission Inventory Guidelines* **EMEP/EEA air pollutant emission inventory guidebook-2009** on the primary pollutants from the heavy road vehicles (*Dumper truck 20t* – **1.A.3.b.iii**) within the section **Transport**.

TABLE 4.1-4: AVERAGE 24-HOUR EMISSIONS FROM THE TRANSPORT ACTIVITY IN KG/KM

CO	NMVOC	NOx	N2O	NH3	Pb	PM2.5	Ideno Pyrene
kg/km							
0.063	0.012	0.263	1.68E-04	1.22E-04	2.98E-07	0.005	5.88E-08

TABLE 4.1-4 CONTINUED

B(k)F	B(b)F	B(a)P	CO_2	SO_2	benzene	tCO_2eq
kg/km						t/km
2.56E-07	2.29E-07	3.78E-08	27.69	0.00014	0.0004	**0.03**

The emissions are released directly into the atmospheric air from the exhaust pipes of the transport vehicles servicing the construction works. The total quantity of the greenhouse gases, expressed in tons equivalent to CO_2, is 0.03 tons per kilometre per day.

4.1.1.1.2 Dust emissions

The inventory of the emissions (area-based) (**Table 4.1-5**) of Total Suspended Particles (TSP) and fine Particulate Matter up to 10 microns (PM_{10}) for the various construction activities was based on the emission factors for open dust sources of the United States Environmental Protection Agency (EPA) AP-42 -**Construction and Aggregate Processing and Fugitive Dust Open Sources**[2], envisaging the emission factors for the assessment of dust emissions from various construction operations: preparation of the construction site (**section 11.9.2** – scraping the surface humus layer, excavations, embankments, tamping

[2] http://www.epa.gov/ttn/chief/ap42/index.html

and compaction of the terrain, reinforcement of the excavation or embankment) and dust from the necessary traffic within the construction site (**section 13.2.2** –traveling over unpaved surfaces).

TABLE 4.1-5: DUST EMISSIONS IN T/Y FROM THE CONSTRUCTION ACTIVITIES WITHIN THE POTENTIAL SITES FOR THE NNU

Sites	Excavated humus		Excavation		Embankment		Processing embankment materials (scraping and loading)		Bulldozing		Wind erosion		Movement over raw open dust sections	
	TSP	PM10	TSP	PM10	TSP	PM10	TSP	PM10	TSP	PM10	TSP	PM10	TSP	PM10
1	1.8	0.9	0.0	0.0	11.9	5.1	16.7	8.1	61.7	30.0	54.2	27.1	49.9	15.9
2	1.9	0.9	5.8	2.8	0.4	0.2	1.0	0.5	61.7	30.0	54.2	27.1	49.9	15.9
3	1.8	0.9	58.1	27.9	9.9	4.2	13.9	6.8	61.7	30.0	52.2	26.1	49.9	15.9
4	0.0	0.0	5.2	2.5	0.0	0.0	0.0	0.0	61.7	30.0	20.7	10.3	49.9	15.9

The intensity of dust formation is highly dependent on the meteorological conditions during the construction activities and on the season during which the construction works will be performed, on the climatic and meteorological factors (wind, humidity, temperature, atmospheric stability), the characteristics of the earth particles and many other conditions.

When the sprinkler system is used to maintain adequate moisture within them, the levels of dust emissions (controlled emissions) are reduced by 80%[3] according to the following formula:

$$E_C = E \times \left(\frac{100 - C}{100}\right),$$

where: E_C is the level of the controlled emission, E is the level of the uncontrolled emission, and C represents control efficiency in %.

4.1.1.1.3 Emissions during the application of asphalt paving

The future technical designs for the construction of the NNU envisage asphalt paving for both the technological areas and for a bypass and operation road. The level of emissions of non-methane volatile organic compounds (**NMVOC),** total suspended particles (**TSP)** and fine particulate matter up to 2.5 (**$PM_{2.5}$**) and up to 10 microns (**PM_{10})** during the laying of

[3] http://www.epa.gov/ttn/chief/ap42/ch11/final/c11s00.pdf

the asphalt mixture can be calculated using **Tier 1**[4] of the method **EMEP/EEA air pollutant emission inventory guidebook-2009** (**NFR** code **1.A.6 – Road paving with asphalt**), where the emission factors are given in grams per ton of asphalt laid.

4.1.1.2 DURING OPERATION

During operation, emissions are expected (linear ones) from the exhaust gases generated by the equipment with internal combustion engines (ICE) such as the transport servicing the NNU personnel, delivering raw materials and removing waste. According to the expert assessment, the intensity of this transport is expected to be half of the transport currently servicing units 5 and 6.

Fugitive dust emissions are not expected.

4.1.1.3 DURING DECOMMISSIONING

The activities for the decommissioning of the NNU are expected after more than 50 years. The actual period of the activities for the decommissioning of the NNU will be a long-term one – more than 15-20 years, and therefore in both annual and spatial aspect these emissions will have lower significance than the ones generated during the construction of NNU.

The emission levels during the decommissioning will depend on both the technological dismantling of engineering structures and the engines of the machinery that will be used after more than half a century, so it is not possible to make quantitative estimates based on the emission factors that are currently valid.

4.1.2 AIR QUALITY STANDARDS

Directive 2008/50/EC on ambient air quality and cleaner air for Europe establishes a EU-level air quality assessment framework and repeals and replaces the preceding directive on air quality (96/62/EC) and the three daughter directives (1999/30/EC, 2000/69/EC, 2002/3/EC), as well as Decision 97/101/EC of the Council of Europe.

Directive 2008/50/EC is supplemented by Directive 2004/107/EC relating to arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons in ambient air.

In the Bulgarian national legislation these directives have been reflected in Regulation No. 11 from 14 May 2007 establishing the standards for arsenic, cadmium, nickel and polycyclic aromatic hydrocarbons in ambient air, and in Regulation No. 12 from 15 July 2010 establishing the standards for sulphur dioxide, nitrogen dioxide, fine particulate matter, lead, benzene, carbon monoxide and ozone in ambient air.

[4] The EMEP/EEA CORINAIR 2009 methodology uses methods of different complexity to determine emission levels – ones that describe the main activities during emission inventory taking. The level of complexity of the method is marked as Tier X, i.e. the higher the X number, the more complex and accurate the method.

Table 4.1-6 and **Table 4.1-7** systematise the standards on air quality from the two directives and the national legislation.

TABLE 4.1-6: STANDARDS ON THE PROTECTION OF HUMAN HEALTH

Pollutant	Concentration	Dimension	Period of average values	Permitted exceedances each year	Entered into force	LAT	UAT
LIMIT VALUE							
$PM_{2.5}$	20	µg/m³	1 year	-	1.1.2015	12	17
Sulphur dioxide (SO_2)	350	µg/m³	1 hour	24	1.1.2005	-	-
	125	µg/m³	24 hours	3	1.1.2005	50	75
Nitrogen oxide (NO_2)	200	µg/m³	1 hour	18	1.1.2010	100	140
	40	µg/m³	1 year	-	1.1.2010	26	32
PM10	50	µg/m³	24 hours	35	1.1.2005	25	35
	40	µg/m³	1 year	-	1.1.2005	20	28
Lead (Pb)	0.5	µg/m³	1 year	-	1.1.2005	0.25	0.35
Carbon monoxide (CO)	10	mg/m³	Max 8 hour average	-	1.1.2005	5	7
Benzene (C_6H_6)	5	µg/m³	1 year	-	1.1.2010	2	3.5
TARGET VALUE							
$PM_{2.5}$	25	µg/m³	1 year	n/a	1.1.2010	-	-
Ozone (O_3)	120	µg/m³	Max 8 hour average	25 days average for 3 years	1.1.2010	-	-
Arsenic (As)	6	ng/m³	1 year	n/a	1.1.2013	2.4	3.6
Cadmium (Cd)	5	ng/m³	1 year	n/a	1.1.2013	2	3
Nickel (Ni)	20	ng/m³	1 year	n/a	1.1.2013	10	14
Polycyclic aromatic hydrocarbons (PAH)	1 *Concentration of Benzo(a)pyrene*	ng/m³	1 year	n/a	1.1.2013	0.4	0.6

TABLE 4.1-7: CRITICAL LEVEL FOR THE PROTECTION OF VEGETATION AND ECOSYSTEMS

Pollutant	Concentration	Dimension	Period of average values	Permitted exceedances each year	Entered into force	LAT	UAT
Sulphur dioxide (SO2)	20	µg/m3	1 year winter (Oct. 1 – Mar. 31)	-	-	8	12
Nitrogen dioxide (NO2)	30	µg/m3	1 year	-	-	19.5	24

4.1.3 ASSESSMENT OF THE POTENTIAL IMPACTS ON THE CLIMATE AND THE AMBIENT AIR

4.1.3.1 CLIMATE

Climate changes result from complex long-term processes, distant in time and space and highly dependent both on the development of the modern geological era (planetary causes) and on solar activity.

The climate in each region is formed under the influence of radiation, circulation, physical and geographic factors, but the determining role for its formation is played by the intensity of solar radiation, its quantity and inter-annual distribution. All of these factors influence the diffusion and transfer of emissions within the air basin of any given region. That is indeed one of the reasons why the World Meteorological Organization defines the years that can serve as the basis for comparative analyses and assessments of the meteorological parameters for a given region.

The implementation of the IP will have no impact on the conditions and the spatial distribution of the values of climatic elements the areas adjacent to the alternative sites.

Climate change is not expected to occur due to the potency of non-radiation emissions during all three phases: construction, operation and decommissioning.

4.1.3.2 NON-RADIOACTIVE POLLUTION OF AMBIENT ATMOSPHERIC

4.1.3.2.1 During construction

4.1.3.2.1.1 Impact of area-based sources

To assess the dispersion of emissions from sources during the construction of each of the 4 sites, a model used by the U.S. Environmental Protection Agency (EPA) ***ISC-AERMOD*** (Industrial Source Complex) [5] will be applied. Windows interface of the model is developed by Canadian software company *Lakes Environmental*[6].

AERMOD consists of three modules:

→ Atmospheric dispersion module (**AERMOD**),

→ Terrain pre-processor (AERMAP), which is used in the presence of a complex terrain to describe the height of each receptor,

→ Meteorological pre-processor (**AERMET**), which is used to prepare meteorological data input for simulation by the dispersion module.

AERMOD requires two types of hourly meteorological data: one, referring to the surface values of meteorological parameters, and another one, describing their vertical profiles, serving to render the vertical non-homogeneity in the structure of the surface boundary layer. The vertical mixing of pollutants with ambient air is limited in the event of stable

[5] http://www.epa.gov/ttn/scram/dispersion_prefrec.htm#aermod
[6] http://www.weblakes.com/products/aermod/index.html

stratification (a positive change of temperature with the height). The dispersion in unstable thermal conditions (strong convection) is not Gauss-like and physically it is described via turbulent convective flux due to which higher concentrations of pollutants are registered close the source.

Based on the ground characteristics of the underlying surface: roughness height, albedo and Bowen ratio (moisture amount which depends on the surface type – urban, rural, forest, water and so on, and varies depending on the season and wind direction), ***AERMET*** calculates the parameters of the surface boundary layer, which account for its development and which affect the pollutants dispersion. These parameters include surface friction velocity (measure of velocity that relates shear between layers of flow); surface heat flow (thermal energy vertical transport); mixing layer height at day; mixing layer height at night, and more.

In the ***AERMET*** model, the stable atmospheric condition is determined based on Monin-Obukhov's length which is a measure of heat transfer near the earth's surface. The relationship between Monin-Obukhov's length and the 6 atmospheric stability classes of Pascal-Gifford is the following.

	L Values	Stability Conditions	Pascal-Gifford Class
Small negative	$-100\ m < \mathbf{L} < 0$	Very unstable	A
Large negative	$-10^5\ m \le \mathbf{L} \le -100\ m$	Unstable conditions	C
Very large(- or +)	$\lvert \mathbf{L} \rvert > 10^5\ m$	Neutral	D
Large positive	$10\ m \le \mathbf{L} \le 10^5\ m$	Stable	E
Small positive	$0 < \mathbf{L} < 10\ m$	Very stable	F

Input data on dust emissions

The quantitative values on emissions for all potential sites have been taken from **Table 4.1-5.**

The effects of each source has been accounted for within a time schedule (i.e. they are a function of time), and the data has been integrated into the so-called "HOURLY EMISSION RATE FILE" (HOREMIS – Hourly Emission), which is an hourly effects schedule for each individual source.

Input parameters for the modelling process

A model has been created where the exact coordinates and boundaries of the 4 sites have been marked, and an exact map of the terrain has been entered in the appropriate shapefile format. Using the program module ***AERMAP*** to calculate the topography, exact data on the latitude of all sites, including the sources of pollution and the receptors for the specific project, has also been put in.

For the process of modelling, a receptor grid has been created, where the expected ground concentrations are calculated at the nodes.

Input meteorological parameters – data for 2012

For the purposes of the model, the software program ***AERMET*** is used to create a profile file containing the meteorological parameters (respectively .SFC and .PFL), representative for the 4 sites. During the preparation of this file, the terrain specifics (arable area, coniferous forest, deciduous forest, water area and so on) is accounted for, whereas the primary meteorological data for them, prepared using the synoptic model **MM5,** are purchased from the **Lakes Environmental Software for a point with coordinates** representative of the region.

The following figures present the analysis on the meteorological file, which contains records on wind speed and direction, stability classes, temperature, etc.

Figure 4.1-2 shows the records on the hourly temperature for 2012.

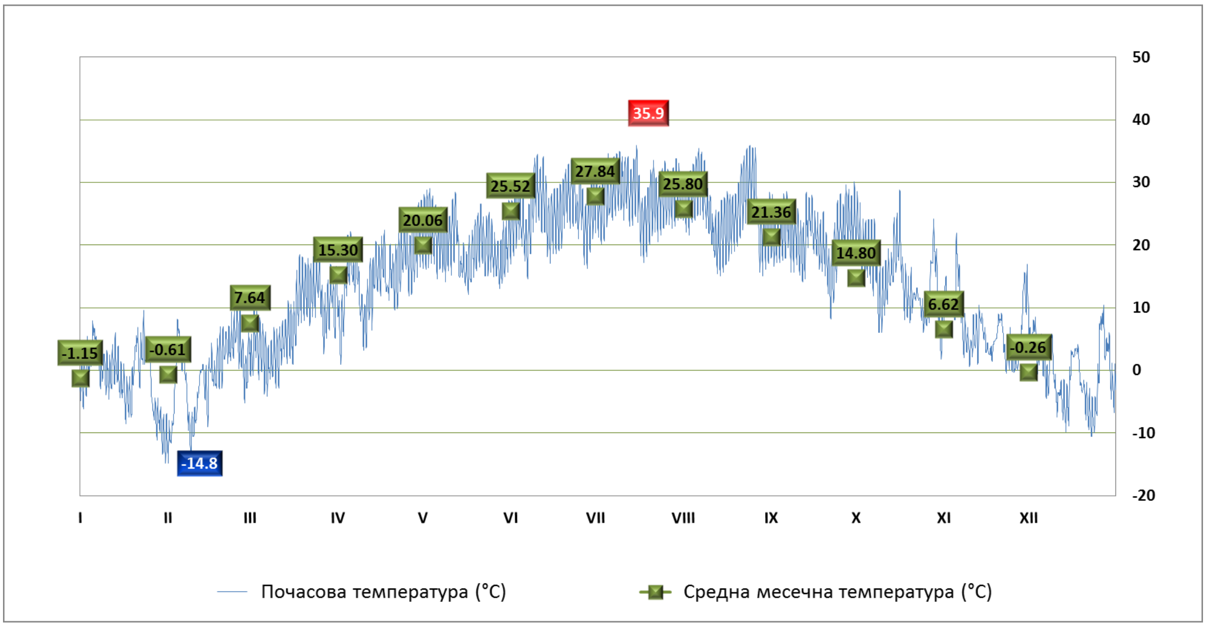


FIGURE 4.1-2: TEMPERATURE FOR 2012

The average annual temperature was 13.61°C. The absolute maximum temperature of 35.9°C was measured in July (15.07.2012 at 17:00) and August (24.08.2012 at 16:00), with the average monthly temperature being 27.84°C and 25.8°C respectively. For the last climatic period 1961-1990 the average monthly temperature norm for the Lom station for the month of July was 19.8°C, and for August – 19.4°C.

The absolute minimum temperature of minus 14.8°C was measured on 31.01.2012 at 08:00, with the average monthly temperature being minus 1.15°C. For the last climatic period 1961-1990 the average monthly temperature norm for the winter months at the Lom station was: for January minus 0.5°C, and for December – plus 0.6°C.

Figure 4.1-3 presents the wind rose from the hourly meteorological file for 2012, with the average annual speed being 3.02 m/s. The rose is typical for the Bulgarian regions along the Danube: its orientation is based on the zonal transfer from the west to the east, and at the same time it reflects the orientation of the large river basin – the Danube River – around the Kozloduy NPP site (northwest-east), whose aeration impact is noticeable – the calm conditions is only about 10%. Wind speeds within the 1÷2 m/s range represent 14.8%, and those within the 2÷4 m/s range represent 38.1%, the 4÷6 m/s range – 20.6%, the 6÷8 m/s range – 5.5%. The highest wind speeds (above 10 m/s) have the winds blowing from west-northwest, followed by those from east-northeast. With the lowest frequency are those winds blowing from north (2.5%) and south (3%).

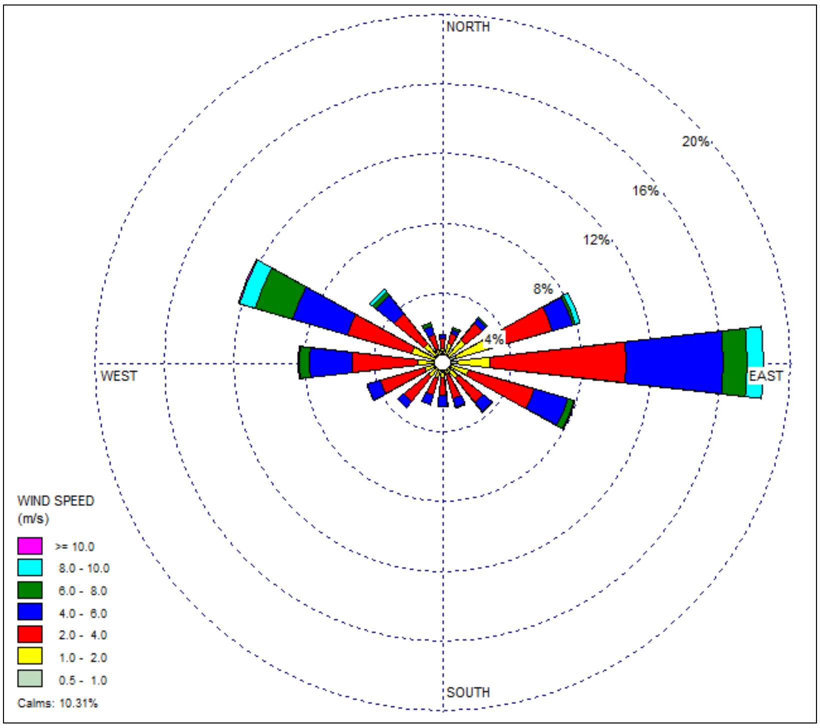


FIGURE 4.1-3: WIND ROSE FOR 2012. CALM CONDITIONS – 10.31%

Figure 4.1-4 shows the rose of stability classes for 2012.[7] The largest share is held by the stable atmospheric stability class (E-class) – 23.96%, and the winds with the highest frequency are those from the west, with 3.4%. The share of neutral conditions (D-class) is 13.67%, where west-southwest winds are most common, at 4.5%. Unstable atmospheric conditions (class A, B and C) have a 42.49% share of the cases.

[7] Gromkova, N. – Pre-processed Hourly Data Set – The Meteorological Input of Applied Diffusion Models, 1998, Bulg. Geoph. J., v. XXIV, No 3-4

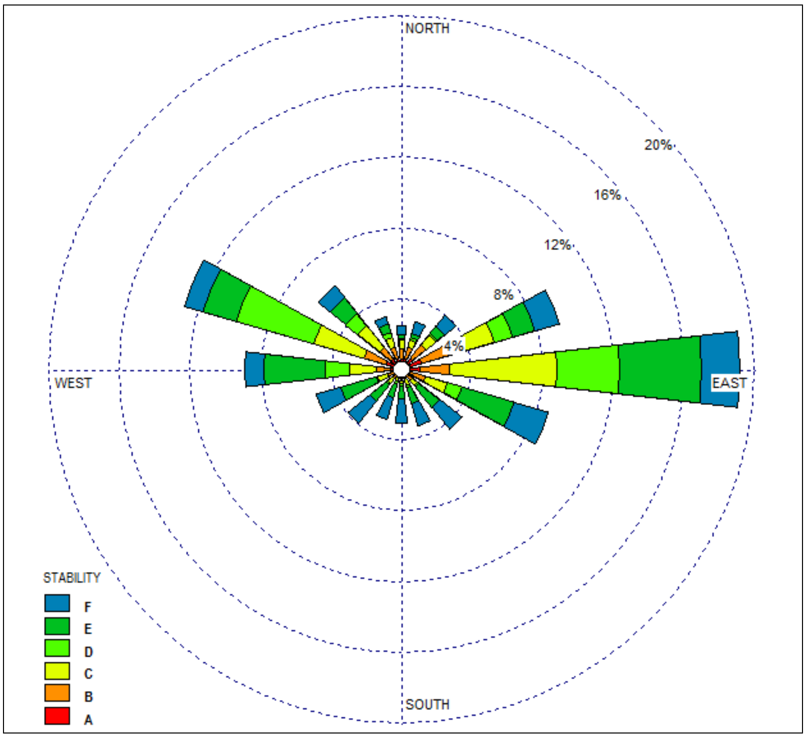


FIGURE 4.1-4: ROSE OF STABILITY CLASSES FOR 2012

4.1.3.2.1.1.1 Site 1

Figure 4.1-5 shows the ground field of pollution with fine particulate matter (**PM_{10}**), and **Figure 4.1-6** and **Figure 4.1-7** show the ground field of pollution with nitrogen and sulphur oxides from the construction activities for Site 1. The predominant wind comes from the east – 18.4%. Speeds between 1 and 4 m/s form 52.9% of the annual speeds (**Figure 4.1-3**).

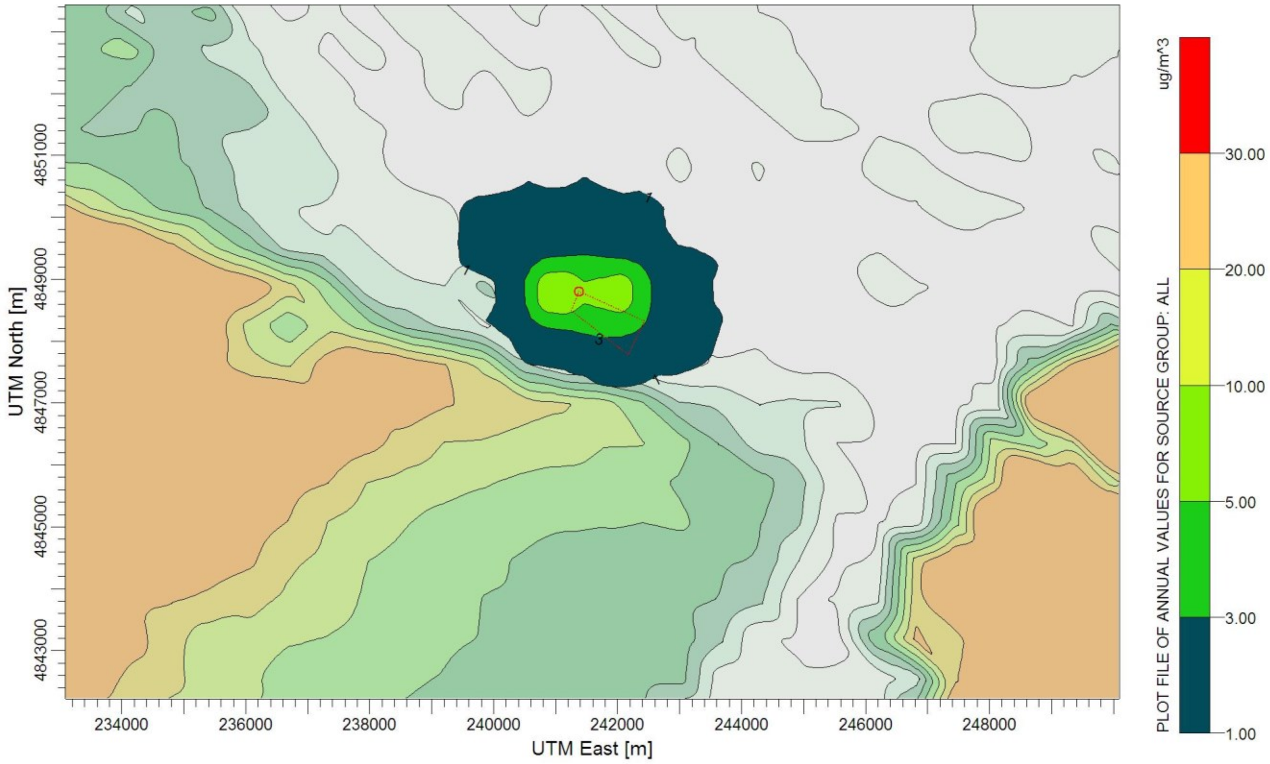
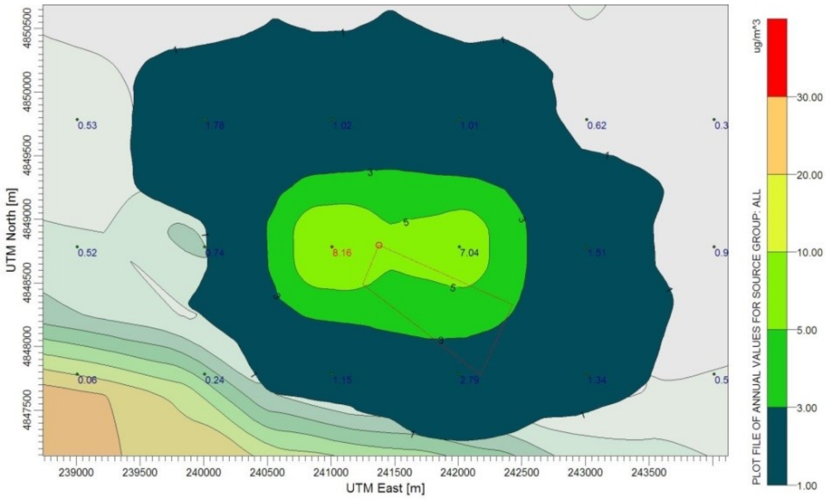


FIGURE 4.1-5: AVERAGE ANNUAL POLLUTION WITH PM10 FROM SITE 1

The maximum value of ground pollution with PM10 is observed to the west of Site 1 (the red number) and has a numeric value of 8.16 μg/m^3, which is 20.4% of the Average Annual Norm (AAN) of 40 μg/m^3 – **Table 4.1-6**.

PM10 norms have not been exceeded.



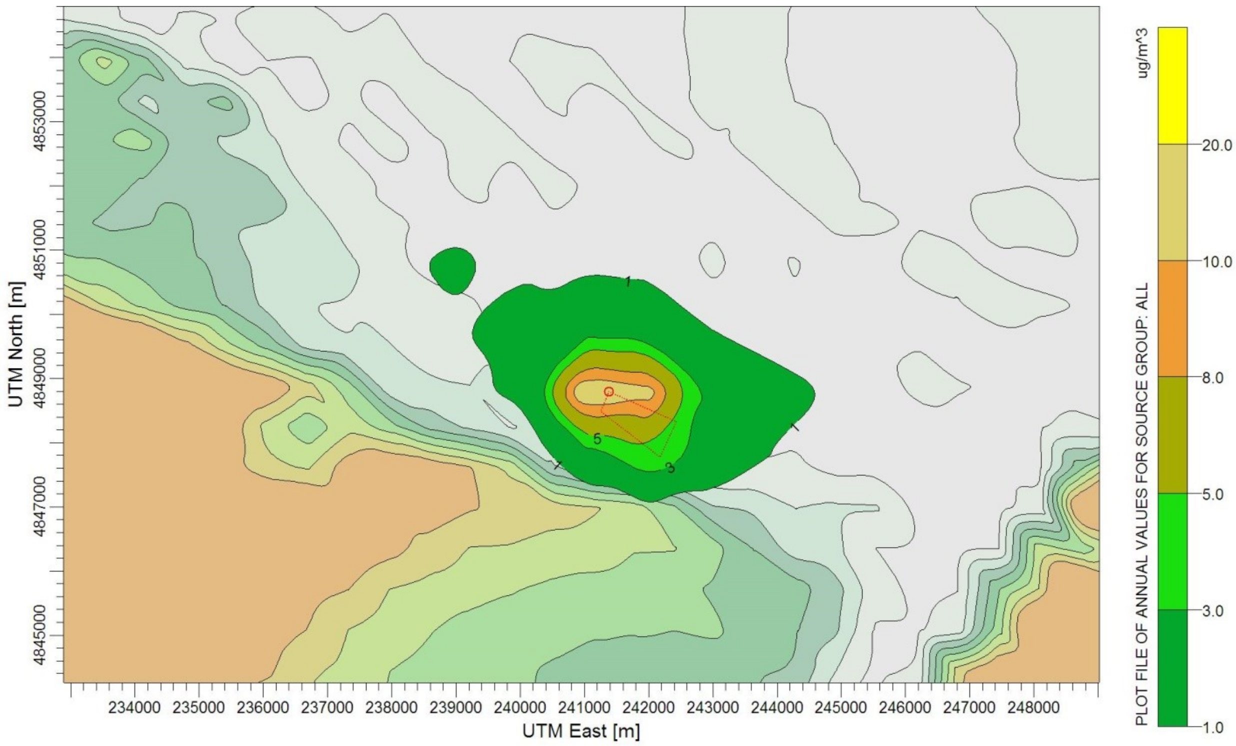
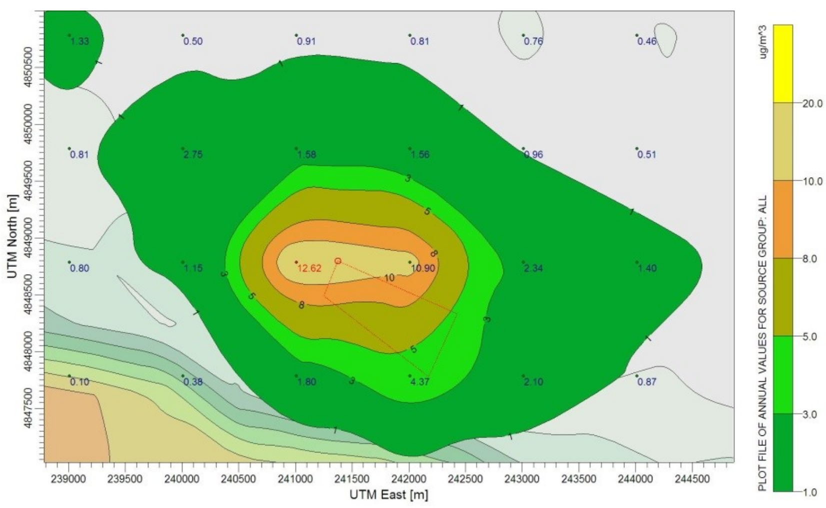


FIGURE 4.1-6: AVERAGE ANNUAL POLLUTION WITH NITROGEN OXIDES FROM SITE 1

The maximum ground pollution with NO_X is marked with a red number and has a numeric value of 12.62 μg/m^3, which is 32% of the Average Annual Norm (AAN) of 40 μg/m^3 and 49% of the average annual Lower Assessment Threshold (LAT) of 26 μg/m^3.

Nitrogen oxide norms have not been exceeded.



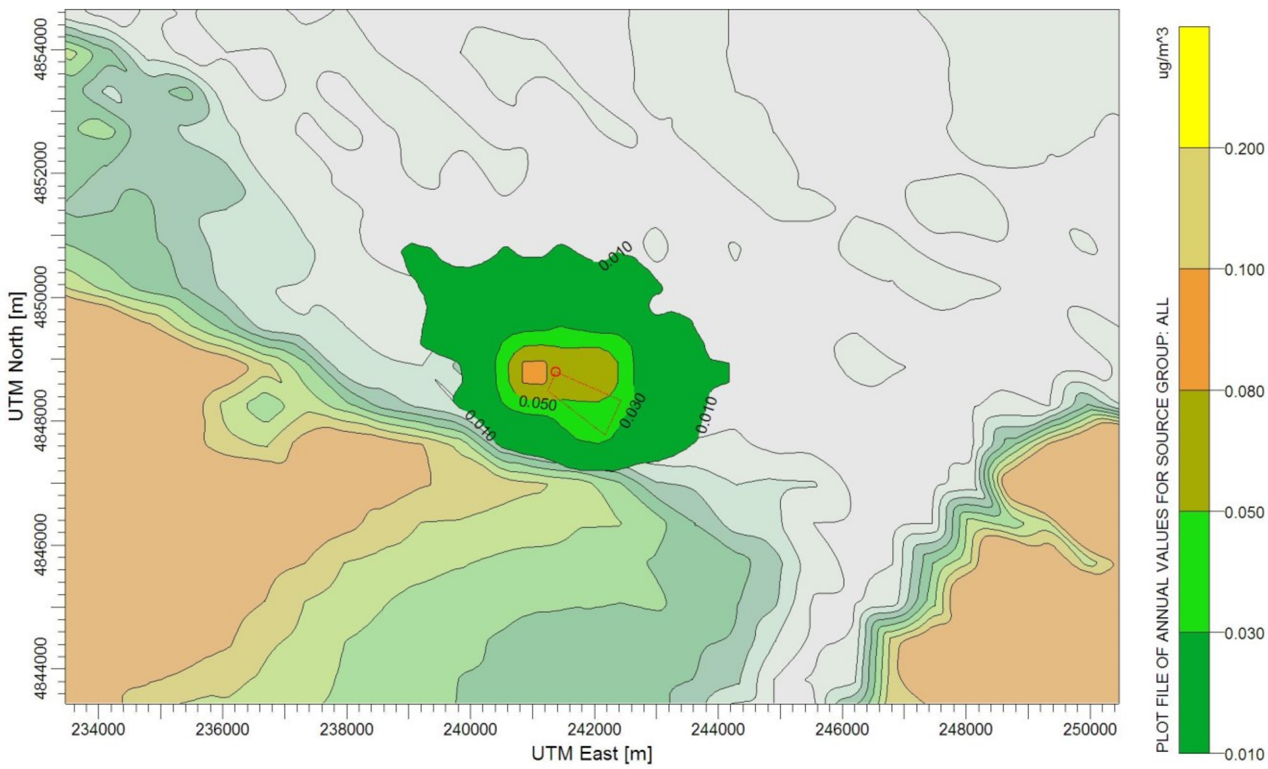
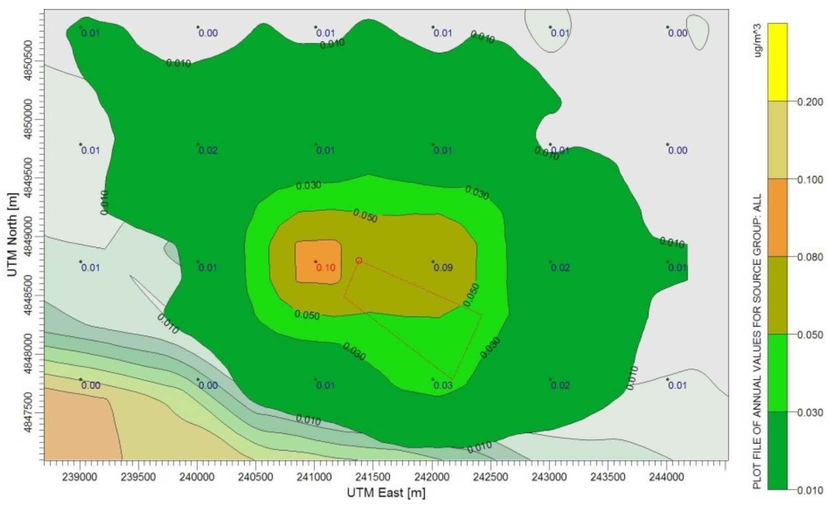


FIGURE 4.1-7: AVERAGE ANNUAL POLLUTION WITH SULPHUR OXIDES FROM SITE 1

The maximum value of ground pollution with SO_X is observed to the west of Site 1 (the red number) and has a numeric value of 0.1 μg/m³, which is just 0.2% of the annual norm of 50 μg/m³ recommended by the World Health Organization (WHO).

Sulphur oxide norms have not been exceeded.



4.1.3.2.1.1.2 Site 2

Figure 4.1-8 shows the ground field of pollution with fine particulate matter (PM10), and **Figure 4.1-9** and **Figure 4.1-10** show the ground field of pollution with nitrogen and sulphur oxides from the construction activities for Site 2.

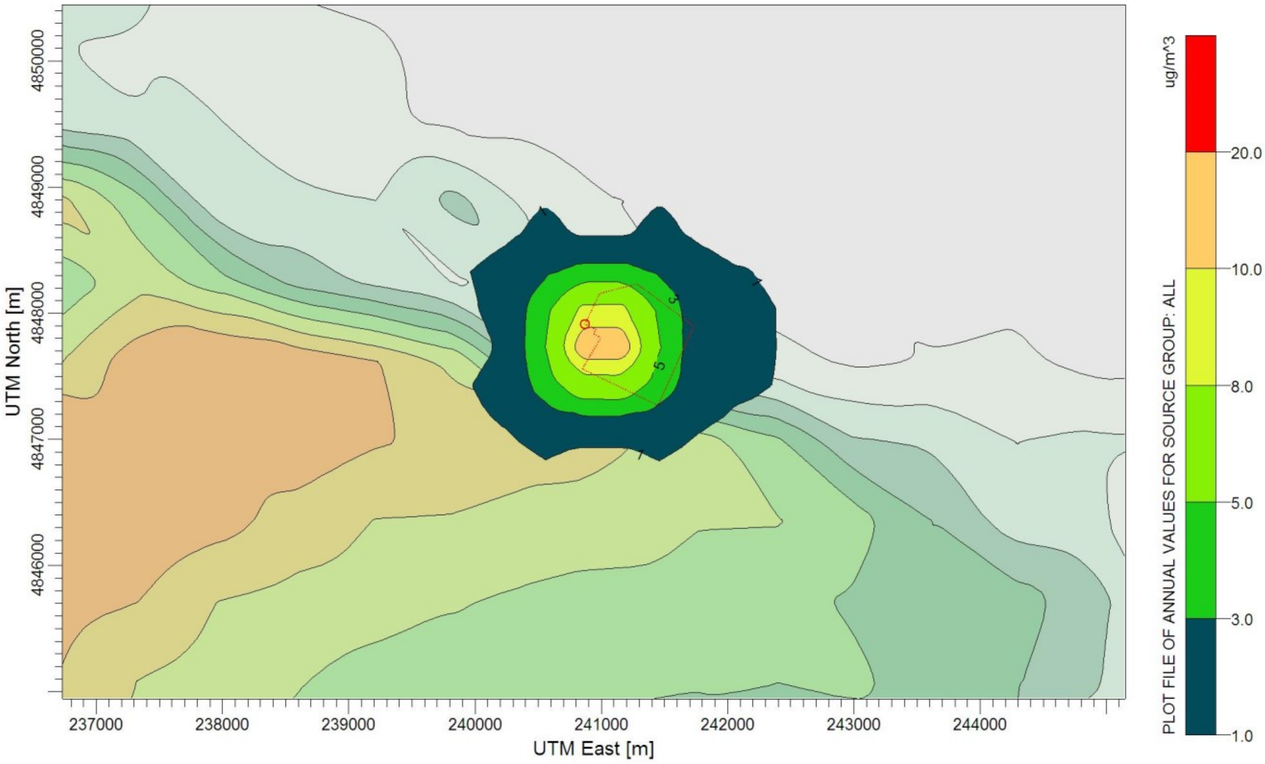
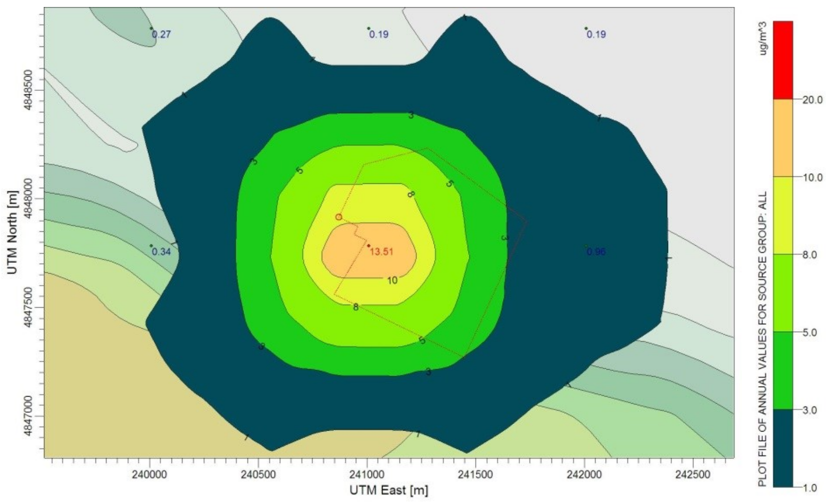


FIGURE 4.1-8: AVERAGE ANNUAL POLLUTION WITH PM10 FROM SITE 2

The maximum value of ground pollution with PM10 (the red number) is observed at the west border of Site 2 and has a numeric value of 13.51 μg/m^3, which is 33.8% of the Average Annual Norm (AAN) of 40 μg/m^3 – **Table 4.1-6**.

PM10 norms have not been exceeded.



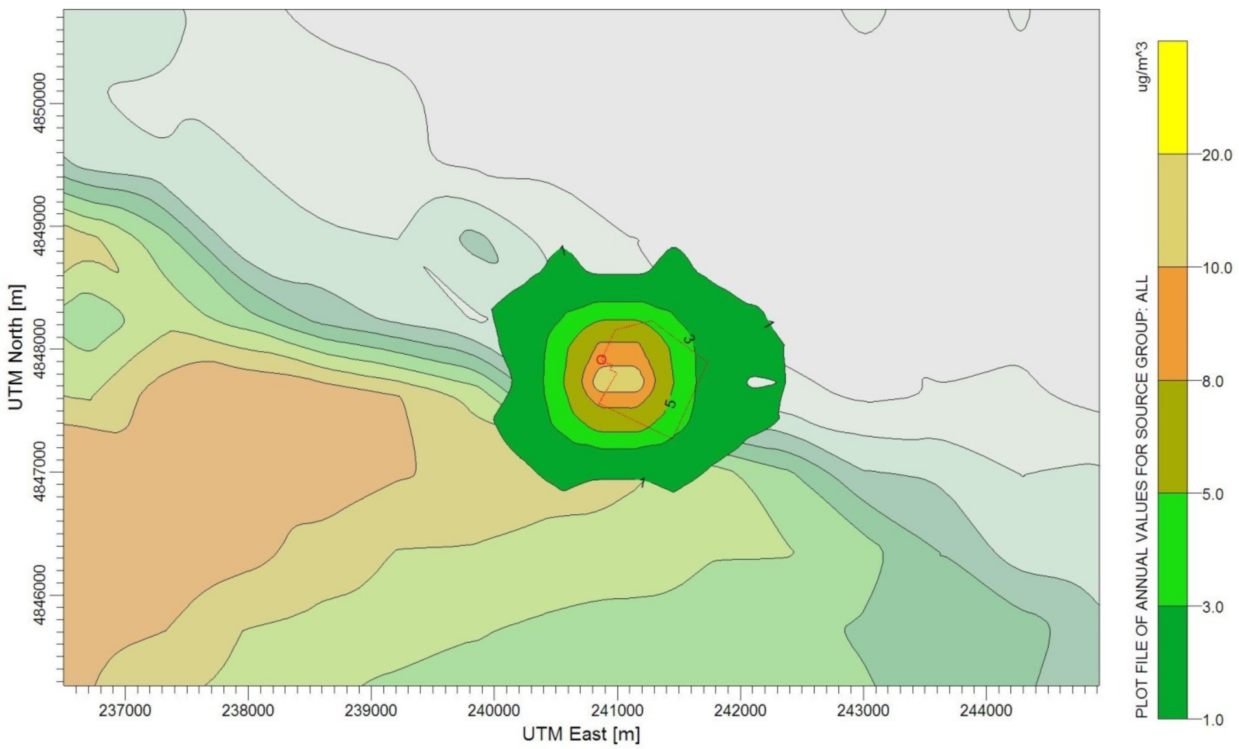
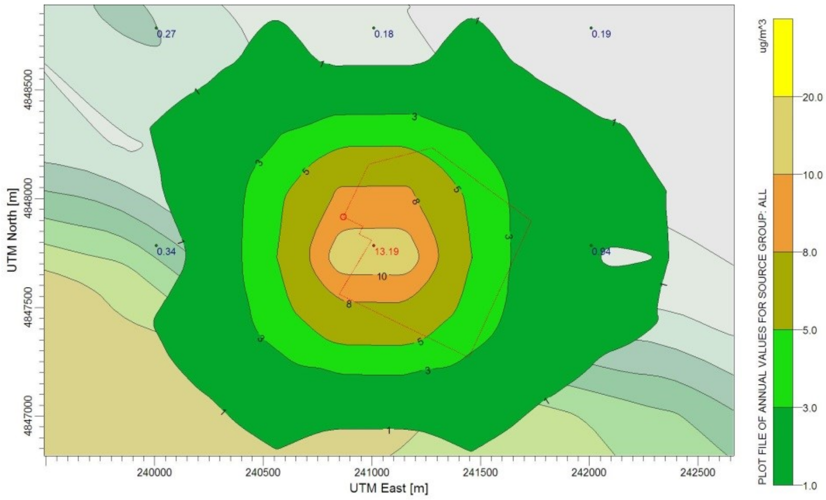


FIGURE 4.1-9: AVERAGE ANNUAL POLLUTION WITH NITROGEN OXIDES FROM SITE 2



The maximum ground pollution with NO_X is marked with a red number and has a numeric value of 13.88 µg/m^3, which is 53% of the Average Annual Norm (AAN) of 40 µg/m^3 and 35% of the average annual Lower Assessment Threshold (LAT) of 26 µg/m^3.

Nitrogen oxide norms have not been exceeded.

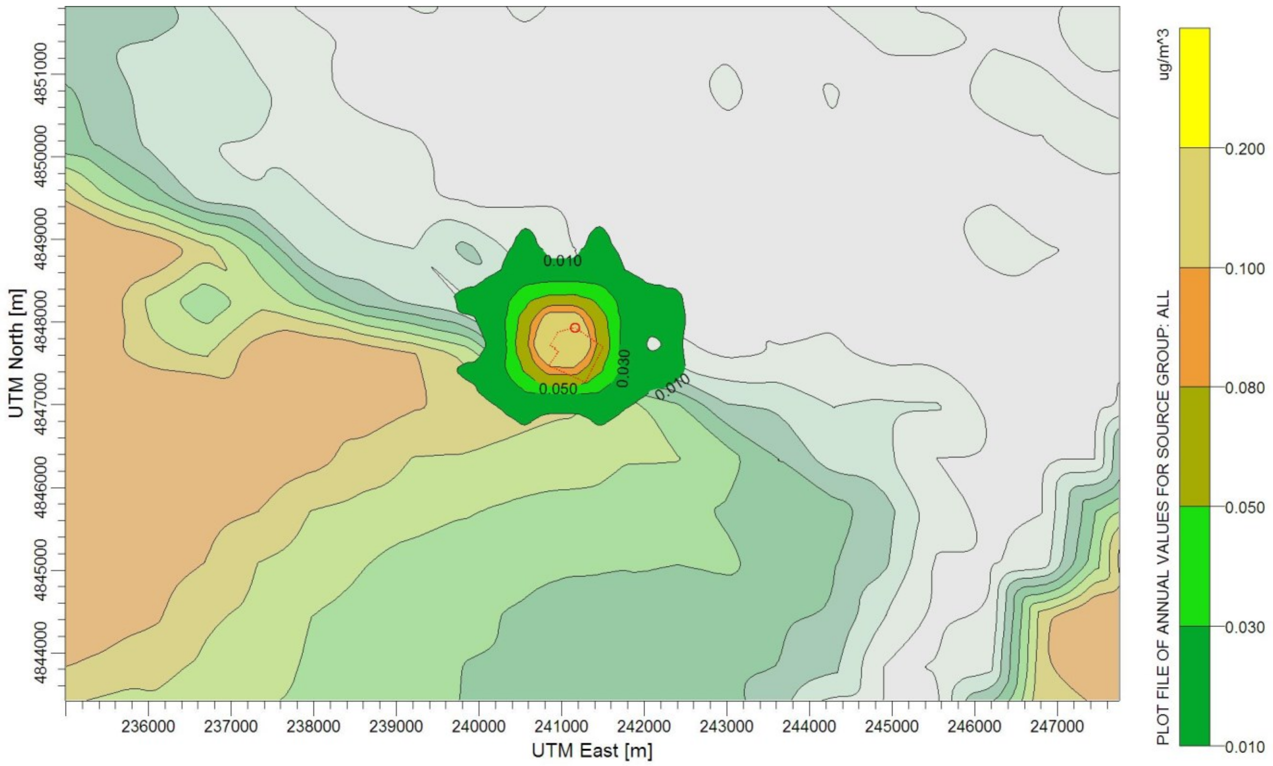
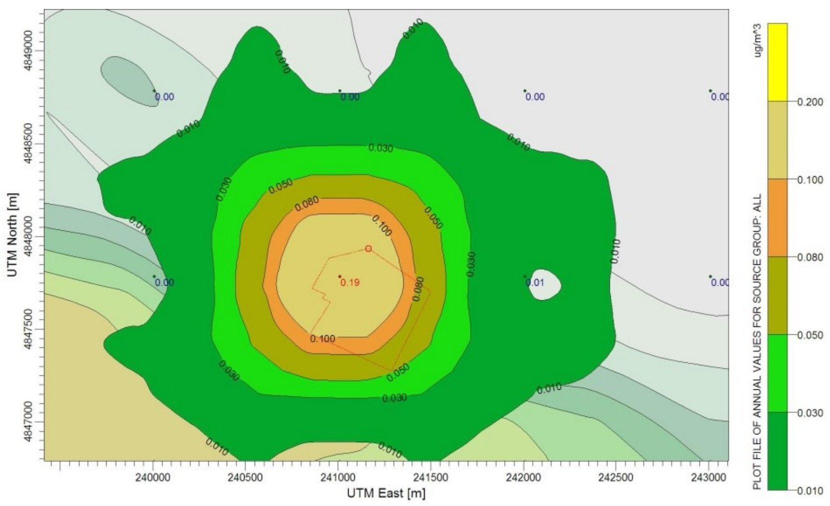


Figure 4.1-10: Average annual pollution with sulphur oxides from Site 2

The maximum value of ground pollution with SO_X is observed to the west of Site 2 (the red number) and has a numeric value of 0.19 µg/m³, which is just 0.4% of the annual norm of 50 µg/m³ recommended by the World Health Organization (WHO).

Sulphur oxide norms have not been exceeded.



4.1.3.2.1.1.3 Site 3

Figure 4.1-11 shows the ground field of pollution with fine particulate matter (PM10), and Figure 4.1-12 and **Figure 4.1-13** show the ground field of pollution with nitrogen and sulphur oxides from the construction activities for Site 3.

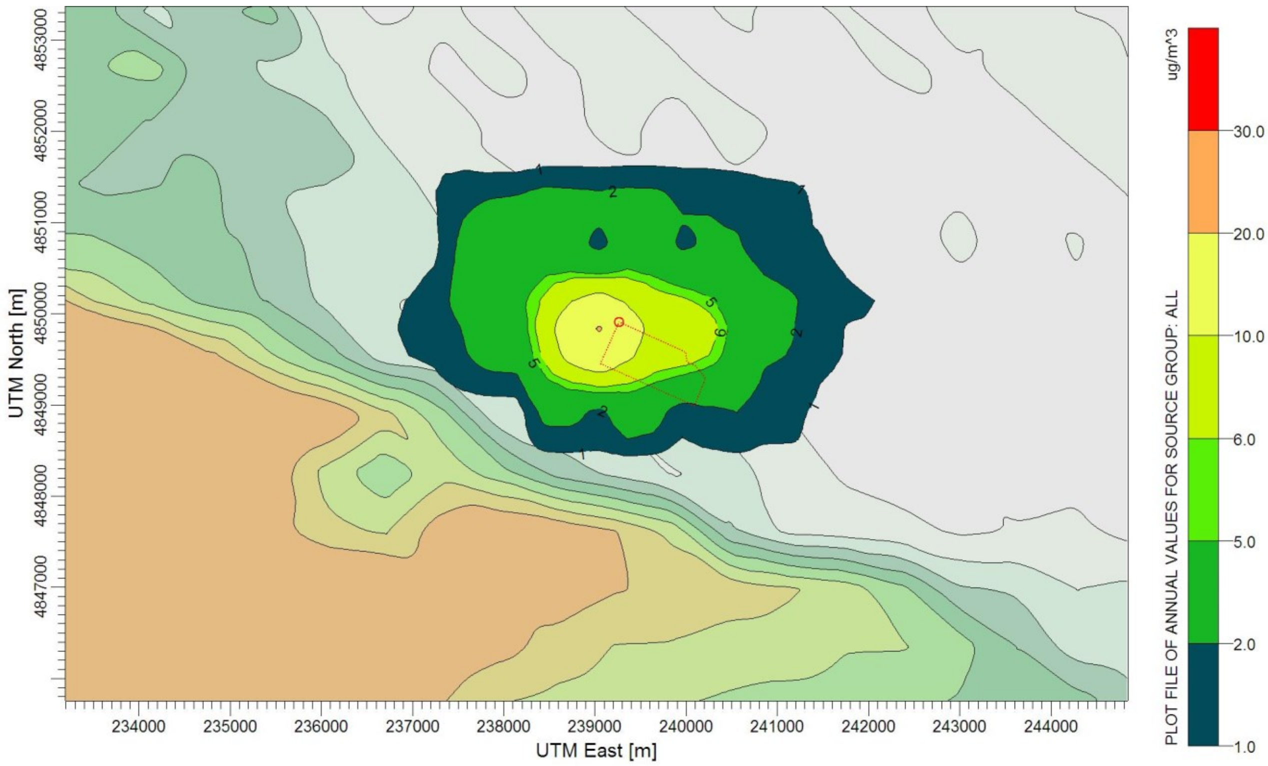
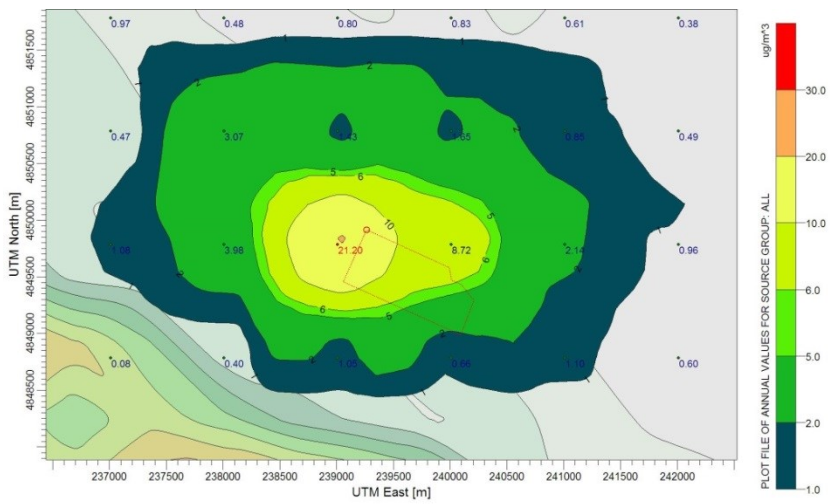


FIGURE 4.1-11: AVERAGE ANNUAL POLLUTION WITH PM10 FROM SITE 3

The maximum value of ground pollution with PM10 is observed to the west of Site 3 (the red number) and has a numeric value of 21.20 μg/m³, which is 53% of the Average Annual Norm (AAN) of 40 μg/m³ – **Table 4.1-6**.



PM10 norms have not been exceeded.

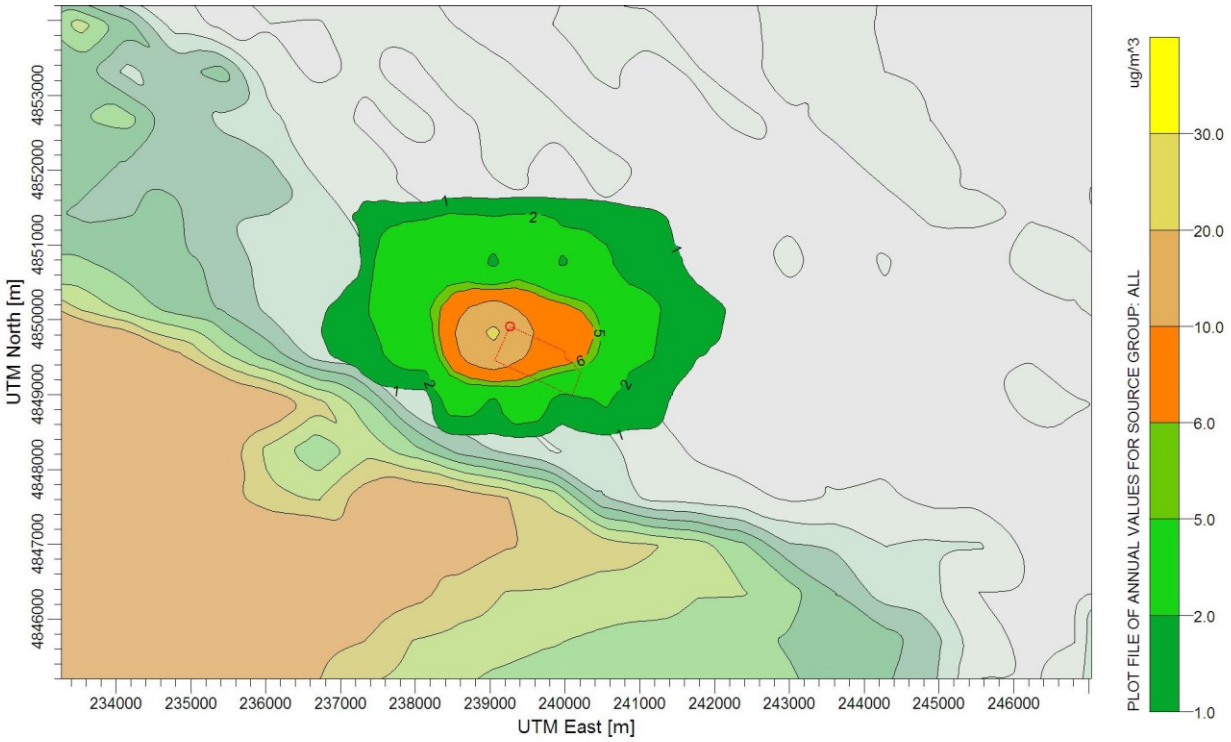
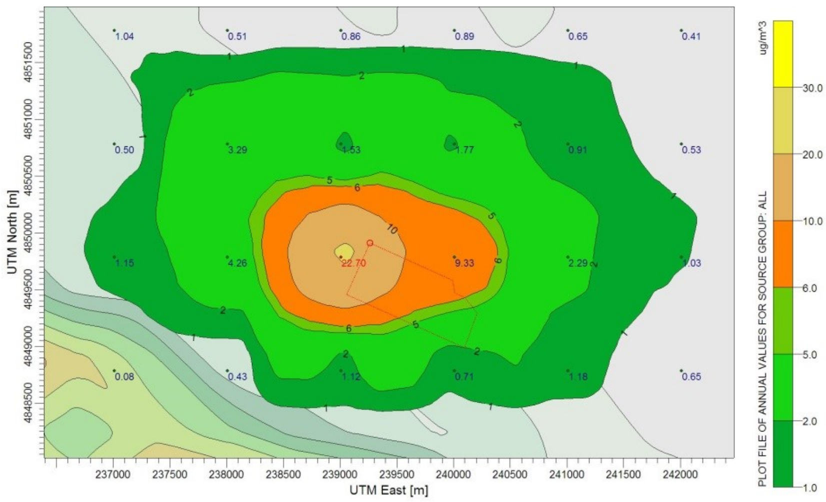


FIGURE 4.1-12: AVERAGE ANNUAL POLLUTION WITH NITROGEN OXIDES FROM SITE 3

The maximum value of ground pollution with NO_X is marked with a red number and has a numeric value of 22.70 µg/m³, which is 87% of the Average Annual Norm (AAN) of 40 µg/m³ and 57% of the average annual Lower Assessment Threshold (LAT) of 26 µg/m³.

Nitrogen oxide norms have not been exceeded.



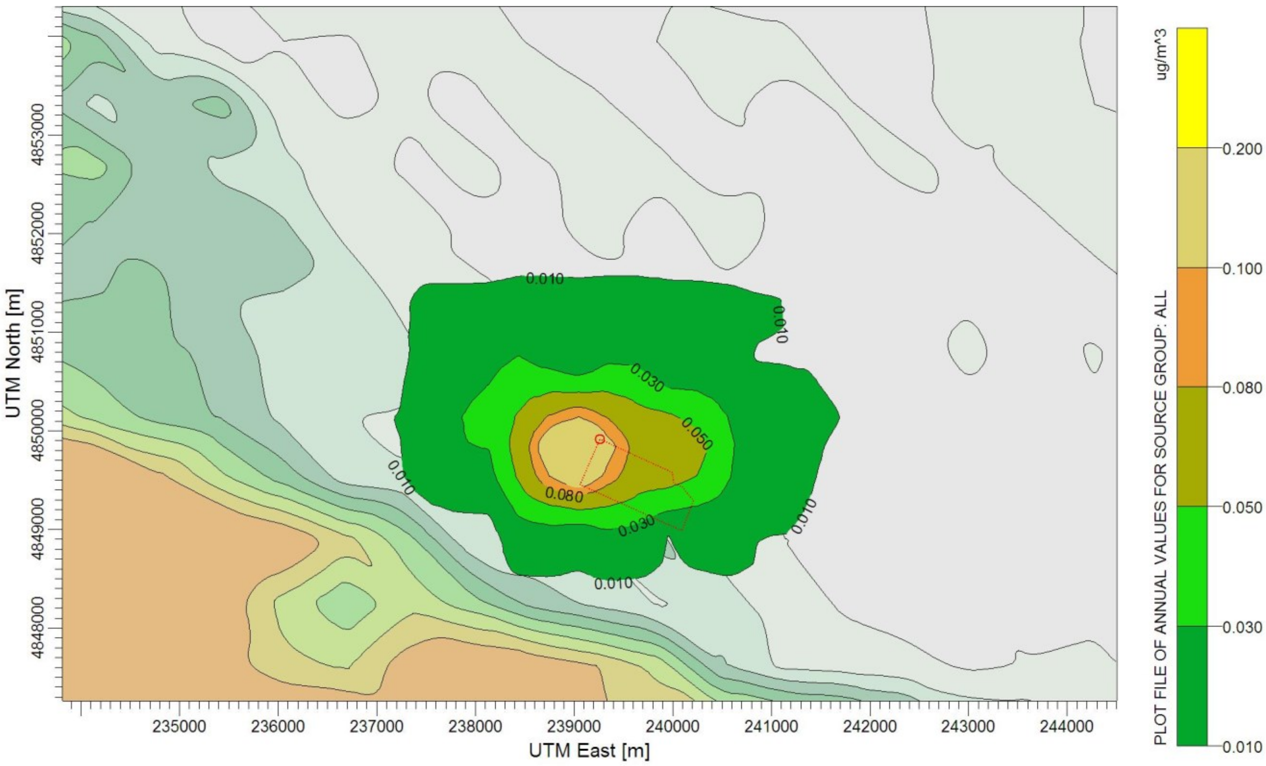
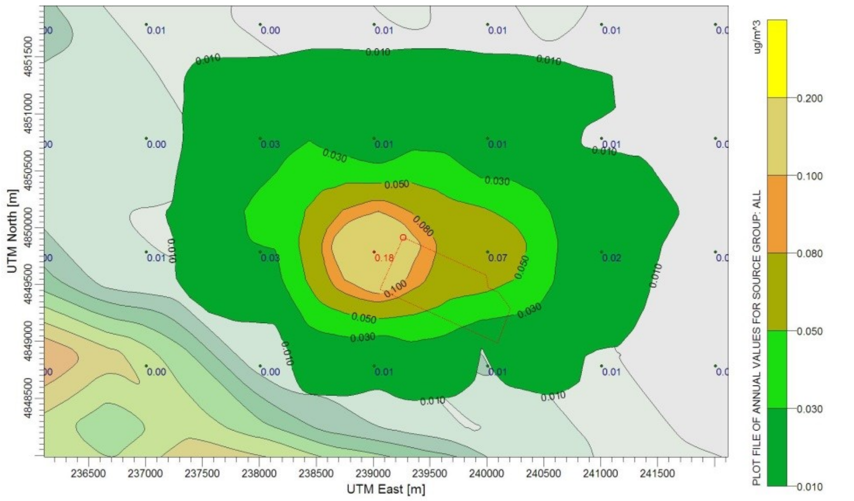


FIGURE 4.1-13: AVERAGE ANNUAL POLLUTION WITH SULPHUR OXIDES FROM SITE 3

The maximum value of ground pollution with SO_X is observed to the west of Site 3 (the red number) and has a numeric value of 0.18 µg/m³, which is just 0.4% of the annual norm of 50 µg/m³ recommended by the World Health Organization (WHO).

Sulphur oxide norms have not been exceeded.



4.1.3.2.1.1.4 Site 4

Figure 4.1-14 shows the ground field of pollution with fine particulate matter (PM10), and Figure 4.1-15 and Figure 4.1-16 show the ground field of pollution with nitrogen and sulphur oxides from the construction activities for Site 4.

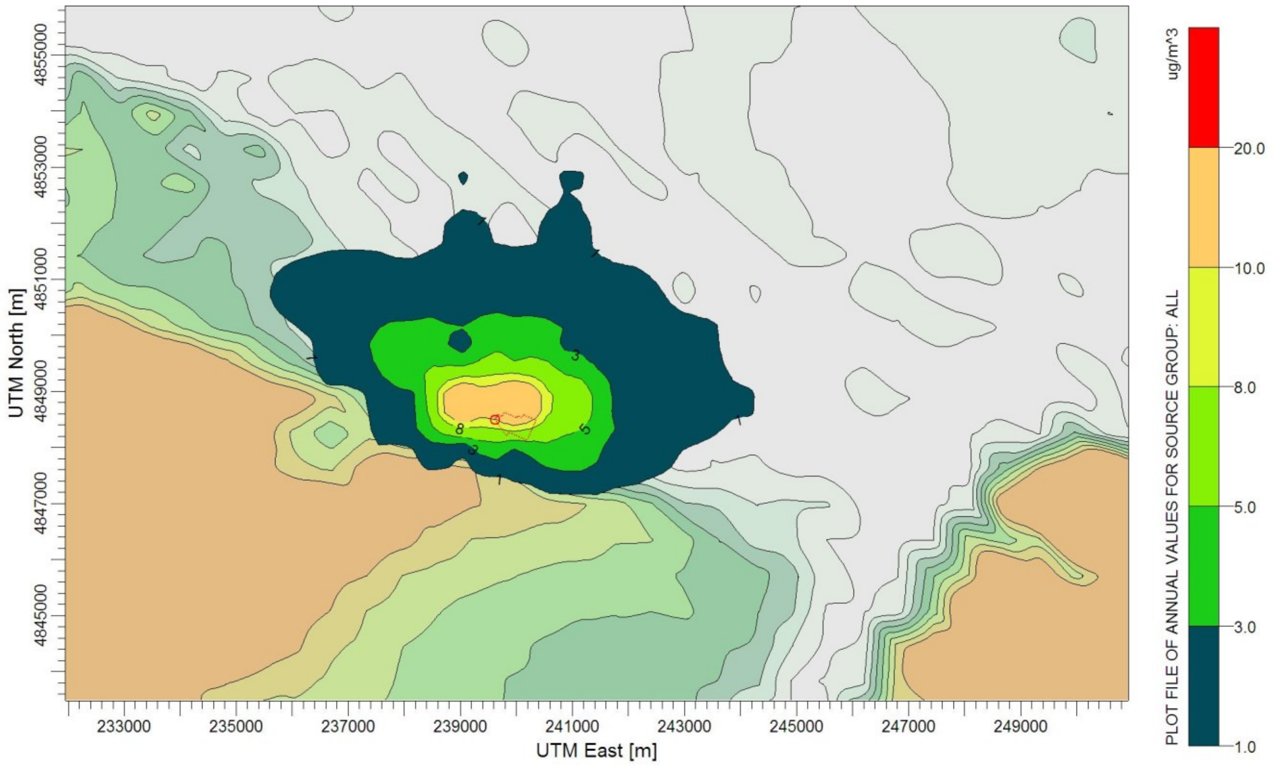
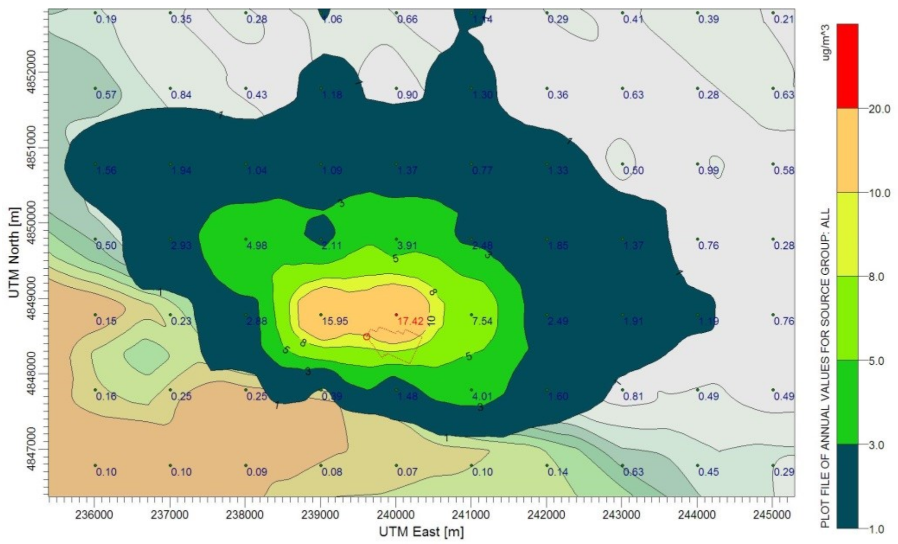


FIGURE 4.1-14: AVERAGE ANNUAL POLLUTION WITH PM10 FROM SITE 4

The maximum value of ground pollution with PM10 is observed to the north of Site 4 (the red number) and has a numeric value of 17.42 μg/m^3, which is 43.6% of the Average Annual Norm (AAN) of 40 μg/m^3 – **Table 4.1-6**.

PM10 norms have not been exceeded.



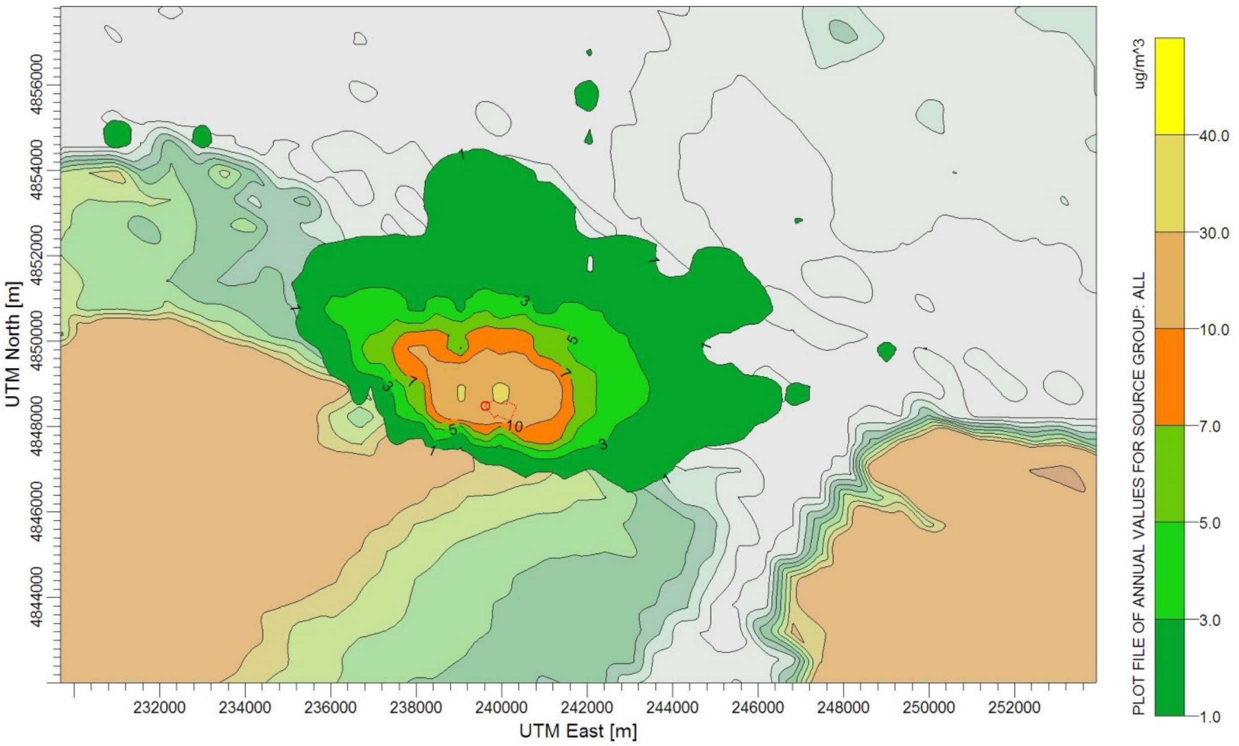
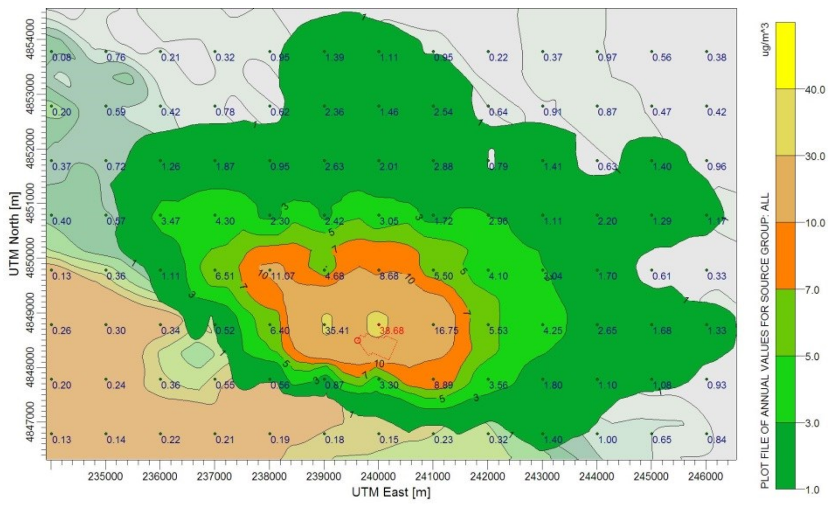


FIGURE 4.1-15: AVERAGE ANNUAL POLLUTION WITH NITROGEN OXIDES FROM SITE 4

The maximum value of ground pollution with NO_X is marked with a red number and has a numeric value of 36.67 μg/m^3, which is 92% of the Average Annual Norm (AAN) of 40 μg/m^3 and 41% of the average annual Lower Assessment Threshold (LAT) of 26 μg/m^3, applicable to industrial areas.

The annual nitrogen oxide norms have not been exceeded.



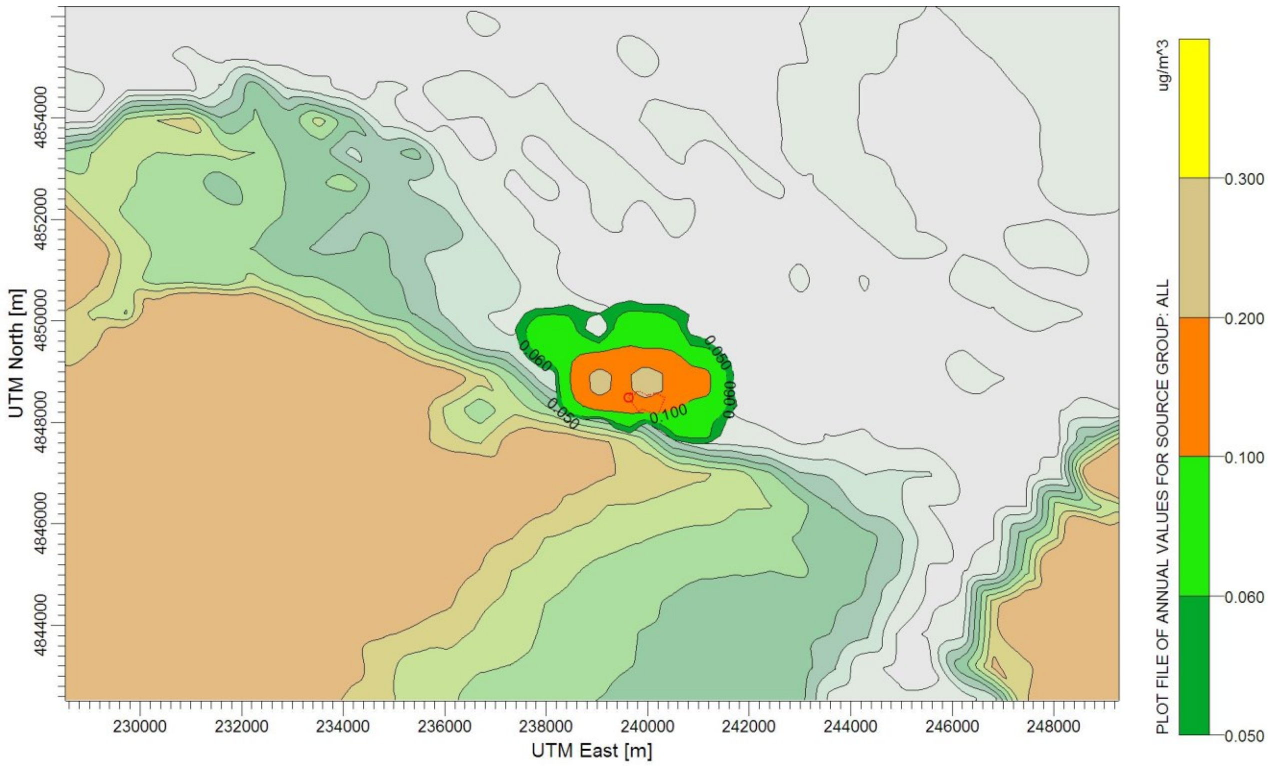
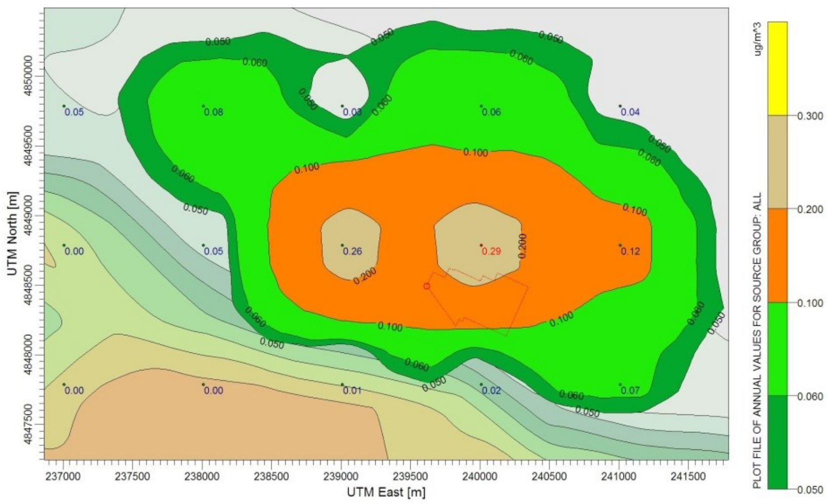


Figure 4.1-16: Average annual pollution with sulphur oxides from Site 4



The maximum value of ground pollution with SO_X is observed to the west of Site 4 (the red number) and has a numeric value of 0.29 $\mu g/m^3$, which is just 0.6% of the annual norm of 50 $\mu g/m^3$ recommended by the World Health Organization (WHO).

Sulphur oxide norms have not been exceeded.

The maximum concentrations are shown in **Table 4.1-8.**

Table 4.1-8: Maximum annual concentrations during the construction stage

Sites	PM10	SO_X	NO_X
	$\mu g/m^3$		
Site 1	8.16	0.10	12.62
Site 2	13.51	0.19	13.88
Site 3	21.20	0.18	22.70
Site 4	17.42	0.29	36.67

The gaseous and dust emissions will not have any significant impact on the quality of atmospheric air during the construction stage. In order to prevent excessive pollution, a schedule must be observed regarding the movement of the transportation vehicles servicing the construction site, and the schedule must reflect meteorological conditions (no wind), i.e. to allow the natural ability of the atmosphere to clean itself.

4.1.3.2.1.2 Impact of linear sources

It is assumed that the pollution from the transport vehicles as a result of their movement along road sections can be described as continuously acting linear sources.

The pollution from linear sources will be determined, in adherence to the European norms and the respective Bulgarian legislation, via the *Method for determining the diffusion of harmful substance emissions from transport vehicles and their concentration in the surface atmospheric layer – based on the software product* **TRAFFIC ORACLE** (Order No. РД 994/04.08.2003 of the MEW). The software consists of 2 main modules – **DIFFUSION** and **EMISSIONS**[8]. It provides statistical or typological assessments of the pollution levels for a specific pollutant.

The **DIFFUSION** module is based on a jet Gaussian model and calculates the pollution (concentrations) from linear sources in the ground atmospheric layer by determining the expected climatic average (average annual) concentrations via the respective annual "wind rose". Concentrations are presented in mg/m^3.

The **EMISSIONS** module calculates the harmful substance emissions from the engines of road vehicles in g/(m.s) per linear source.

Input parameters for the modelling process

Input parameters of the model – the area for which pollution is calculated is 12 000x6 750m (48 steps in the west-east direction and 27 steps in the north-south direction, 200 m each) – **Figure 4.1-1**.

Input data on the meteorological parameters

The study is based on the wind rose for 2012 – **Figure 4.1-3**.

5.2.2.3. Input data on the source

The heavy vehicle traffic from the NNU is 42 trips per day. The forecasts on the average 24-hour intensity of the road vehicle traffic along Road II-11 from the national road network for 2020 in the 6 main categories of vehicles: light vehicles (8535), light cargo vehicles (1333), medium duty vehicles (229), heavy duty vehicles (59), buses (intercity) (346) and heavy trucks with trailers (208) – a total of 10771 road vehicles, were received from the

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[8] European Topic Centre on Air and Climate Change, Long description of model 'TRAFFIC ORACLE' (http://pandora.meng.auth.gr/mds/showlong.php?id=158)

"Road Infrastructure" Agency[9] for Additional Counting Point (ACP)-496 in the section Mizia-Kozloduy (**Chapter 3.1**, **Table 3.1-12**).

The input parameters for each individual source are: X_1, Y_1, X_2 и Y_2 – coordinates for the start and end of the segment [m]; width of the road [m] and emission [$g.m^{-1}.s^{-1}$].

5.2.3. Results from the modelling process

5.2.3.1. Average concentrations for the period

Since it is an annual meteorological file that was used, the isopleths of expected concentrations for the different sections of the route are compared to the values of the average annual norms.

Table 4.1-9 shows the expected average annual maximum concentrations for the pollutants for which the Bulgarian legislation envisages average annual norms and an annual Lower Assessment Threshold (LAT) – **Table 4.1-6**.

Table 4.1-9: Annual concentrations of individual pollutants

	Pollutant	NO_2	Pb	PM10	SO_2	C_6H_6
Maximum annual concentration [mg/m³]	AAN [mg/m³]	**0.04**	**0.0005**	**0.04**	**0.05***	**0.005**
	LAT [mg/m³]	**0.026**	**0.00025**	**0.02**	**-**	**0.002**
Road vehicle traffic for 2020		0.004615	0.00000106	0.000287	0.000301	0.000059
Heavy cargo vehicle traffic		0.000044	0.00000002	0.000002	0.000004	0.000010
TOTAL		0.004659	0.00000108	0.000289	0.000305	0.000069

**Norm recommended by the World Health Organisation (WHO).*

As evident from **Table 4.1-9,** there is no pollutant that exceeds either the AAN (in **red**), or the respective annual LATs (in **purple**) under average 24-hour intensity of conventional road vehicle traffic for 2020. **The transport traffic does not cause any exceeded limits.**

Figure 4.1-17 shows the ground field of pollution with nitrogen oxides only to ensure the comprehensiveness of the study – the pollution from the two traffics has been overplayed.

[9] *Appendix 8* – INPUT DATA – Letter No. ЦИ-0167-0158 from 04.02.2013.

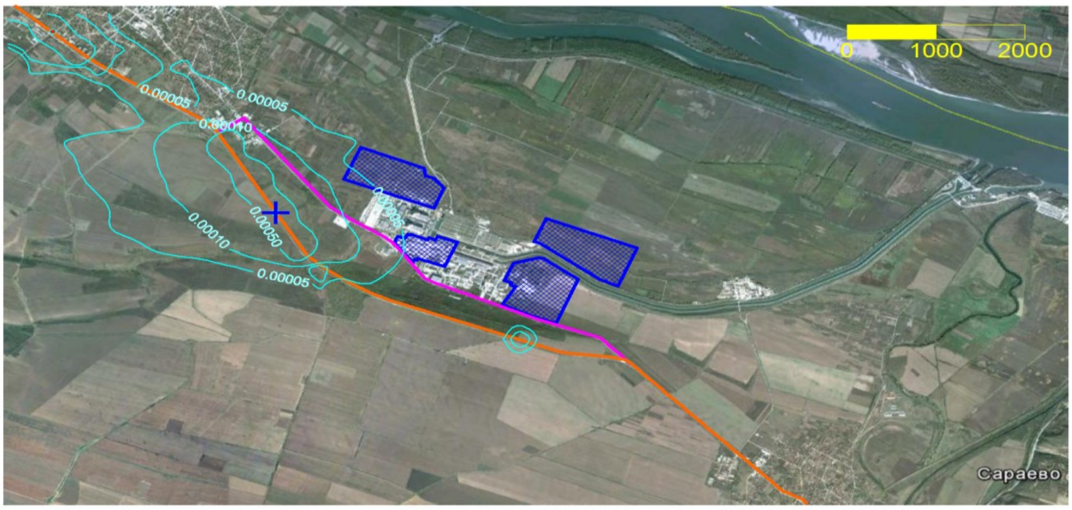

FIGURE 4.1-17: AVERAGE ANNUAL POLLUTION WITH NITROGEN OXIDES FROM THE LINEAR SECTION FROM NATIONAL ROAD II-11 AND THE INTERNAL ROAD OF THE POWER PLANT FROM THE TWO TRAFFICS

The maximum concentration of 0.004659 mg/m^3 (marked with a blue cross) is over 8 times lower than the AAN of 0.04 mg/m^3.

The linear gaseous emissions will not impact the quality of atmospheric air during the construction.

4.1.3.2.2 During operation

During the operation of the NNU no pollution from area-based dust emissions is expected. Gaseous emissions will be insignificant compared to the pollution from the average 24-hour intensity of the road vehicle traffic along Road II-11 from the national road network.

4.1.3.2.3 During decommissioning

The Impact of all types of emissions during the decommissioning stage will be similar to those established during the construction, but since the impact will be distributed over a greater time interval, their significance is expected to be negligible.

4.1.3.2.4 Conclusion

In terms of the "atmospheric air" component, the 4 alternative sites for the deployment of the NNU have almost equal significance of impact – very low. None of the sites bears any potential hazard of anthropogenic air pollution by non-radioactive pollutants in the area of the IP. Both the impact of emissions and the concentrations of pollutants are well below the limits of admissible standards.

4.1.3.2.4.1 During construction

The expected impact will be short-term, temporary and with a limited scope for people and ecosystems, without any accumulating effect for soils and a reversible effect for the atmosphere. The expected significance of the impact is very low.

4.1.3.2.4.2 During operation

No impact is expected during the operation.

4.1.3.2.4.3 Transboundary Impact

There is no transboundary impact is expected on the "atmospheric air" component.

Based on the above rationale regarding the favourable climatic and meteorological characteristics of the area and the fact that the region has no major industrial polluters, we can draw the conclusion that the impact of the implementation of the IP on air quality will be negligible. The indirect impact – via air as a medium – on other components of the environment: soil, flora and fauna, and health and hygiene conditions, will also be negligible.

4.1.3.3 RADIOACTIVE POLLUTION OF ATMOSPHERIC AIR

The radioactive pollution of atmospheric air is caused by radioactive releases (emissions) from the nuclear power plant. Airborne radionuclides can lead to exposure via two principal pathways: externally – by the photons emitted as a result of radioactive decay, and internally – through their inhalation.

In terms of human health, these releases are evaluated by the radiation exposure of the human body in comparison to the threshold concentration levels for conventional pollutants in the atmospheric air.

The assessment of the radiation exposure of the population within the 30 km zone from gaseous and aerosol releases is done by means of modelling in **Section 4.11**. The LEDA-CM, "SHIELD Normal Operation" modelling software program, adapted to the geographic and meteorological characteristics of the region of the Kozloduy NPP, has been used. The methodology accounts for both the external and the internal impact of radioactive releases and evaluates the individual effective dose, the annual individual equivalent dose, and the critical group dose, as well as the collective population dose by age groups. The program is based on the method adopted by the European Union (EU) – CREAM (Consequences of Releases to the Environment Assessment Methodology) Radiation Protection 72 – Methodology for assessing the radiological consequences of routine releases of radionuclides to the environment.

4.2 WATER

4.2.1 SURFACE WATER

The existing site of the Kozloduy NPP is situated on the right bank (at the 694th km) of the Danube River. It is situated in the northern part of the first unflooded terrace of the Danube River (elevation level +35.0 m based on the Baltic Elevation System) and has an area of 4471.712 decares. No natural water bodies pass through it.

In close proximity and of major significance to the NPP, to the north of the site flows the Danube River, signified by the name "Danube River RWB01" and by the code BG1DU000R001, in accordance with the River Basin Management Plans for the Danube Region, responsible for the basin water management in Bulgaria.

Between the river water and ground waters in the terraces there is a hydraulic connection. The latter are situated at a shallow depth and that is why high water levels cause marshes in the lowest sections of the lowlands. In order to reduce these influences, a system of drainage channels has been constructed to the north of the site – leading the water to pumping stations (PS) which transfer the water back into the Danube River. This is how a relatively low level of ground water is controlled and maintained in the lowlands, situated to the north of the existing site of the Kozloduy NPP.

Due to the constantly high level of ground water across a large area of the lowlands in the area of the Kozloduy NPP, as well as to provide protection against the slope water running down the north slopes of the plateaus, a system of drainage channels and facilities has been constructed. These systems protect the area against cases of abundant precipitations and also prevent marshes in the lowlands. These drainage systems also protect the power plant site against flooding. They include three types of channels: drainage, collector, and main ones. The water from the main channels is transferred to the Danube River over the embankments via pump stations (PS). The Main Drainage Channel (MDC) is one of the recipients of four streams of wastewater from the NPP, entirely from the territory of Electricity Production – 1 (EP-1), via the constructed mixed drainage system, and a part of the wastewater from Electricity Production – 2 (EP-2). These drainage facilities are essential to the protection of the agricultural land in the area and the existing infrastructure that is why their existence is clearly necessary.

Provisionally called Site 1 – The site is situated on the flooded terrace of the Danube River, to the northeast of units 1 and 2 of the Kozloduy NPP, between the OSG and "Valyata", in the vicinity of the constructed cold and hot channels – to the north of them. The area of the site amounts to approximately 55 ha. The terrain is flat, with a slight slope from the southwest to the northeast. The elevation level of the terrain is 25.0-26.0 m. The area of the site houses some open drainage channels, which will have to be restructured. The level of groundwater fluctuates depending on the water levels of the Danube River. It overflows to surface level or close to it.

The area is used for the cultivation of agricultural crops.

Provisionally called Site 2 – The site is situated to the east of units 1 and 2 of the Kozloduy NPP in the direction of the village of Harlets, to the south of the constructed cold and hot channels. The area of the site amounts to approximately 55 ha. The land is hilly, with a considerable slope from the south to the north, more expressed in the southeastern part of the site, and the elevation level of the surface of the land varies between 34 and 37 m. Only one-story warehouses and other service premises are constructed at the site. A former farmyard is situated within the area of the site. The ground water level is from 8.0 to 10 m from the surface. The remaining area is used for the cultivation of agricultural crops.

Provisionally called Site 3 – the site is situated on the flooded terrace of the Danube River, to the northwest of units 5 and 6 of the **Kozloduy NPP**, in the vicinity of the bypass road of the existing power plant. The area of the site amounts to approximately 53 ha. The terrain is flat, with a slight slope from the south to the north. The elevation level of the terrain is 25.0-26.0 m. The area of the site houses some open drainage channels, which will have to be restructured. The level of groundwater fluctuates depending on the water levels of the Danube River. It overflows to surface level or close to it.

The humus loess layer will have to be removed in advance from the arable land.

Provisionally called site 4 – the site is situated on the first unflooded terrace of the Danube River, to the west of units 3 and 4 of the Kozloduy NPP and the WSFSF, to the south of the cold and hot channels. It is situated at elevation level of about 36 m. The usable area is around 21 ha, within the boundaries of the alienated terrains of the Kozloduy NPP. The terrain houses the existing constructed service facilities – the Equipment storage facility, the Vehicle Repair Workshop and the Assembly Facility. In order to utilize the site, the main underground communications of the NPP need to be reconstructed and displaced, and the aforesaid facilities need to be displaced to free up the area. The ground water level is from 8.0 to 10 m from the surface.

The sites in the area of the Kozloduy NPP which are considered as suitable for deployment of the NNU are presented in **Figure 4.2-1**. The area of the proposed sites, regardless of the type of nuclear reactor, will accommodate all the major and auxiliary buildings and facilities, and the equipment necessary for operation. The overall plan that will be developed for the specific selected site in the next design stage of the IP will offer a specific configuration for the site depending on the functional design of the buildings and facilities, their technological connectivity and their link to the existing communications, and the respective zones will be established.

FIGURE 4.2-1: OVERVIEW OF THE FOUR ALTERNATIVE SITES FOR THE NNU IP.

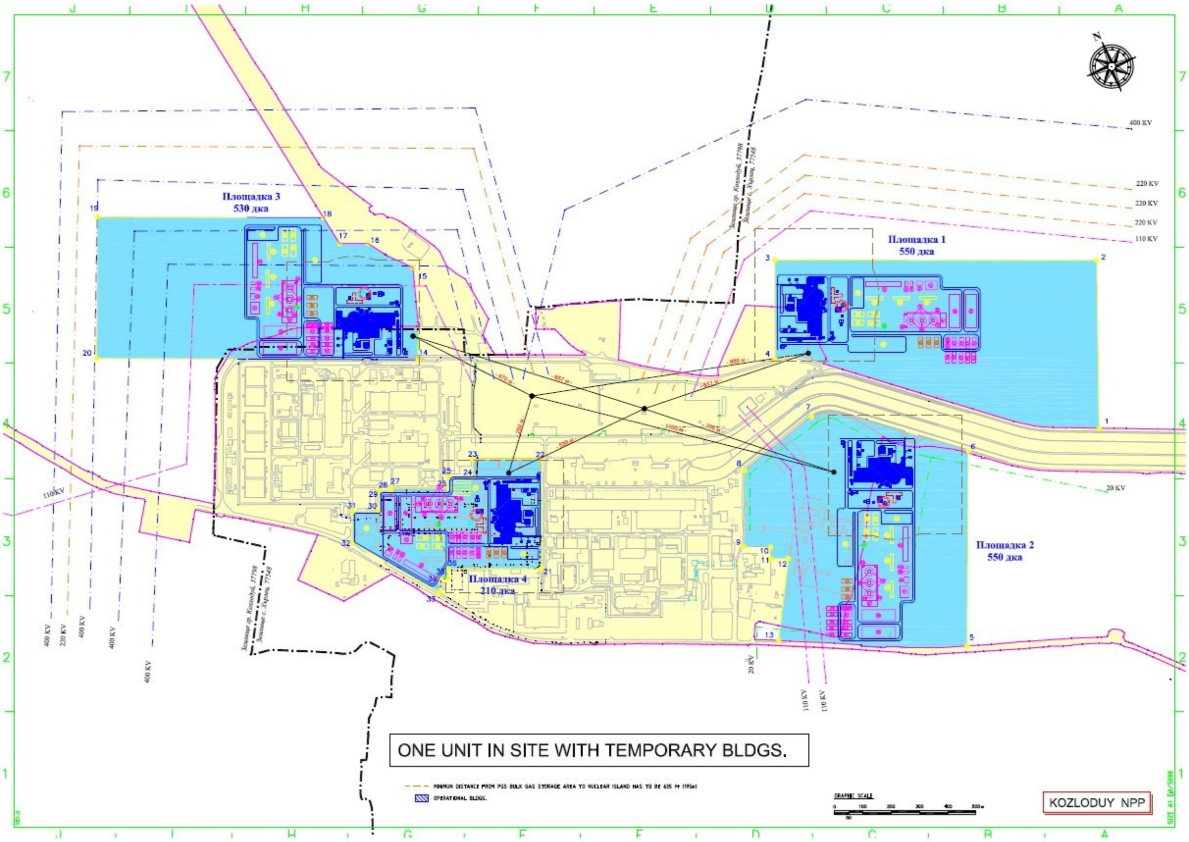

FIGURE 4.2-2: POSSIBLE POSITION OF ONE OF THE REACTOR UNITS AT THE ALTERNATIVE SITES

For all Sites – 1, 2, 3 and 4, before the main construction works it will be necessary to apply methods for improving the earth foundation, so that its carrying capacity to be in accordance with the load, and the subsidence to be within admissible limits.

With regard to the selection of the type of reactor, all analysed options operate under the principle of modular construction. This includes the need for storage areas and workhouses for the construction and storage of the modules.

For all sites it will be necessary to organise temporary facilities related to the storage of bulk materials, ready-made steel, concrete, steel-concrete, metal and other construction elements, fuels and lubricants, temporary offices, temporary living premises to house the manpower from other parts of the country, temporary social and health amenities, a drinking water network and a network directing domestic wastewater for purification, as well as structures for the removal of rain water and a system of lowering ground water. Such an organisation of the construction site will be possible with sites 1, 2, and 3. For Site 4 the actual design would have to be adjusted to the area where the Client offers for the temporary buildings, and they must be situated out of the site where the new unit will be constructed.

The vertical planning of each of the proposed sites will have to be coordinated with the working elevation of the existing site of the power plant, which is +35.00 m according to the Baltic Elevation System. This is determined by the fact that they will have to be connected to the existing Cold (intake) Channel (CC-1) and Hot (outlet) Channel (HC-1). Thus, for instance, choosing site 1 or 3 will require shifting or reconstructing of the drainage channels passing through them during the preparatory construction stage, whereas choosing site 4 will require demolishing and shifting of the available service buildings and their displacement to a new terrain. Choosing site 3 will also require shifting of the 400 kV overhead power line (OPL) route.

For all sites there is a feasible technical option of providing drinking water supply using the existing water-main of the NPP and providing water for technical purposes – for cooling and for other purposes – using the existing hydro technical facilities.

All sites will be equipped with separate sewerage systems for domestic wastewater, and for industrial and rain water.

All sites feature appropriate options for providing access for the required transportation vehicles through forks of the available road infrastructure.

For each of the suggested sites, the liquid radioactive waste to be generated during the operation of the power unit from the primary circuit as a result of equipment leakages, by the equipment decontamination and ion-exchange filter regeneration and flushing facilities, the special clothing laundries and the Sanitary loops, the radio-chemical laboratories, etc. will be processed within the territory of the respective site in accordance with the requirements of the Regulation for safe management of radioactive waste.

4.2.1.1 DURING CONSTRUCTION

Each of the alternative sites is of sufficient size to house the NNU. Sites 1, 2 and 3 can also provide the necessary room for the construction of modern buildings during the construction phase. The necessary room for the construction of the NNU with one unit is from 21 ha (AP-1000) to 35 ha (for AES-92 and AES-2006). For Site 4 the actual design would have to be adjusted to the area where the Client offers for the temporary buildings, and they must be situated out of the site where the new unit will be constructed.

4.2.1.1.1 Site 1

No natural water bodies pass through this site. Drainage channels pass through the site, including the Main Drainage Channel (MDC), receiving the wastewater from Electricity Production – 1 and a part of the water from Electricity Production – 2 of the existing site of the Kozloduy NPP. The MDC is a part of the drainage system of the Kozloduy lowlands and is owned by "Napoitelni Sistemi" EAD (irrigation systems) – Vratsa, representing an artificial water body, forming a part of the water body of the Danube River. The utilization of this site will require its overall reconstruction (shifting). The site is situated on the flooded terrace of the Danube River, at elevation level 25.0-26.0 m, with high ground water overflowing to the terrain. In order to reach the design elevation level of the site, the vertical planning will require an embankment of 5.00 to 10.00 m with a volume of over 4 420 000 m^3 for an area of about 55 ha[10]. The layout of the buildings and facilities for the site (General Layout) will differentiate a primary production area and an auxiliary production area. This applies to all of the proposed types of reactors.

This site has sufficient space to set apart the necessary construction area and the adjacent infrastructure required for the construction process.

4.2.1.1.1.1 Household water supply

Two water supply networks will be constructed, feeding water to all buildings, in order to provide the required drinking water supply for the site. A branch of the existing water-main of the NPP will be constructed, thus ensuring the water needed for internal fire control as well.

In order to ensure the global supply of the water necessary for firefighting needs, a link to FFPS-2 will be constructed, which will also ensure the respective water pressure within the system.

The number of workers occupied in the different construction phases may vary considerably. Based on the data submitted by the Client[11], this number may vary depending on the type of reactors, as follows:

- for the AP-1000 reactor – about 2000 workers;
- for the AES-92 reactor – about 2500 workers;
- for the AES-2006 reactor – about 2500 workers;

[10] Feasibility Report – "New nuclear unit in the Republic of Bulgaria", "Energoproekt" EAD – 1999
[11] Letter No. 416 from 13.05.2013 with PPP No. 31 from 13.05.2013

For the calculation of the quantity of the necessary water for drinking and household purposes at a rate of 140 l/d per person, the resulting quantity is $Q_{max.h}$= 10÷12 l/s , $Q_{av.d}$= 280÷350 m^3/d. The necessary water for drinking and household purposes will be provided from the existing water mains of the NPP via a Ø 125mm branch. This branch will provide $Q_{max.h}$ =20 l/s, which will fully satisfy the drinking water needs during the construction stage and during the operation stage (According to a letter by "NPP Kozloduy" EAD АЕЦ with No. Д"П"58/19.04.2013, the water supply network has a reserve capacity of 70.9 l/s).

Until the construction of the water supply branch, the workers will be supplied with bottled water, and portable facilities will be provided for the hygienic and household needs.

All pipelines of the drinking-and-household, production and firefighting systems will be designed and constructed in reinforced concrete casing because of the quality of the earth foundation and for the protection of ground water from pollution.

4.2.1.1.1.2 Sewerage network and household wastewater

During the construction of the IP for NNU there may be pollution to the construction site with household wastewater, rain water with high contents of undissolved substances and oils (from the construction machinery), wastewater from the construction works, water from the cleaning of the site, etc. In order to prevent these time-limited sources of local impact, main sewer collectors will be constructed, as well as a sewerage and water supply network for the so-called "controlled zone" and "pure zone", and a WWTP for the household wastewater, which will also service the NNU during the operational stage.

Portable facilities will be used /chemical toilets / by the time the sewage and water supply system and the wastewater treatment plant are finalized.

Gradually the entire sewerage and water supply system of the site will be constructed, and it will be divided for household wastewater, industrial wastewater, and rain water. The sewerage and water supply system will be built with materials providing high water tightness and preventing infiltration of contaminants into the ground water and the subsoil.

During construction household wastewater will be formed by about 2000 to 2500 people.

The expected pollution burden, formed by the maximum number or workers, is:

- Qav.day = 350 m^3/d;
- BOD_5 = 50 kg/d;
- COD = 100 kg/d;
- Undissolved substances /SS = 60 kg/d;
- Total nitrogen /N = 8.6 kg/d;
- Total phosphorus/P = 1.4 kg/d;

A wastewater treatment plant will be built for the treatment of wastewater, with adequate capacity to also process the water from the operation of the NNU, and during the construction stage it will treat all household wastewater generated on-site. The wastewater treatment unit will provide complete biological treatment of waste household water and adequate treatment of the resulting sediments in compliance with the relevant statutory requirements. The recipient of all wastewater form the NNU will be the Danube River, via HC-1 or the newly constructed link to the recipient, in adherence to the statutory requirements. The discharged treated wastewater will have such parameters as those stipulated in a new Permit for the discharge of wastewater in surface water bodies, pursuant to Regulation No.2/2011, issued by the Water Basin Management Directorate for the Danube Region in accordance with the condition of the water basin and the purposes envisaged for it in the Water Basin Management Plan. Provided the stipulated requirements during construction are strictly observed, no significant impact is expected on the water quality of the Danube River.

4.2.1.1.1.3 Dewatering system/drainage system

The presence of high and close to the surface groundwater will necessitate the engineering and construction of a dewatering/drainage system at the site, which should be in continuous operation both during construction and during the operational period. At the next engineering stage the design of the system will take into consideration the requirements for protection of NNU against harmful effect of underground water, as well as the ecological objectives and measures related to the water resources and the water protection areas listed in ПУРБ 2010-2015 in the Danube region for ensuring good quantative and chemical condition of the water body with code BG1G0000QAL005–Pore waters in Quaternary – Kozloduy lowland.

4.2.1.1.1.4 Rain wastewater

During the construction stage, rain water will be generated during rainfall, snow melt, cleaning of work areas, etc. During the construction phase it may include a large quantity of undissolved substances, oils and dust from the construction works. For the rain water a separate sewerage system will be constructed, which will initially be partial, and then expanded so that it encompasses the whole site of the IP. Before discharging, water will be collected in buffer arrester tanks and after adequate treatment and control they will be released into the recipient water body, the Danube River, in compliance with the requirements envisaged in the relevant legislation.

4.2.1.1.1.5 Technical water supply during construction

The construction of a nuclear unit is a process lasting several years and depending on a number of factors determining the duration of the construction, such as: site licensing, preparation of the construction site, improving the earth foundation, number of reactors accompanied with the auxiliary and primary buildings and facilities, necessity to construct new production plants for the various types of construction and assembly works – concrete batching plants, vehicle depots, reinforcement and assembly workshops, warehouses, construction of underground and ground communications and many other specific activities. The so-called "wet" construction processes that will be performed on-site also play a role here.

It will be necessary to secure the technical water supply of the site for this long period and large volume of construction and installation works. This water should be provided from the sources of technical water that are supplying the existing site.

The Kozloduy NPP has a sufficient capacity to provide the connection to such a source. The "Valyata" shaft well is the closest source with the capacity to provide the necessary water, but it is also possible to use another point from the technical water supply system of the existing site. The construction of a temporary (during the construction) or permanent link for the technical water, as well as the estimates of the necessary quantity, will be defined in subsequent design developments.

4.2.1.1.1.6 Connection of the new nuclear unit to CC-1 and HC-1

The connection of the NNU with Cold Channel-1 and Hot Channel-1 for this particular site is feasible via a branch from the cold channel and a new fore-chamber for the circulation water. The distance to CC-1 is about 60 m. The connection to the hot channel is complicated but technically feasible. The distance to HC-1 is about 120 m. Another possibility is to establish the connection via a supply and bypass cold water channel and an open channel for the hot water. The bypass channel will be necessary in the event that the connection is established while the channels are in operation, which would require a reduction of the water quantity in them during the cut-in. The best solution will be developed in subsequent phases of the investment project.

Advantages:

- ✓ For this particular site, a definite advantage is the close location of the "dual channel" – about 75 m on average, allowing a shorter and easier connection, and respectively lower investment and faster fulfilment;
- ✓ Another advantage is the well-suited area for the construction of the facility and the good prospects for the structuring of the construction area.

Disadvantages:

- ✓ The location of the site, which demands reconstruction of the existing drainage channels;
- ✓ The connection to HC-1 must pass under/above CC-1;
- ✓ Substantial embankment and excavation work is required in order to reach the elevation level of the main existing site;
- ✓ Very high groundwater overflowing to the surface.

  - ➢ **Expected impact**

- During construction wastewater will have a local impact on the ecological status of the region. No irreversible negative impact is expected on environment under strict implementation of the investment plan for the construction of the necessary sewerage and water supply system and the construction of wastewater treatment facilities, ensuring compliance with statutory requirements.
- The discharge of wastewater into the recipient water body – the Danube river – during the construction works will not lead to any significant change in the quality of the river water, provided that environmental requirements are observed.
- It is possible to expect some impact during construction if the treatment and organised removal of wastewater to the point of discharge is not ensured.

➢ **Impact Scope** – indirect, negative, with a low degree of impact, limited – if regulatory requirements and relevant planned measures are observed.

➢ **Impact Characteristics** – temporary, short-term (for the construction period) and with no cumulative effect, region-sensitive, reversible after the end of construction works.

4.2.1.1.2 Site 2

This site, which is situated to the east of units 1 and 2 of the Kozloduy NPP in the direction of the village of Harlets and to the south of the constructed cold and hot channels, has an area of about 55 ha, with hilly land with a considerable slope from the south to the north, more pronounced in the southeastern part of the site, and with an elevation level of the surface between 34 and 37 m. Only one-story warehouses and other service premises are constructed at the site. A former farmyard is situated within the area of the site. The ground water level is from 8.0 to 10 m from the surface.

The site is situated on the unflooded terrace of the Danube River. No water bodies pass through it. The vertical planning of the site, according to the estimates of "Energoproekt" EAD[12] will require about 343 000 m^3 excavation and about 165 000 m^3 embankment.

This site has sufficient space to set apart the necessary construction area and the adjacent infrastructure required for the construction process.

The layout of the buildings and facilities for the site (General Layout) will differentiate a primary production area and an auxiliary production area. This applies to all of the proposed types of reactors.

This site has sufficient space to set apart the necessary construction area and the adjacent infrastructure required for the construction process.

[12] Feasibility Report – "New nuclear unit in the Republic of Bulgaria", "Energoproekt" EAD – 1999

4.2.1.1.2.1 Drinking and household water supply

The necessary water for drinking and household purposes will be provided from the existing water mains of the NPP via a Ø125mm branch. This branch will provide $Q_{max.h}$=20 l/s, which will fully satisfy the drinking water needs during the construction stage and during the operation stage. Until the construction of the water supply branch, the workers will be supplied with bottled water, and portable facilities will be provided for the hygienic and household needs.

In order to ensure the global supply of the water necessary for firefighting needs, a link to FFPS-2 will be constructed, which will also ensure the respective water pressure within the system.

All estimates on this topic for Site 1 are also applicable to this site.

4.2.1.1.2.2 Sewerage network and household wastewater

During the construction of the IP for NNU there may be pollution to the construction site with household wastewater, rain water with high contents of undissolved substances and oils (from the construction machinery), wastewater from the construction works, water from the cleaning of the site. In order to prevent these time-limited sources of local impact, main sewer collectors will be constructed, as well as a sewerage and water supply network for the so-called "controlled zone" and "pure zone", and a WWTP for the household wastewater, which will also service the NNU during the operational stage.

The method for the construction of the sewerage and water supply network, the quantity of household wastewater, as well as the expected contamination load, formed by the maximum number of workers, is similar to those for Site 1.

A wastewater treatment plant will be built for the treatment of wastewater, with adequate capacity to also process the water from the operation of the NNU, and during the construction stage it will treat all household wastewater generated on-site.

The treatment facility will be constructed in compliance to statutory requirements.

The recipient of all wastewater form the NNU will be the Danube River, via HC-1 or the newly constructed link to the recipient, in adherence to the statutory requirements.

Under strict adherence to the requirements for the construction stage, observance of the guidelines envisaged in a new Permit for the discharge of wastewater in surface water bodies, pursuant to Regulation No.2/2011, issued by the Water Basin Management Directorate for the Danube Region, no significant impact is expected on the water quality of the Danube River.

4.2.1.1.2.3 Dewatering system

The groundwater in the area of this site is located lower, at a greater depth. Notwithstanding this circumstance, a dewatering system will be necessary for the protection of the NNU and for satisfying the requirements for safe operation of all buildings and facilities. It should be in continuous operation both during construction and during the operational period.

The monitoring on the quality of the water in the drainage system will be conducted during the entire construction stage, and will continue during the operation and decommissioning stages, as a part of the monitoring system of the NNU.

Drainage water can be discharged into the Danube River after passing through an arrester settling tank and undergoing a quality control check.

4.2.1.1.2.4 Rain wastewater

During construction, rain water will be generated during rainfall, snow melt, cleaning of work areas, etc. During the construction phase it may include a large quantity of undissolved substances, oils and dust from the construction works. For this water a separate sewerage system will be constructed, which will initially be partial, and then expanded so that it encompasses the whole site of the IP. Before discharging, water will be collected in buffer arrester tanks and after adequate treatment and control they will be released into the recipient water body, the Danube River, in compliance with the requirements envisaged in the relevant legislation.

4.2.1.1.2.5 Technical water supply during construction

The construction of a nuclear unit is a process lasting several years and depending on a number of factors determining the duration of the construction. It will be necessary to secure the technical water supply of the site for this long period and large volume of construction and installation works. The so-called "wet" construction processes that will be performed on-site also play a role here.

This water should be provided from the sources of technical water that are supplying the existing site.

The Kozloduy NPP has sufficient capacity to provide a connection to such a water source or to an appropriate point from the technical water supply network of the existing site. The construction of a temporary (for the time of construction) or permanent link for the technical water, as well as the estimates on the necessary quantity, will be defined in subsequent design developments.

4.2.1.1.2.6 Connection of the new nuclear unit to CC-1 and HC-1.

Here the connection of the technical water supply facilities for the NNU will not be different in principle from that of Site 1, the difference lying in the building of an inverted siphon for the cold water coming from Cold Channel-1 or using Circulator Pump Station-1, and a bypass line for the hot water coming from Hot Channel-1. It will also be possible to implement the connection while the double channel is in operation, by limiting the water amount in the channels during cut-in. The distance to CC-1 is 75 m. The possible connection with CC-1 via CPS-1 extends the length of the supply pipelines. The specific technical solution will be chosen at the next design phase when the site for the NNU is selected.

Advantages:

- ✓ A definite advantage for this particular site is the close location of the “dual channel” – about 75 m, allowing a shorter and easier connection, and respectively lower investment and faster fulfilment. There is also an option of making a connection with the CC-1 through CPS-1. The dual channel actually represents the border of the site to the north.
- ✓ The absence of already constructed facilities needing reconstruction is an advantage.
- ✓ Other advantages are the well-suited area for the construction of the facility, the good prospects to adequately organise the construction works and the possibility to use the existing buildings and structures for the purposes of the construction process.
- ✓ The performance of the vertical planning is another advantage – considerably less excavation and embankment works.

Disadvantages:

- ✓ The connection with CC-1 must pass under/above the HC-1.
- ✓ The connection through CPS-1 would be much longer.
  - ➢ **Expected impact**
    - During construction wastewater will have a local impact on the ecological status of the region. No irreversible negative impact is expected on environment under strict implementation of the investment plan for the construction of the necessary sewerage and water supply system and the construction of wastewater treatment facilities, ensuring compliance with statutory requirements.
    - The discharge of wastewater into the recipient water body – the Danube river – during the construction works will not lead to any significant change in the quality of the river water.
    - It is possible to expect some impact during construction if the treatment and organised removal of wastewater to the point of discharge is not ensured.
  - ➢ **Impact Scope** – indirect, negative, with a low degree of impact, limited – if regulatory requirements and relevant planned measures are observed.
  - ➢ **Impact Characteristics** – temporary, short-term (for the construction period) and with no cumulative effect, region-sensitive, reversible after the end of construction works.

4.2.1.1.3 Site 3

The site is situated on the flooded terrace of the Danube River, to the northwest of units 5 and 6 of the Kozloduy NPP, in the vicinity of the bypass road of the existing power plant. The area of the site amounts to approximately 55 ha. The terrain is flat, with a slight slope from the south to the north. The elevation level of the terrain is 25.0-26.0 m. The area of the site houses some open drainage channels, which will have to be restructured. The level of groundwater fluctuates depending on the water levels of the Danube River. It overflows to surface level or close to it.

In order to reach the design elevation level of the site (to reach the elevation level "0" of the existing site of the NPP), the vertical planning will require significant excavation and filling activities – an embankment of 6.00 to 8.50 m with a volume of over 3 650 000 m^3 for an area of about 55 ha.[13]

Here, construction and assembly works will be required, related with reconstruction and/or shifting of the available open drainage channels from the irrigation and drainage system of the Kozloduy low-land, which is of significance for the flood protection of the existing NPP site.

The terrain of this site is situated under the fan of the 400 KV power lines coming out of the NPP, which would necessitate their shifting.

This site has sufficient space to set apart the necessary construction area and the adjacent infrastructure required for the construction process.

The layout of the buildings and facilities for the site (General Layout) will differentiate a primary production area and an auxiliary production area. This applies to all of the proposed types of reactors.

This site has sufficient space to set apart the necessary construction area and the adjacent infrastructure required for the construction process.

4.2.1.1.3.1 Drinking and household water supply

The necessary water for drinking and household purposes will be provided from the existing water mains of the NPP via a Ø125mm branch (the same as for Site 1).

All estimates on this topic for Site 1 are also applicable to this site.

4.2.1.1.3.2 Sewerage network and household wastewater

The generation of household wastewater during the construction of the NNU IP has been examined in detail for Site 1.

The method for the construction of the sewerage and water supply network, the quantity of household wastewater, as well as the expected contamination load, formed by the maximum number of workers, is similar to those for Site 1.

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[13] Feasibility Report by "Energoproekt" EAD, 1999

A wastewater treatment plant will be built for the treatment of wastewater, with adequate capacity to also process the water from the operation of the NNU, and during the construction stage it will treat all household wastewater generated on-site.

The treatment facility will be constructed in compliance to statutory requirements.

Under strict adherence to the requirements for the construction stage, observance of the guidelines envisaged in a new Permit for the discharge of wastewater in surface water bodies, pursuant to Regulation No.2/2011, issued by the Water Basin Management Directorate for the Danube Region, no significant impact is expected on the water quality of the Danube River.

4.2.1.1.3.3 Dewatering system

The presence of high and close to the surface groundwater will necessitate the construction of a dewatering system at the site, which should be in continuous operation both during construction and during the operational period.
The monitoring on the quality of the water in the drainage system will be conducted during the entire construction stage, and will continue during the operation and decommissioning stages, as a part of the monitoring system of the NNU.

Drainage water can be discharged into the Danube River after passing through an arrester settling tank and undergoing a quality control check.

4.2.1.1.3.4 Rain wastewater

For the rain water during construction a separate sewerage system will be constructed, which will initially be partial, and then expanded so that it encompasses the whole site of the IP. Before discharging, water will be collected in buffer arrester tanks and after adequate treatment and control they will be released into the recipient water body, the Danube River, in compliance with the requirements envisaged in the relevant legislation.

4.2.1.1.3.5 Technical water supply during construction

The technical water supply during the construction phase will be implemented in the same way as for Site 1.

The construction of a temporary (during the construction) or permanent link for the technical water, as well as the estimates of the necessary quantity, will be defined in subsequent design developments.

4.2.1.1.3.6 Connection of the new nuclear unit to CC-1 and HC-1.

Here the connection can be made without disturbing the operation of the other units, provided there is an additional constructed cold channel – CC-2. After units 1÷4 were shut down, fresh service water from the Danube River amounting to about 80 m^3/s has become available for use. This secured reserve capacity does not require the construction of any additional service water supply facility, i.e. CC-2, therefore, other technical solutions would be required for the connection with the existing CC-1. For example, the connection with CC-

1 requires the construction of a new CPS at its end, which would complicate the operation of the existing units. The distance from the site to CC-1 is about 235 m.

This site is situated close to HC-2, which was constructed in order to transfer a water quantity of Q=110 m^3/s for the needs of just units 5 and 6, and that is why the IP does not review the use of this channel.

Constructing a new channel from Site 3 to the open section of HC-1 is proposed as an option, and it is recommended to avoid any connection through its underground part.

Advantages:

- ✓ No demolition of any existing buildings would be required.

Disadvantages:

- ✓ The location of the site, which demands reconstruction of the existing drainage channels;
- ✓ Substantial excavation and embankment work would be required in order to reach the elevation level of the main existing site;
- ✓ Very high groundwater overflowing to the surface;
- ✓ A long connection to CC-1;
- ✓ A long connection to HC-1;
- ✓ Displacement of the fan of the 400 KV power lines would be required.

- ➢ **Expected impact**
  - During construction wastewater will have a local impact on the ecological status of the region. No irreversible negative impact is expected on environment under strict implementation of the investment plan for the construction of the necessary sewerage and water supply system and the construction of wastewater treatment facilities, ensuring compliance with statutory requirements.
  - The discharge of wastewater into the recipient water body – the Danube river – during the construction works will not lead to any significant change in the quality of the river water.
  - It is possible to expect some impact during construction if the treatment and organised removal of wastewater to the point of discharge is not ensured.
- ➢ **Impact Scope** – indirect, negative, with a low degree of impact, limited – if regulatory requirements and relevant planned measures are observed.
- ➢ **Impact Characteristics** – temporary, short-term (for the construction period) and with no cumulative effect, region-sensitive, reversible after the end of construction works.

4.2.1.1.4 Site 4

The site is situated on the first unflooded terrace of the Danube River, to the west of units 3 and 4 of the Kozloduy NPP and the WSFSF, to the south of the cold and hot channels, and is fully urbanised. It is situated at elevation level of about 36 m. The usable area is around 21 ha, within the boundaries of the alienated terrains of the Kozloduy NPP. The terrain houses the existing constructed service facilities – the Equipment storage facility, the Vehicle Repair Workshop and the Assembly Facility. In order to utilize the site, the main underground communications of the NPP need to be reconstructed and displaced, and the aforesaid facilities need to be displaced to free up the area. The ground water level is from 8.0 to 10 m from the surface.

For Site 4 the actual design would have to be adjusted to the area where the Client offers for the temporary buildings, and they must be situated out of the site where the new unit will be constructed.

4.2.1.1.4.1 Drinking and household water supply

The necessary water for drinking and household purposes will be provided from the existing water mains of the NPP via a Ø125mm branch (the same as for Site 1).

All estimates on this topic for Site 1 are also applicable to this site.

4.2.1.1.4.2 Sewerage network and household wastewater

The generation of household wastewater during the construction of the NNU IP has been examined in detail for Site 1.

The method for the construction of the sewerage and water supply network, the quantity of household wastewater, as well as the expected contamination load, formed by the maximum number of workers, is similar to those for Site 1.

A wastewater treatment plant will be built for the treatment of wastewater, with adequate capacity to also process the water from the operation of the NNU, and during the construction stage it will treat all household wastewater generated on-site.

The treatment facility will be constructed in compliance to statutory requirements.

Under strict adherence to the requirements for the construction stage, observance of the guidelines envisaged in a new Permit for the discharge of wastewater in surface water bodies, pursuant to Regulation No.2/2011, issued by the Water Basin Management Directorate for the Danube Region, no significant impact is expected on the water quality of the Danube River.

4.2.1.1.4.3 Dewatering system

The groundwater in the area of this site is located lower, at a greater depth. Notwithstanding this circumstance, a dewatering system will be necessary for the protection of the NNU and for satisfying the requirements for safe operation of all buildings and facilities. It should be in continuous operation both during construction and during the operational period.

The monitoring on the quality of the water in the drainage system will be conducted during the entire construction stage, and will continue during the operation and decommissioning stages, as a part of the monitoring system of the NNU.

Drainage water can be discharged into the Danube River after passing through an arrester settling tank and undergoing a quality control check.

4.2.1.1.4.4 Rain wastewater

For the rain water during the operation stage, a separate sewerage system will be constructed, which will initially be partial, and then expanded so that it encompasses the whole site of the IP, in the same way as for Site 1. Before discharging, water will be collected in buffer arrester tanks and after adequate treatment and control they will be released into the recipient water body, the Danube River, in compliance with the requirements envisaged in the relevant legislation.

4.2.1.1.4.5 Technical water supply during construction

The technical water supply during the construction phase will be implemented in the same way as for Site 1.

The construction of a temporary (for the time of construction) or permanent link for the technical water, as well as the estimates on the necessary quantity, will be defined in subsequent design developments.

4.2.1.1.4.6 Connection of the new nuclear unit to CC-1 and HC-1

According to the IP, the supply of service water for the cooling of the NNU can be done at the place for that which was used for units 3 and 4 (decommissioned), where the pipelines must pass above the underground part of the hot channel (HC-1), which, as a location, is the northern corner of this site. The distance to CC-1 is about 75 m. It is possible to construct a new CPS.

Even though the underground part of HC-1 is in the northern corner of the site, in order to avoid any connection with it in the underground part, as the recommendation states, the connection must be made in the open part of the channel.

Advantages:

- ✓ The site is situated on the unflooded terrace of the Danube River, property of the Kozloduy NPP, and represents an industrial site;
- ✓ A short connection with CC-1;
- ✓ An easy connection with HC-1.

Disadvantages:

- ✓ The site accommodates many industrial buildings and facilities that have to be demolished and displaced to new terrains;
- ✓ It is possible to detect underground communication infrastructure pertinent to the operation of the existing site.
- ✓ The area is small for a NNU with a reactor requiring a construction site of great size.

  - **Expected impact**
    - During construction wastewater will have a local impact on the ecological status of the region. No irreversible negative impact is expected on environment under strict implementation of the investment plan for the construction of the necessary sewerage and water supply system and the construction of wastewater treatment facilities, ensuring compliance with statutory requirements;
    - The discharge of wastewater into the recipient water body – the Danube river – during the construction works will not lead to any significant change in the quality of the river water;
    - It is possible to expect some impact during construction if the treatment and organised removal of wastewater to the point of discharge is not ensured.
  - **Impact Scope** – indirect, negative, with a low degree of impact, limited – if regulatory requirements and relevant planned measures are observed.
  - **Impact Characteristics** – temporary, short-term (for the construction period) and with no cumulative effect, region-sensitive, reversible after the end of construction works.

Conclusion:

Based on the conducted analysis on the construction and assembly works and the expected impact during the construction of the NNU, the impact on surface water can be estimated as follows:

Impact Scope – direct, negative, with a low degree of impact, limited – if regulatory requirements and relevant planned measures are observed.

Impact Characteristics – temporary, short-term (for the construction period) with no cumulative effect, region-sensitive, reversible after the end of construction works.

4.2.1.2 DURING OPERATION

The investment proposal for the construction of a new nuclear unit of the latest generation (III, III+) at the proposed alternative sites considers 3 types of reactors: These are:

- AES-92 type reactor;
- AP-1000 reactor – generation III+;
- AES-2006 reactor – generation III+.

AES-92 has been designed as a Pressurized Water Reactor of the WWER-1000/V466B type, with four circulation loops, based on a standard design for a PWR AES-92 power plant, which in 2006 successfully passed all analysis stages for compliance with the European power facilities requirements, supported by the major European energy companies for the next generation of NPPs with light pressurized water. The reactor is licensed in the producing country – Russia. The flow rate of the coolant in the first circuit of the reactor is 23.9 m^3/s with 4 Main Circulation Pumps (MCP) with a nominal flow rate of 21 500 m^3/h. In the first circuit the cold water enters the lower part of the active zone at a flow rate of 86 000 m^3/h. The necessary water quantity to supply the cooling system from the Danube river, based on data provided by the Client, amounts to 60m^3/s[14].

In this reactor there are significant improvements of the hermetic sealing, providing a maximum barrier to the release of radioactive products into the environment. It has been designed as a double-containment structure where the internal containment is made of prestressed reinforced concrete with a hermetic metal casing, and the external containment is made of prestressed reinforced concrete. The external containment was designed to resist external forces such as: a hit from a large passenger aircraft, external blast waves, hurricane winds, snow, extreme temperatures and earthquakes. The construction of the internal containment has been designed to withstand seismic impacts, and all security systems meet the seismic safety requirements.

The reactor offers a unique combination of active and passive parts of the safety systems which ensure a higher level of protection for the NPP, including by using a system trapping corium from the active zone.

The estimated personnel needed for a WWER-1000/B466Б reactor is 550 people.

The **AP-1000 reactor** of generation III+ is an advanced passive reactor with pressurized water, with a net electrical power output of 1117-1154 MW. Supplier: Westinghouse (USA). AP-1000 is approved in 2005 by the American Nuclear Regulatory Commission. Intermediate confirmation for project approval (iDAC) in Great Britain approved in December, 2011. It meets the requirements of EPRI-URD and EUR.

The AP-1000 reactor is based on the proven pressurized water design of Westinghouse. An NPP with this reactor is an advanced one, since the unit employs safety enhancing modules during operation. The coolant pumps (MCP) are mounted directly on top of the steam generator, eliminating the pipelines between the pumps and the steam generators, which favours natural convection and eliminates the need for an MCP sealing and lubrication system.

In comparison with a standard power plant of similar power output, AP-1000 has 35% less pumps, 80% less pipes of high safety class, and 50% less valves of ASME safety class. There are no high safety class pumps. This makes the AP-100 power plant much more compact compared to older designs. As it has less equipment and pipes, the greater part of the safety

[14] A letter with outgoing No. 236/11.3.2013

equipment is mounted within the hermetic construction. That is why AP-1000 has approximately 55 % less turbine connections to the hermetic construction in comparison with current-generation power plants.

AP-1000 has two circulation circuits, uses two vertical steam generators, model Delta-125, and four circulation pumps, mounted two by two directly on each steam generator, in order to eliminate the pipeline connection between the steam generator and the Main Circulation Pump. The flow rate of the coolant in the first circuit is 19.87 m^3/s, with 4 MCPs with a nominal flow rate of 17 886m3/h. The necessary water quantity to supply the cooling system from the Danube River, based on data provided by the Client, amounts to 40 m^3/s[15].

The total number of staff needed for a site equipped with an AP-1000 reactor is 502 people for one unit; shutting down and refuelling operations might need an additional number of 500 people for these particular periods. The necessary personnel is presented in **Table 4.2-1**.

TABLE 4.2-1: PERSONNEL FOR A NNU WITH A AP-1000 REACTOR

Group	Unit 1
Engineering	47
Repairs	108
Operation	77
Radiation protection	38
Safety	113
Site Maintenance	100
Workflow Management	19
TOTAL	**502**

AES-2006 is a generation III+ reactor with electrical power output of 1200 MW and is a direct successor of the previous PWR model of Atomstroyexport-Russia. The design of AES-2006 incorporates the requirements of the IAEA and the Technical requirements of the European operating organizations (EUR).

Both the active and the passive systems of the AES-2006 power plant are used to fulfil safety functions. In addition, AES-2006 has systems for the management of severe accidents. It is designed with a double containment and a corium-catching system.

The increased quantity of the reactor coolant improves the cooling of the active zone in the event of an accident involving the loss of coolant. The circulation circuits are four, and the flow rate for the first circuit is 23.9 m^3/s, 4 MCPs, the nominal flow rate is 21 500 m^3/h. The necessary water quantity to supply the cooling system from the Danube river, based on data provided by the Client, amounts to 60m^3/s[16].

[15] A letter with outgoing No. 416/13.05.2013 by the Client

[16] A letter with outgoing No. 236/11.3.2013

The nominal operational life of the power plant is 60 years.

The estimated personnel needed for its operation is 600 people on-site and another 500 people for periods of planned repair and maintenance operations.

Each of the alternative sites is of sufficient size to house the NNU. The necessary areas for the operation of the NNU for one unit are: 7 ha for AP-1000; 25 ha for AES-92 and AES-2006. For Site 4 the actual design will be adjusted to accommodate the area offered by the Client.

All sites offer an adequate technical capacity to provide drinking water supply using the existing water-supply network of the Kozloduy NPP and technical water supply – for cooling and other purposes – through the existing hydrotechnical constructions of the power plant.

All sites will be equipped with separate sewage systems for household wastewater, industrial wastewater and rain wastewater.

4.2.1.2.1 SITE 1

This site has sufficient area to accommodate all considered reactor types and the facilities and infrastructure necessary for their operation.

4.2.1.2.1.1 Water supply

4.2.1.2.1.1.1 Drinking and household water supply

The water needed for drinking and household purposes will be provided from the existing water-supply network of the NPP by means of a branch, which will ensure the necessary water quantity.

The personnel occupied in the operation of the NNU varies depending on the type of reactors, as already stated:

- For the AES-92 reactor – about 550 workers;
- For the AP-1000 reactor – about 502 workers;
- For the AES-2006 reactor – about 600 workers.

The water needed for the different types of reactors is as follows[17]:

- For the AES-92 reactor – Qmax.h.= 6.90 l/s, Qav.d= 165 m^3/d
- For the AP-1000 reactor – Qmax.h.= 6.30 l/s, Qav.d= 150.6 m^3/d
- For the AES-2006 reactor – Qmax.h.= 7.50 l/s, Qav.d= 180 m^3/d

The branch of the existing water-supply network of the Kozloduy NPP, constructed in order to satisfy the needs for drinking and household water of the workers during the

[17] Regulation No. 2 from 22.03.2005 of the Ministry of Regional Development and Public Works on the design, construction and operation of water supply systems, SG No. 34 from 19.04.2005.

construction period (Ø125 mm), provides Qmax.h.=20 l/s, which is completely sufficient to cover the needs for drinking water during operation. The pressure across the water supply network of the NPP is 8 atm.

4.2.1.2.1.1.2 Provisionally pure water (non-drinking) for bathing, washing, toilets, etc.

The provisionally clean water for washing will be taken from the "Valyata" Pump Station, for which there is water abstraction permit, issued by the Water Basin Management Directorate for the Danube Region. The maximum daily flow rate of the pump station is 50 l/s, in accordance with the special requirements on the hygienic standards in the NPP. The maximum water consumption rate for about 1 hour (after the shift) is about 20 l/s.

This water is provided via a branch from the water main of the NPP, which have been constructed using Ø250 mm steel pipes.

4.2.1.2.1.1.3 Technical water (non-drinking) for fire control purposes

The system will be like the one for the existing site – in 2 circuits.

An automatic fire extinguishing ring. The technical water supply system for fire extinguishing purposes, which has an interconnection with the automatic fire alarm system, will be supplied with water from CC-1 via a connection at FFPS-2.

Household firefighting purposes will be covered by a household firefighting pipeline – external and internal. It will also be supplied via FFPS-2, with the option to use pumps from CPS-1.

4.2.1.2.1.2 Technical water supply

Technical water supply provides cooling water (circulation water – for the condensers of the turbines; and technical water – for Chemical Water Treatment and for other purposes). It is realised via 3 Bank Pump Stations from the Danube River, as well as 6 shaft pump stations situated in the terrace of the Danube River – for emergency water supply.

The water intake from the Danube River and the bank pumping stations is located at km 687 from the Danube River mouth, after the island at the town of Kozloduy. The capacity of the cold channel is 180 m^3/s, with demonstrated maximum capacity of 200 m^3/s[18]. For the use of water from the Danube River and from underground sources, the relevant water abstraction permits have been issued by the Water Basin Management Directorate for the Danube Region.

Water from the Danube River is supplied to the power plant via the constructed hydro-technical facilities, which are crucial for the normal operation of the power plant. The cold channel connects the outflow tanks of the BPS with CPS-1 (Circulation Pump Station) with a length of 7023 m. The CPSs (Circulation Pump Stations) are located in front of the turbine halls of the respective power units.

[18] Scientific Centre "Energoproekt"-1991 – Existing technical water supply systems

The used water from the power units is returned to the Danube River by means of the Hot (outlet) Channel HC-1. The Hot Channel (HC-1) starts at the outlet shaft of the low-pressure channels and ends next to the overflow drain of the bypass channel for discharging the of hot water into the Danube River. It has a length of 6 930 m. The capacity of the hot channel is 180 m^3/s, with demonstrated maximum capacity of 200 m^3/s, which depends on the elevation level of the overflow drain after the low-pressure channels and the water level of the Danube River. The "hot" channel passes parallel to the "cold" channel (CC-1) along the greater part of their route. The two channels have a common dike and form a double channel.

For the provision of technical water, considering the fact that the first four power units of the existing power plant have been decommissioned, there is some available capacity up to 80 m^3/s, so that the cooling water for the turbine condensers and the other systems of the IP will be partially supplied from the water freed up after their decommissioning, where the necessary quantity is considerably smaller than the available one and is fully guaranteed. The removal of fresh water from the Danube River for the new nuclear unit will **not** lead to any disturbance to the permitted quality of raw water envisaged in the water abstraction permit, issued by the Water Basin Management Directorate for the Danube Region, which is up to 5 000 $mil.m^3/y$, including up to 4997 $mil.m^3/y$ for cooling purposes and up to 2.68 $mil.m^3/y$ for the production of demineralised water.

The different types of reactors need different quantities of cooling water, and specifically:

- For AES-92 $60m^3/s=216\,000m^3/h=5\,184\,000m^3/day=1\,892\,160\,000m^3/y$[19]
- For AP-1000 $40m^3/s=144\,000m^3/h=3\,456\,000m^3/day=1\,261\,440\,000m^3/y$[20]
- For AES-2006 $60m^3/s=216\,000m^3/h=5\,184\,000m^3/day=1\,892\,160\,000m^3/y$[21].

The reports from the Own Non-radiation Monitoring (ONM) of the Kozloduy NPP show that for instance after 2007 the utilised annual water quantity of fresh raw water from the Danube river varies at about 2 600 000 000m^3/y, which is $Q_{av.d.}$~7$mil.m^3/day$~82m^3/s. If we consider the conservative Q=60m^3/s for the reactor and 4800m^3/d for technological purposes, as envisaged in the IP, then the annual volume of water drawn from the source for the purposes of the NNU is expected to be approximately Q=1 892 160 000m^3/y. The total expected water quantity to be drawn from the river would be approximately Q=4 492 160 000m^3/y together with the operating units 5 and 6. This quantity of water is close to the one drawn from the water body during the operation of units 1÷6 by 2002.

[19] A letter with outgoing No. 236/11.03.2013 by the Client.
[20] Letter No.416/13.05.2013 with PPP No.31/13.05.2013 by the Client.
[21] A letter with outgoing No. 236/11.03.2013 by the Client.

The estimates indicate that the hydrotechnical facilities constructed to bring cold water from the Danube River and lead the spent cooling water back into the river have sufficient capacity to guarantee the joint operation of the NNU and the currently existing active power units 5 and 6. The treated cooling water from the NNU is expected to have a temperature up to T≤14.5°C.

Site 1 is situated close to the cold channel which enables an easy access to it. The distance to it is 60 m. The distance to HC-1 is about 120 m. The connection options for the two channels that are envisaged in the IP are presented in **Section 4.2.1.1**.

4.2.1.2.1.3 Sewerage network

The sewerage network of the site of the new IP will be divided into: household wastewater from the controlled zone and the pure zone; industrial wastewater; and rain wastewater. The sewerage system will be constructed using materials that ensure high water tightness and prevent the infiltration of contaminants into groundwater and the subsoil. The detailed design of the network, including exact sizes, diameters, flow rate capacity, placement of the splits for each building, secondary branches and main sewerage branches, will be the subject of subsequent design stages. The network will fully handle the removal of the respective wastewater to the recipient water body.

The wastewater from the NNU site will be formed from the following sub-sites: energy building, special building, sanitary and amenities building, chemical water treatment, mechanical repairs workshop, oil facility, diesel generator stations, administrative buildings and other necessary supporting units.

4.2.1.2.1.3.1 Household wastewater

The household wastewater will be formed by the everyday activities of the personnel, the sanitary facilities and the laundry equipment of the “pure zone” and the "controlled zone".

The quantity of household wastewater for the different types of reactors is presented in **Table 4.2-2**.

TABLE 4.2-2: EXPECTED QUANTITIES OF HOUSING WASTEWATER

Reactor type	Personnel people	Water quantity	
		Q max, h, l/s	Qmax, d, m^3/d
AES-92	550	6.90	165.0
AP-1000	502	6.30	150.6
AES-2006	600	7.50	180.0

The expected contamination load, formed by the personnel for the AP-**1000** reactor is:

- BOD5 = 10 kg/d;
- COD = 20 kg/d;

- Undissolved substances /SS = 12 kg/d;
- Total nitrogen /N = 1.7 kg/d;
- Total phosphorus/P = 0.3 kg/d;

The expected contamination load, formed by the personnel for the **AES 92** reactor is:

- BOD5 = 11 kg/d;
- COD = 22 kg/d;
- Undissolved substances /SS = 13 kg/d;
- Total nitrogen /N = 1.9 kg/d;
- Total phosphorus/P = 0.3 kg/d;

The expected contamination load, formed by the personnel for the **AES-2006** reactor is:

- BOD5 = 12 kg/d;
- COD = 24 kg/d;
- Undissolved substances /SS = 14.4 kg/d;
- Total nitrogen /N = 2.1 kg/d;
- Total phosphorus/P = 0.34 kg/d;

The treatment of household wastewater will be carried out in the Wastewater Treatment Plants, which will be built during the construction of the NNU and will start functioning during the construction.

Bringing household wastewater to the treatment facilities will be carried out via two sewage collectors, depending on the location of the subsites and on the way they are formed – from the “pure zone” and from the “controlled zone”.

The sewerage branches leading wastewater from the subsites of the "pure zone" and the "controlled zone" will be constructed out of materials that are resistant to aggressive and other types of adverse impact. These waters will be led to a treatment facility consisting of two wastewater treatment plants – one for the waters from the “pure zone” and one for that from the “controlled zone”. The situational plans on the deployment of the different reactors envisage the position of the treatment facility. Its final positioning will be reflected in the next design phase, depending on the selected site and type of reactor.

4.2.1.2.1.3.2 Production wastewater

Industrial wastewater is formed as acidic and alkaline wastewater in the production of demineralised and deeply demineralised water from the Chemical Water Treatment and water contaminated with petroleum products and oils.

The treatment of the raw water to demineralised and deeply demineralised water at the CWT installations will be implemented via subsequent technological processes, depending on the specific technology selected and the natural properties of the raw water.

The control on the technological processes will be implemented from the control room of the CWT facility.

The maximum quantity of wastewater (acidic and alkaline) varies for the different types of reactors. It represents the periodic consumption and depends on the processing technology and on the quality of the raw water.

For AES-92 it is about 125 m^3/h, for AP-1000 – about 10.0 m^3/h for AES-2006 – about 80 m^3/h.

The wastewater from the CWT facility, via the sewerage for this type of water, constructed using pipelines with the necessary parameters and from materials with anti-corrosive properties, will be conveyed to the neutralising pools. After its processing, it will be directed to the discharge point.

The formation of industrial wastewater contaminated with petroleum products results from the drainage water coming from the engine room (ER), the diesel generator station (DGS), the transformer platforms and the oil and petroleum plant.

Local treatment facilities will be built for the separate subsites for the rough removal of petroleum products, and then water will be collected for additional purification in the treatment plant, followed by dosimetric control.

The specific design solutions for the treatment facilities – local ones and global ones for all petroleum-content wastewater, will be developed in the next design phase, depending on the adopted decisions on the construction of the NNU.

Non-radiation wastewater, for instance for a WWER-1000/B466Б reactor can be illustrated from the available information on the WWER-1000/B412 (Kudankulam NPP), since the two models are rather similar.

The expected non-radiation wastewater for the Kudankulam NPP is conventional waste, such as the wastewater from the settlement for the power plant personnel, the canteen and the toilets.

The release of liquid wastewater is shown at the following **Table 4.2-3** for the Kudankulam NPP.

TABLE 4.2-3: RELEASE OF LIQUID WASTEWATER FROM THE KUDANKULAM NPP[22]

Design releases of liquid waste	Quantity (m^3/d)
Household sewerage from the pure zone (PZ)	264
Household sewerage from the controlled zone (CZ)	120
Water contaminated with petroleum products	480
TOTAL	864

[22] Letter No. 416 from 13.05.2013 with PPP No. 31 of 13.05.2013

The discharge of all types of industrial wastewater will be carried out by means of a new channel directly to the Danube River or by discharging into Hot Channel 1.

The overall solution for the sewerage system for the production wastewater will be the subject of a specific plan in the next design phase, in accordance with the conditions laid down by the competent authority regarding their discharge, and the situational plan for the specific reactor and its supporting buildings and facilities.

4.2.1.2.1.3.3 Rain water

A separate sewage system will be built for the disposal of rain water falling on the site.

Rain water will pass through buffer arrester tanks, two-sectional, amply dimensioned to absorb the first contaminated rain water from the site, average its physical and chemical composition, subject it to precipitation in order to reduce the concentration of any undissolved substances and control the formation of sludge. The quantity of rain water collected by the rain sewer system depends on the situational positioning of the buildings and facilities within the site, and the surface area of the dewatered areas and surfaces. It will be defined through the method of threshold intensity, specifically in the next design phase.

Subsequently, and following a mandatory radiation control, the water from the arrester tanks will be discharged into the Danube River in carefully planned doses.

4.2.1.2.1.3.4 Cooling water from the technical water system

The cooling water taken from the Danube River is sent back using HC-1. The conservative estimate for the expected quantity of 60 m^3/s[23] – for the cooling of one reactor for the needs of the NNU, is sent back to the Danube River as treated cooling water, amounting to approximately Q=1 892 160m3/y. The total expected water quantity to be drawn from the river would be approximately Q=4 492 160 000 m^3/y together with the operating units 5 and 6. This quantity of water is close to the one drawn from the water body during the operation of units 1÷6 by 2002.

This water quantity falls within the limits of the authorized water absorption from the Danube River pursuant to Permit No.05628/14.03.2005 under the Water Act, issued by the competent authority. The estimated temperature above the raw water temperature will be up to T≤14.5°C.

The connection with the hot channel from this site is complicated, since the pressure pipelines must pass through the cold channel. The distance to hot channel – 1 (HC-1) is about 120 m. Due to the fact that the new hot channel (HC-2) is used only for units 5 and 6, the IP does not review the use of this channel for the NNU.

[23] A letter with outgoing No. 236/11.3.2013

4.2.1.2.1.4 Treatment facilities for non-radioactive wastewater

4.2.1.2.1.4.1 Treatment facilities for household wastewater

Two separate wastewater treatment plants have been planned for the household wastewater from the “pure zone” and the “controlled zone”. For the household wastewater from the “pure zone”, the treatment technological scheme will include facilities for mechanical and biological treatment, such as:

- grates for the retainment of floating substances;
- a drawing tank;
- a pump station elevating the level of wastewater to the level of the treatment facilities;
- a biopool with continuous aeration and complete mineralization of the sludge;
- secondary precipitators;
- a contact tank;
- a sludge-compacting unit for the excess active sludge.

The supply of air to the biopool will be implemented via airblowers.

The treatment facilities will implement a purification effect according to BOD_5 up to 90% and for the undissolved substances – up to 65%. Treatment facilities for the removal of nitrogen and phosphorus may not be envisaged because the facility is for less than 10 000 equv., which is the mandatory level. This kind of treatment is expected to bring the parameters of the treated wastewater in compliance with the regulatory requirements for the discharging of wastewater into the Danube River, which will be laid down in the discharge permit.

For the treatment of household wastewater from the "controlled zone" also involves the construction of treatment facilities. The technological scheme of the household wastewater treatment plant for the “controlled zone” will include the same facilities for mechanical and biological treatment. The bio-pool is planned as a low-burden biopool with full mineralization of the sledge. Having passed through the treatment plant, water will then undergo dosimetric radiation control before being discharged into the recipient basin. In case wastewater does not meet the regulatory requirements during the radiation control, it will be returned for second treatment.

In the treatment facility, which unifies the household wastewater treatment plants for the two zones, the untreated and the treated wastewater will be subjected to a number of analyses each day: pH, temperature, permanganate oxidisability, chemical oxygen demand (COD) and quantity of dissolved oxygen in the bio-pool, etc.

It is possible to mix the two types of treated wastewater before discharging thus fulfilling only one discharge with continuous monitoring and radiologic control.

The investment proposal offers no data on the quantities of household wastewater from the "pure zone" and the "controlled zone", nor on the quantities of the formed sludge from the treatment facilities.

The final decision regarding the treatment of household wastewater from the two zones will be taken in the next design phase.

4.2.1.2.1.4.2 Treatment facilities for wastewater from Chemical Water Treatment

For the treatment of wastewater from Chemical Water Treatment, a neutralizing pool is to be built with the purpose of neutralizing aggressive water (acidic and alkaline) released during the technological processes in the Chemical Water Treatment facility. The pool will have two chambers – a working chamber and a reserve chamber. The neutralization of the incoming acidic and alkaline waters will be conducted without using any reagents, and wastewater stirring will be done via compressed air. In the next design phase it will be necessary to specify the quantity of acidic and alkaline water from the CWT facility, the time necessary for its neutralisation, the volumes of the neutralising pools, their positioning and everything related to this process.

The wastewater coming out of the neutralising pool must have a pH between 6,5 and 9 in order to meet the requirements of the recipient water body. After its neutralisation, the wastewater is conveyed to the discharge point.

4.2.1.2.1.4.3 Treatment facilities for wastewater contaminated with oils and petroleum products

Local treatment facilities for the elimination of petroleum products – mud/oil traps and grease arresters – will be built for the treatment of industrial wastewater from the diesel generator station, the transformer platforms and the oil and mazut plant. It is imperative that parameters on the treatment facilities for petroleum-content wastewater are presented at the next design phase. The technological solution and design configuration of these facilities should utilize more advanced technologies and should meet the regulatory provisions on the indicators required for discharge into the recipient water body.

4.2.1.2.1.5 Major flows of non-radioactive wastewater

Wastewater within Site 1 will form the following major flows:

- Household wastewater from the sanitary facilities and laundry units of the “pure zone” and the “controlled zone”, led to the treatment plants through separate collectors;
- Acidic and alkaline wastewater from the Chemical Water Treatment facility, led to a neutralising pool through a separate collector;
- Oil-containing wastewater collected in a holding tank and then led to a local treatment facility (mud/oil trap);

– Rain wastewater that is led through street effluents via the rain sewerage and across a buffer tank to be discharged into the recipient water body.

4.2.1.2.1.6 Wastewater characteristics

For the final characteristics of non-radioactive wastewater, the data available at the present phase is not specific enough, and that is why we will use data by analogy. The expected characteristics of wastewater and its impact on the environment can be estimated, to a certain degree, based on data on the long-term operation of the Kozloduy NPP and of other nuclear power plants already in operation or in the process of construction, which utilise the same types of reactors.

The contamination rates of wastewater resulting from the NNU will be considered by analogy with the contamination levels of the existing power units of the Kozloduy NPP.

The characteristics of the wastewater from the NNU discharged into the Danube River must comply with the pollution requirements laid down for the Danube River – **Table 4.2-4**.

TABLE 4.2-4: STATUTORY REQUIREMENTS ON THE QUALITY OF WATER DISCHARGED INTO THE DANUBE RIVER

Indicator	Measure	Individual emission limits
Active reaction pH	-	6.0-9.0
Total beta activity	mBq/dm^3	500
Undissolved substances	mg/dm^3	50
BOD_5	mg/dm^3	25
COD (bichromatic)	mg/dm^3	100
Total phosphorus (as PO_4)	mg/dm^3	3
Iron (total)	mg/dm^3	5
Chloride ions	mg/dm^3	400
Petroleum products	mg/dm^3	5
Total nitrogen	mg/dm^3	25
Zinc	mg/dm^3	10
Boron	mg/dm^3	1
Cobalt	mg/dm^3	0.5
Detergents	mg/dm^3	3
Manganese (total)	mg/dm^3	0.8
Nickel	mg/dm^3	0,5
Sulphate ions	mg/dm^3	400

TABLE 4.2-5: EXPECTED CONTAMINATION LEVELS AND CONTAMINATION LOADS OF THE NNU WASTEWATER DISCHARGED INTO THE DANUBE RIVER VIA HC-1

Indicator	Individual emission limits	Contaminant quantities	Contamination loads, kg/d
Active reaction pH	6.0-9.0	8	
Total beta activity	500 mBq/dm³	80 mBq/dm³	< 500 mBq/dm³
Undissolved substances	50 mg/dm³	14.2 mg/dm³	73 375
BOD_5	25 mg/dm³	2.6 mg/dm³	13 435
COD (bichromatic)	100 mg/dm³	9.1 mg/dm³	47 022
Iron (total)	5 mg/dm³	0.05 mg/dm³	258
Residual chlorine	0.1 mg/dm³	0.01 mg/dm³	52
Petroleum products	5 mg/dm³	<0.05 mg/dm³	<258
Total nitrogen	25 mg/dm³	2.1 mg/dm³	10 851
Zinc	10 mg/dm³	0.002 mg/dm³	10
Boron	1 mg/dm³	1 mg/dm³	5 167
Cobalt	0.5 mg/dm³	0. 001 mg/dm³	5
		Q av. day	5 185 000 m³/d

Notes:

1. **Table 4.2-5**: presents the expected contamination levels and contamination loads of the NNU wastewater discharged into the Danube River via HC1.
2. The contamination levels presented above have been derived from the data from the own monitoring programme of the Kozloduy NPP – water discharged into Hot Channel 1 (accepted as analogous data for the NNU water with AES-92 and AES-2006, which in the new IP would be discharged into HC-1).
3. The wastewater quantity of 60 m³/s was taken from data provided by the Client[24]

No exceeded levels above the Individual Emission Limits are expected for the water from the Hot Channel, for which there is a permit issued by the Water Basin Management Directorate for the Danube Region **Permit No. 13120037 / 22.11.2010**.

Wastewater from the NNU is not expected to have any heavy metal content above the levels specified in the Individual Emission Limits.

The data provided by the Client[25] also presents the expected non-radioactive wastewater from the advanced reactor type AP-1000. It is equipped with systems ensuring guaranteed quantities and emissions in the separate wastewater flows.

[24] A letter with outgoing No. 236/11.03.2013 by the Client.

[25] Letter No.416/13.05.2013 with PPP No.31/13.05.2013

TABLE 4.2-6: EXPECTED OPERATIONAL LIQUID CONVENTIONAL WASTE FROM THE OPERATION OF THE SYSTEMS OF THE AP-1000 REACTOR

System	Waste Description	Physical/chemical description	Expected quantities		
			Normal volume, m^3/h	Maximum Volume, m^3/h	Average Annual, m^3/y
Circulation water system	Cooling water of the circulation water system	Contactless (flow-through) cooling	126275	136275	1.19E+09
Technical water system	Cooling water of the technical water system		2385	4770	2.09E+07
Steam generator blowdown system	Steam generator blowdown	Coolant in the secondary circuit	4	42	37000
Steam generator blowdown system	Bypass flow activating the condensate demineralising installation	BOU water with characteristics differing from the design ones	26	82	329000
System for wastewater treatment and chemically demineralised water	Reverse osmosis and electrode ionization waste		13	41	164400
Misc.	Wastewater from the secondary circuit	BOU water with insignificant concentration of solids	18	74	257000
Circulation water system	Filter backwashing		2	413	18900
Technical water system	Filter backwashing		1	681	8360
Steam generator blowdown system	Drainage from firefighting tests		0.1	170	756
CPS	Washing of condensate treatment filters		0.01	466	103
Wastewater system	Rinsing and backwashing of the condensate demineralisation installation		0.01	466	103
Main condensate system	Drainage from the water chamber of the condenser		0	250	2,8

TABLE 4.2-7: EXPECTED CONTAMINATION LEVELS AND CONTAMINATION LOADS OF THE NNU, WASTEWATER DISCHARGED INTO HOT CHANNEL-1

Indicator	Individual emission limits	Contaminant quantities	Contamination loads, kg/d
Active reaction pH	6.0-9.0	8	
Total beta activity	500 mBq/dm³	80 mBq/dm³	< 500 mBq/dm³
Undissolved substances	50 mg/dm³	14.2 mg/dm³	49 075

Indicator	Individual emission limits	Contaminant quantities	Contamination loads, kg/d
BOD_5	25 mg/dm³	2.6 mg/dm³	8 986
COD (bichromatic)	100 mg/dm³	9.1 mg/dm³	31 450
Iron (total)	5 mg/dm³	0.05 mg/dm³	173
Residual chlorine	0.1 mg/dm³	0.01 mg/dm³	35
Petroleum products	5 mg/dm³	<0.05 mg/dm³	<172
Total nitrogen	25 mg/dm³	2.1 mg/dm³	7 258
Zinc	10 mg/dm³	0.002 mg/dm³	7
Boron	1 mg/dm³	1 mg/dm³	3 456
Cobalt	0.5 mg/dm³	0. 001 mg/dm³	3
		Q av. day	3 456 000 m³/d

Notes:

1. The quantities of wastewater have been derived from the expected water volumes resulting from the operation of the AP-1000 reactor systems shown in the investment proposal.
2. The contamination levels presented above have been derived from the data from the own monitoring programme of the Kozloduy NPP – water discharged into Hot Channel 1 (accepted as analogous data for the NNU water with an AP-1000 reactor).

The operation under normal conditions of a pressurized water nuclear reactor is ensured by means of different systems related to water preparation:

System for wastewater treatment and chemically demineralised water

The system for chemical water treatment and chemically demineralised water is supplied with water by a raw water system and feeds water to the chemically demineralised water system. These systems enable the purification of the raw water and its softening for the needs of the cooling system.

System for the transmission and storage of chemically demineralised water

This system manages a tank for chemically demineralised water to be fed to a tank for the storage of condensate and its distribution around the power plant. Apart from feeding water for the supply/supplementation of the systems requiring pure water, the chemically demineralised water is used for the flushing of spent radioactive resins from the ion-exchange vessels in the system for volume compensation and boron control, the system for cooling of the pool where the bundles are stored (SFP) and the system for liquid radioactive waste to the system for solid radioactive waste.

For instance, for the wastewater from the CWT facility there are neutralisation pits where this water will be treated. We can assume that post-neutralisation water is provisionally pure – their average concentrations will be below the established detectable value.

As already mentioned above, reference data by analogy is used to determine the expected contamination loads. It is recommended to clarify in the next design phase all wastewater quantities by flows and their contamination level.

Regarding the quantities of discharged wastewater, they can be compared with the water volumes flowing into the receiving water body – the Danube River (average and minimum water quantity). The data on the quantities of the Danube River have been derived based on the data submitted by the Executive Agency for Exploration and Maintenance of the Danube River – Ruse. The input water quantities refer to the town of Oryahovo. They are used due to the absence of such at the town of Kozloduy.

- ✓ Average water quantity in the Danube River – Qav. year. = 4251 m^3/s.
- ✓ Minimum water quantity in the Danube River – Qav. year. = 1 665 m^3/s.
- ✓ The water quantity released from the NNU (for AES-92) is 216 000 m^3/h.
- ✓ The share of the water volumes released from the IP into the Danube River is the following:
  - for an average water quantity – 1.4%;
  - for a minimum water quantity – 3.6%.

The expected released water quantity from the NNU will not affect the debit of the river even under minimum water quantities.

Based on the information submitted, the following major **characteristics** of conventional wastewater might be expected:

- ✓ a relatively constant wastewater debit in the absence of rainwater;
- ✓ low organic contamination of wastewater, which is expected to comply with regulatory requirements and be relatively steady during the different hours of the day in view of the continuous operation mode of the NNU. In isolated cases it is possible for values above the regulatory standards to occur, but the average 24-hour values will be below the standards;
- ✓ heavy metal content above the Individual Emission Limits is not expected for the recipient water body, because the technological processes are not expected to yield water containing heavy metals;
- ✓ regarding the functioning of oil yards, in the event of leakage from tanks, etc. it is possible to get considerably higher values of petroleum products than the statutory requirements for the recipient water body, but the proper operation of the treatment facilities will ensure that the released contamination will meet the regulatory requirements.

4.2.1.2.1.7 Radioactively contaminated industrial wastewater

The radioactively contaminated wastewater generated by the NNU will be similar to those released from the currently existing nuclear units.

During the operation of the nuclear power units, production radioactive wastewater will be formed from:

- ✓ Leaks in the primary circuit of the nuclear reactors;
- ✓ The spent fuel ponds and storage facility;
- ✓ During decontamination of equipment;
- ✓ During regeneration and flushing of the ion-exchange filters;
- ✓ By the laundries for special clothing and the sanitary loops;
- ✓ At the radio-chemical laboratories, etc.

These waters will be processed (treated) consecutively in installations and filter facilities (special water purification systems) in the Special operation building of the new power unit. The purified water, called “unbalanced”, will be collected in intermediate tanks (reservoirs) and after radioactive control will be disposed in the HC-1, provided they meet the standards. Otherwise, they will be returned for further treatment.

The design function of the special water purification systems is:

- to purify pit water from the Controlled Zone (CZ), given that sources of such water are the fugitive leaks from the primary circuit, the decontamination of facilities and systems, the flushing and regeneration of filters, as well as of the system itself – if the treated waters do not meet with the standards for the water chemistry of the NPP or for the treated water discharges, etc.;
- treatment of the radioactive water from the special laundries and the hot showers.

The radioactive sludge will be disposed of into special tanks for evaporated concentrate. It is subject to treatment (cementing) at the "RAW – Kozloduy" Specialised Division, a subsidiary of the "Radioactive Waste" State Enterprise.

The systems for the management of liquid waste include the following:

- Steam generator blowdown system
- Radioactive waste drainage system
- Liquid RAW system

The systems for the collection and processing of liquid waste are closely linked to the System for volume compensation and boron control.

The steam generator blowdown system controls and maintains the water chemistry regime (WCR) in the secondary circuit of the steam generators. The blowdown is normally recycled in the condenser via an electronic ion-exchange system, but in the event of high radiation the blowdown is directed to the liquid RAW system. This allows for great simplification of the steam generator blowdown system, without any increase of the quantity of equipment in the liquid RAW system.

The liquid RAW system uses ion-exchange vessels for the processing and separation of all waste from the primary circuit.

The analysis on liquid RAW is reviewed in detail in section 4.7.2, and the estimate on the expected impact made through evaluation of the statutory collective effective doses for the population from these releases is presented in section 4.11.

The input data will represent the radionuclide composition and the activity of the releases into the treated water.

The liquid radioactive releases into the Danube River are spread due to the basic water movement and the precipitation processes. The main exposure pathways with regard to people are the following: external exposure from contact with the water environment and the accumulated precipitations at the river bottom, consumption of foods derived from the river, using the river water for drinking purposes, consumption of foods from crops and pastures irrigated with water from the river.

To assess the radiation exposure of the population to liquid releases, we have used a modelling program, adapted to the hydrology of the area of the Kozloduy NPP, and using a conservative estimate of the exposure dose for the critical population group. The program is based on the method adopted by the European Union (EU) – CREAM (Consequences of Releases to the Environment Assessment Methodology) Radiation Protection 72 – Methodology for assessing the radiological consequences of routine releases of radionuclides to the environment.

Verified and validated software programs have been used to evaluate the individual and collective effective doses to the population from radioactive releases in the environment.

4.2.1.2.1.8 Expected impact

- ✓ No significant contamination of the recipient of the conventional household and industrial wastewater resulting from the operation of the NNU is expected.
- ✓ The statutory requirements regarding the implementation of a separate sewerage network in compliance with the modern requirements on the prevention of leaks into and contamination of groundwater and avoidance of the mixing of the flows from the radioactive and the non-radioactive zone, as well as compliance with all the requirements for proper operation of the treatment facilities, will ensure conformity with the environmental standards for the operation of the NNU.
- ✓ Wastewater discharge into the recipient water body during operation is not expected to cause any significant changes in the qualitative composition of the water in the Danube River.

- ✓ The investment proposal will envisage measures aimed at minimising the quantity and contamination level of the production wastewater.
- ✓ The implementation of the treatment facilities for household wastewater and oil-containing wastewater, and arrester tanks for rain water, which is incorporated in the investment proposal, is not expected to cause any impact on the recipient water body and the environment.
- ✓ The operation of the local treatment plants will target the emission limit values that will be prescribed in the Permit for wastewater discharge issued by the Water Basin Management Directorate for the Danube Region.
- ✓ The monitoring process currently conducted at the NPP, will be further continued after the implementation of the IP for the new nuclear unit and will be improved and expanded to effectively screen the performance of the new unit.
- ✓ The efficient control and management of the treatment processes, and the continuous monitoring on the quality of water in terms of radiation and non-radiation impact, will guarantee that the emission limit values of the water discharged into the recipient water body – the Danube River – will be met and the quality of the aquatic ecosystem will be preserved.

The strategic and well-defined goals laid down in the River Basin Management Plan concerning the Danube River Basin, focused on efficient water management aimed to prevent the degradation of the aquatic ecosystem and achieve "a good ecological status" of Danube River waters, will not be threatened by the construction of the new nuclear unit.

During operation, wastewater will have a local impact on the ecological status in the region. No irreversible negative impact on the environment is expected.

- **Impact Scope** – local.
- **Impact Type** – direct, negative, low level of impact. Negative impact could be expected in case of improper operation of the treatment facilities or as a result of accidental releases.
- **Impact Characteristics** – continuous, long-term, cumulative, and reversible.

4.2.1.2.2 SITE 2

This site is situated on the first unflooded terrace of the Danube River.

The site has a sufficient capacity to accommodate the deployment of a NNU with AP-1000, AES-92 or AES-2006 reactors, as well as all the necessary buildings, facilities and infrastructure necessary for their operation.

4.2.1.2.2.1 Water supply

4.2.1.2.2.1.1 Drinking and household water supply

The water needed for drinking and household purposes will be provided from the existing water-supply network of the NPP by means of a branch, which will ensure the necessary water quantity.

The water needed for the different types of reactors is as follows:

- For the AES-92 reactor – Qmax.h.= 6.90 l/s, Qav.d= 165 m^3/d
- For the AP-1000 reactor – Qmax.h.= 6.30 l/s, Qav.d= 150.6 m^3/d
- For the AES-2006 reactor – Qmax.h.= 7.50 l/s, Qav.d= 180 m^3/d

The needs for drinking and household water during the operation period will be covered by the branch of the existing water-supply network of the Kozloduy NPP, constructed in order to satisfy the needs for drinking and household water of the workers during the construction period (Ø125mm).

4.2.1.2.2.1.2 Provisionally pure water (non-drinking) for bathing, washing, toilets, etc.

The provisionally clean water for washing will be taken from the "Valyata" Pump Station, for which there is water abstraction permit, issued by the Water Basin Management Directorate for the Danube Region. The maximum water consumption rate for about 1 hour (after the shift) is about 20 l/s.

This water is provided via a branch from the water main of the NPP, which have been constructed using Ø250 mm steel pipes.

4.2.1.2.2.1.3 Technical water (non-drinking) for fire control purposes

The system will be like the one for the existing site – in 2 circuits.

An automatic fire extinguishing ring. The technical water supply system for fire extinguishing purposes, which has an interconnection with the automatic fire alarm system, will be supplied with water from CC-1 via a connection at FFPS-2.

Household firefighting purposes will be covered by a household firefighting pipeline – external and internal. It will also be supplied via FFPS-2, through the use of pumps at CPS1.

4.2.1.2.2.2 Technical water supply

Technical water supply provides cooling water (circulation water – for the condensers of the turbines; and technical water – for Chemical Water Treatment and for other purposes). It is realised via 3 Bank Pump Stations from the Danube River, as well as 6 shaft pump stations situated in the terrace of the Danube River – for emergency water supply.

The water intake from the Danube River and the bank pumping stations is located at km 687 from the Danube River mouth, after the island at the town of Kozloduy. The capacity of the cold channel is 180 m^3/s, with demonstrated maximum capacity of 200 m^3/s[26].

Water from the Danube River is supplied to the power plant via the constructed hydro-technical facilities, which are crucial for the normal operation of the power plant. The cold channel connects the outflow tanks of the BPS with CPS-1 (Circulation Pump Station) with a length of 7023 m. The CPSs (Circulation Pump Stations) are located in front of the turbine halls of the respective power units.

The used water from the power units is returned to the Danube River by means of the Hot (outlet) Channel HC-1. The Hot Channel (HC-1) starts at the outlet shaft of the low-pressure channels and ends next to the overflow drain of the bypass channel for discharging the of hot water into the Danube River. The capacity of the hot channel is 180 m^3/s, with demonstrated maximum capacity of 200 m^3/s, which depends on the elevation level of the overflow drain after the low-pressure channels and the water level of the Danube River. The "hot" channel passes parallel to the "cold" channel (CC-1) along the greater part of their route. The two channels have a common dike and form a double channel.

For the provision of technical water, considering the fact that the first four power units of the existing power plant have been decommissioned, there is some available capacity up to 80 m^3/s, so that the cooling water for the turbine condensers and the other systems of the IP will be partially supplied from the water freed up after their decommissioning, where the necessary quantity is considerably smaller than the available one and is fully guaranteed. The removal of fresh water from the Danube River for the new nuclear unit will **not lead** to any disturbance to the permitted quality of raw water envisaged in the water abstraction permit, issued by the Water Basin Management Directorate for the Danube Region, which is up to 5 000 mil.m^3/y, including up to 4997 mil.m^3/y for cooling purposes and up to 2.68 mil.m^3/y for the production of demineralised water.

The different types of reactors need different quantities of cooling water, and specifically:

- For AES-92
  60m^3/s=216 000m^3/h=5 184 000m^3/day=1 892 160 000m^3/y[27]
- For AP-1000
  40m^3/s=144 000m^3/h=3 456 000m^3/day=1 261 440 000m^3/y[28]
- For AES-2006
  60m^3/s=216 000m^3/h=5 184 000m^3/day=1 892 160 000m^3/y[29]

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[26] Scientific Centre "Energoproekt"-1991 – Existing technical water supply systems.

[27] A letter with outgoing No. 236/11.3.2013

[28] Letter No.416/13.05.2013 with PPP No.31/13.05.2013 by the Client.

[29] A letter with outgoing No. 236/11.03.2013 by the Client.

The reports from the Own Non-radiation Monitoring (ONM) of the Kozloduy NPP show that for instance after 2007 the utilised annual water quantity of fresh raw water from the Danube river varies at about 2 600 000 000m^3/y, which is $Q_{av.d.}$~7mil.m^3/day~82m^3/s. If we consider the conservative Q=60m^3/s for the reactor and 4800m^3/d for technological purposes, as envisaged in the IP, then the annual volume of water drawn from the source for the purposes of the NNU is expected to be approximately Q=1 892 160 000m^3/y. The total expected water quantity to be drawn from the river would be approximately Q=4 492 160 000m^3/y together with the operating units 5 and 6. This quantity of water is close to the one drawn from the water body during the operation of units 1÷6 by 2002.

The hydrotechnical facilities constructed at the Kozloduy NPP site to bring cold water from the Danube River and lead the spent cooling water back into the river have sufficient capacity to guarantee the joint operation of the NNU and the currently existing active power units 5 and 6. The treated cooling water from the NNU is expected to have a temperature up to T≤14.5°C.

Here the connection of the technical water supply facilities for the NNU will not be different in principle from that of Site 1, the difference lying in the building of an inverted siphon for the cold water coming from the CC-1 or the repeated use of the CPS-1 and a bypass line for the hot water coming from the HC-1. It will also be possible to implement the connection while the double channel is in operation, by limiting the water amount in the channels during cut-in. The distance to CC-1 is 75 m. The possible connection with CC-1 via CPS-1 extends the length of the supply pipelines. The specific technical solution will be chosen at the next design phase when the site for the NNU is selected.

4.2.1.2.2.3 Sewerage network

The sewage system of the site of the new IP will be constructed as separate sub-systems for: household wastewater from the "controlled zone" and the "pure zone"; industrial wastewater; and rain wastewater. The sewerage system will be constructed using materials that ensure high water tightness and prevent the infiltration of contaminants into groundwater and the subsoil.

The detailed design of the network, including exact sizes, diameters, flow rate capacity, placement of the splits for each building, secondary branches and main sewerage branches, will be the subject of subsequent design stages. The network will have to ensure the complete removal of the respective wastewater to the recipient water body.

The wastewater from the NNU site will be formed from the following sub-sites: energy building, special building, sanitary and amenities building, chemical water treatment, mechanical repairs workshop, oil facility, diesel generator stations, administrative buildings and other necessary supporting units.

4.2.1.2.2.3.1 Household wastewater

The household wastewater will be formed by the everyday activities of the personnel, the sanitary facilities and the laundry equipment of the “pure zone” and the "controlled zone".

The quantity of household wastewater for the different types of reactors is presented in **Table 4.2-2** for Site 1.

Table 4.2-8 presents the expected contamination load caused by the personnel of the NNU in terms of household wastewater for the different reactor types, based on the estimates on the personnel necessary for the operation of the facility.

TABLE 4.2-8: EXPECTED CONTAMINATION LOAD, FORMED BY THE PERSONNEL FOR THE NNU FOR THE DIFFERENT REACTOR TYPES:

Indicator	Measure	Quantity		
		AES-92	AP-1000	AES-2006
BOD_5	kg/d	11	10	12
COD	kg/d	22	20	24
HB/SS	kg/d	13	12	14,4
Total nitrogen/N	kg/d	1.9	1.7	2.1
Total phosphorus/P	kg/d	0.3	0.3	0.34

Bringing household wastewater to the treatment facilities will be carried out via two sewage collectors, depending on the location of the subsites and on the way they are formed – from the "pure zone" and from the "controlled zone".

At this site the treatment of the household wastewater will be identical to the solutions outlined for **Site 1.** Wastewater will be treated in the Treatment Facility (TF), consisting of two treatment plants – one for the water from the "pure zone" and one for that from the "controlled zone".

The situational plans on the deployment of the different reactors envisage the position of the treatment facility. Its final positioning will be reflected in the next design phase, depending on the selected site and type of reactor.

4.2.1.2.2.3.2 Production wastewater

Industrial wastewater is formed as acidic and alkaline wastewater in the production of demineralised and deeply demineralised water from the Chemical Water Treatment and water contaminated with petroleum products and oils.

The treatment of raw water will be done depending on the specific technology that is selected.

The maximum quantity of wastewater (acidic and alkaline) varies for the different types of reactors. It represents the periodic consumption and depends on the processing technology and on the quality of the raw water. For AES-92 it is about 125 m^3/h, for AP-1000 – about $100m^3/h$, and for AES-2006 – about $80m^3/h$.

The available information regarding the treatment facilities and the methods of treatment for this water has been examined in detail for **Site 1.**

For the production wastewater contaminated with petroleum products, the IP envisages the construction of local treatment facilities.

The specific design solutions for the treatment facilities will be developed in the next design phase, depending on the adopted decisions on the construction of the NNU.

The discharge of all industrial wastewater will be carried out by means of a new channel directly to the Danube River or via a discharge into Hot Channel 1.

Like for Site 1, the overall solution for the sewerage system for the production wastewater will have to be developed in the next design phase, in accordance with the conditions laid down by the competent authority regarding their discharge, and the situational plan for the specific reactor and its supporting buildings and facilities.

4.2.1.2.2.3.3 Rain water

A separate sewage system, like the one for Site 1, will be built for the disposal of rain water falling on the site. Rain water will pass through buffer arrester tanks, two-sectional, amply dimensioned to absorb the first contaminated rain water from the site and allow for their precipitation.

Subsequently, and following a mandatory radiation control, the water from the arrester tanks will be discharged into the Danube River in carefully planned doses.

4.2.1.2.2.3.4 Cooling water from the technical water system

The cooling water taken from the Danube River is sent back using HC-1. The conservative estimate for the expected quantity of 60m^3/s for the cooling of one reactor is sent back to the Danube River as treated cooling water, amounting to approximately Q=1 892 160 000m^3/y. The estimated temperature above the raw water temperature will be up to T≤14.5°C.

For this site the discharge into the Hot Channel (HC-1) is not complicated, since the Hot Channel is actually the northern border of Site 2.

Due to the fact that Hot Channel (HC-2) is used only for units 5 and 6, the IP does not review the use of this channel for the new unit.

4.2.1.2.2.4 Treatment facilities for non-radioactive wastewater

4.2.1.2.2.4.1 Treatment facilities for household wastewater

Two separate wastewater treatment plants have been planned for the household wastewater from the “pure zone” and the “controlled zone”. For the household wastewater from the “pure zone”, the treatment technological scheme includes facilities for mechanical and biological treatment.

The treatment facilities for this site will be like the ones for **Site 1.**

This kind of treatment is expected to bring the parameters of the treated wastewater in compliance with the regulatory requirements for the discharging of wastewater into the Danube River, which will be laid down in the discharge permit.

For the treatment of the household wastewater from the "controlled zone", after the treatment plant the water undergoes dosimetric radiation control before being discharged into the recipient basin. In case wastewater does not meet the regulatory requirements during the radiation control, it will be returned for second treatment.

In the treatment facility, which unifies the household wastewater treatment plants for the two zones, the untreated and treated wastewater is subjected to the following analyses each day: pH, temperature, permanganate oxidisability, chemical oxygen demand (COD) and quantity of dissolved oxygen in the bio-pool.

It is possible to mix the two types of treated wastewater before the discharge into the Danube River, thus performing only one discharge with continuous monitoring and radiologic control.

In the next design phase it will be necessary to present current data on the quantities of household wastewater from the "pure zone" and the "controlled zone", as well as the quantities of the formed sludge from the treatment facilities.

The final decision regarding the treatment of household wastewater from the two zones will be taken in the next design phase.

4.2.1.2.2.4.2 Treatment facilities for wastewater from Chemical Water Treatment

The treatment of wastewater from Chemical Water Treatment facility is envisaged in a two-chamber neutralising pool.

In a subsequent design phase it will be necessary to specify the quantity of acidic and alkaline water from the CWT facility, as well as everything related to the neutralisation process.

The wastewater coming out of the neutralising pool must have a pH between 6.5 and 9 in order to meet the requirements of the recipient water body. After its neutralisation, the wastewater is conveyed to the discharge point.

4.2.1.2.2.4.3 Treatment facilities for wastewater contaminated with oils and petroleum products

Local treatment facilities for the elimination of petroleum products – mud/oil traps and grease arresters – will be constructed for the treatment of industrial wastewater from the diesel generator station, the oil plant and the transformer platforms. It is imperative that parameters on the treatment facilities for petroleum-content wastewater are presented at the next design phase.

The technological solution and design configuration of these facilities should utilize more advanced technologies and should meet the regulatory provisions on the indicators required for discharge into the recipient water body.

4.2.1.2.2.5 Major flows of non-radioactive wastewater

The wastewater from **Site 2** will form the same major flows as in the case of **Site 1.**

4.2.1.2.2.6 Wastewater characteristics

For the present there are no sufficient specific data to fully outline the wastewater characteristics, therefore, as in the case of **Site 1,** data by analogy will be used for this purpose. The expected characteristics of wastewater and its impact on the environment can be estimated, to a certain degree, based on data on the long-term operation of the Kozloduy NPP and of other nuclear power plants already in operation, which utilise the same types of reactors. It is necessary to present exact data on the quantities and contamination load of non-radioactive wastewater at the next design phase.

The characteristics of the wastewater from the NNU must comply with the quality requirements on the physical and chemical elements, and the quality standards for the chemical elements and specific pollutants applicable to the Danube River.

The expected contamination levels and contamination loads for the cooling and industrial wastewater from the NNU, discharged into the Danube River, are presented in **Table 4.2-5** for **Site 1.**

No exceeded levels above the Individual Emission Limits are expected for the water from the Hot Channel, for which there is a permit issued by the Water Basin Management Directorate for the Danube Region – **Permit No. 13120037 / 22.11.2010**.

The wastewater from the NNU is not expected to have any heavy metal content above the Individual Emission Limits.

The contamination levels and contamination loads for the cooling and industrial wastewater from the NNU (with a AP-1000 power unit), discharged into the Danube River through Hot Channel-1, are presented in **Table 4.2-7** for **Site 1.**

No exceeded levels above the Individual Emission Limits are expected for the wastewater from the Hot Channel, for which there is a permit issued by the Water Basin Management Directorate for the Danube Region – **Permit No. 13120037 / 22.11.2010**.

Wastewater from the NNU is not expected to have any values above the levels of heavy metals specified in the Individual Emission Limits.

4.2.1.2.2.7 Radioactively contaminated industrial wastewater

The radioactively contaminated wastewater generated by the NNU will be similar to those released from the currently existing nuclear units. These estimates are presented in the section on **Site 1.**

As already mentioned above, data by analogy is used to determine the expected contamination loads. It is recommended to present specific estimates on all wastewater quantities, by flows and contamination level, in the next design phase.

Based on the information submitted, the expected wastewater characteristics will be identical to those for Site 1.

4.2.1.2.2.8 Expected impact

- ✓ No significant contamination of the recipient of the conventional household and industrial wastewater resulting from the operation of the NNU is expected.
- ✓ The statutory requirements regarding the implementation of a separate sewerage network in compliance with the modern requirements on the prevention of leaks into and contamination of groundwater and avoidance of the mixing of the flows from the radioactive and the non-radioactive zone, as well as compliance with all the requirements for proper operation of the treatment facilities, will ensure conformity with the environmental standards for the operation of the NNU.
- ✓ Wastewater discharge into the recipient water body during operation is not expected to cause any significant changes in the qualitative composition of the water in the Danube River.
- ✓ The investment proposal will envisage measures aimed at minimising the quantity and contamination level of the production wastewater.
- ✓ The implementation of the treatment facilities for household wastewater and oil-containing wastewater, and arrester tanks for rain water, which is incorporated in the investment proposal, is not expected to cause any impact on the recipient water body and the environment.
- ✓ The operation of the local treatment plants will target the emission limit values that will be prescribed in the Permit for wastewater discharge issued by the Water Basin Management Directorate for the Danube Region.
- ✓ The monitoring process currently conducted at the NPP, will be further continued after the implementation of the IP for the new nuclear unit and will be improved and expanded to effectively screen the performance of the new unit.
- ✓ The efficient control and management of the treatment processes, and the continuous monitoring on the quality of water in terms of radiation and non-radiation impact, will guarantee that the emission limit values of the water discharged into the recipient water body – the Danube River – will be met and the quality of the aquatic ecosystem will be preserved.

The strategic and well-defined goals laid down in the River Basin Management Plan concerning the Danube River Basin, focused on efficient water management aimed to prevent the degradation of the aquatic ecosystem and achieve “a good ecological status” of Danube River waters, will not be threatened by the construction of the new nuclear unit.

During operation, wastewater will have a local impact on the ecological status in the region. No irreversible negative impact on the environment is expected.

- **Impact Scope**– local.
- **Impact Type** – direct, negative, low level of impact. Negative impact could be expected in case of improper operation of the treatment facilities or as a result of accidental releases.
- **Impact Characteristics** – continuous, long-term, with minimal cumulative impact, reversible.

4.2.1.2.3 SITE 3

This alternative site, similar to Site 1 and Site 2, has enough capacity to accommodate an NNU with reactors of the types AP-1000, AES-92 or AES-2006.

4.2.1.2.3.1 Water supply

4.2.1.2.3.1.1 Household water supply

The needs for drinking and household water during the operation period will be covered by the branch of the existing water-supply network of the Kozloduy NPP, constructed in order to satisfy the needs for drinking and household water of the workers during the construction period (Ø125mm). The necessary quantity of drinking water is the same as that for **Site 1.**

4.2.1.2.3.1.2 Provisionally pure water (non-drinking) for bathing, washing, toilets, etc.

The provisionally clean water for washing will be taken from the "Valyata" Pump Station, for which there is water abstraction permit, issued by the Water Basin Management Directorate for the Danube Region. The maximum water consumption rate for about 1 hour (after the shift) is about 20 l/s.

This water is provided via a branch from the water main of the NPP, which have been constructed using Ø250 mm steel pipes.

4.2.1.2.3.1.3 Technical water (non-drinking) for fire control purposes

The system will be developed in the same manner as for Sites 1 and 2.

4.2.1.2.3.2 Technical water supply

Technical water supply provides cooling water (circulation water – for the condensers of the turbines; and technical water – for Chemical Water Treatment and for other purposes). It is realised via 3 Bank Pump Stations from the Danube River, as well as 6 shaft pump stations situated in the terrace of the Danube River – for emergency water supply.

The type of water intake, the water inlet scheme form the Danube River and the return of spent water back to the river will be identical to the solutions suggested for **Sites 1 and 2.**

For the provision of technical water, considering the fact that the first four power units of the existing power plant have been decommissioned, there is some available capacity up to 80 m^3/s, so that the cooling water for the turbine condensers and the other systems of the IP will be partially supplied from the water freed up after their decommissioning, where the necessary quantity is considerably smaller than the available one and is fully guaranteed.

The different types of reactors need different quantities of cooling water, and specifically:

- For AES-92 $60m^3/s=216\ 000m^3/h=5\ 184\ 000m^3/day=1\ 892\ 160\ 000m^3/y$[30]
- For AP-1000 $40m^3/s=144\ 000m^3/h=3\ 456\ 000m^3/day=1\ 261\ 440\ 000m^3/y$[31]
- For AES-2006 $60m^3/s=216\ 000m^3/h=5\ 184\ 000m^3/day=1\ 892\ 160\ 000m^3/y$[32].

The reports from the Own Non-radiation Monitoring (ONM) of the Kozloduy NPP show that for instance after 2007 the utilised annual water quantity of fresh raw water from the Danube river varies at about 2 600 000 000m^3/y, which is $Q_{av.d.}$~7mil.m^3/day~82m^3/s. If we consider the conservative Q=60m^3/s for the reactor and 4800m^3/d for technological purposes, as envisaged in the IP, then the annual volume of water drawn from the source for the purposes of the NNU is expected to be approximately Q=1 892 160 000m^3/y. The total expected water quantity to be drawn from the river would be approximately Q=4 492 160 000m^3/y together with the operating units 5 and 6. This quantity of water is close to the one drawn from the water body during the operation of units 1÷6 by 2002.

The removal of fresh water from the Danube river for the new nuclear unit will not result in any disturbance to the permitted quality of raw water, envisaged in the water abstraction permit, issued by the Water Basin Management Directorate for the Danube Region, which is up to 5 000 mil.m^3/y, including up to 4997 mil.m^3/y for cooling purposes and up to 2.68 mil.m^3/y for the production of chemically demineralised water.

The connection between the existing CC-1 and this site will be the longest – 235 m. A new Circulation Pump Station will have to be constructed at the end of the cold channel, thereby extending the existing CC-1, which would not hinder the normal operation of the existing units.

This site is situated close to HC-2, which was constructed in order to transfer a water quantity of Q=110 m^3/s for the needs of units 5 and 6, and that is why the IP does not review the use of this channel.

[30] A letter with outgoing No. 236/11.03.2013 by the Client.
[31] Letter No.416/13.05.2013 with PPP No.31/13.05.2013 by the Client.
[32] A letter with outgoing No. 236/11.03.2013 by the Client.

Constructing a new channel from Site 3 to the open section of HC-1 is proposed as an option, and it is recommended to avoid any connection through its underground part.

4.2.1.2.3.3 Sewerage network

The sewage system of the site of the new IP will be constructed as separate sub-systems for: household wastewater from the "controlled zone" and the "pure zone"; industrial wastewater; and rain wastewater – in the same manner as for **Sites 1 and 2.**

4.2.1.2.3.3.1 Household wastewater

The household wastewater contamination level and contamination load for the different types of reactors is presented in **Table 4.2-8 for Site 2.**

For **Site 3** the treatment of the household wastewater will be identical to the solutions outlined for Site 1. Wastewater will be treated in a Treatment Facility, consisting of two treatment plants – one for the water from the "pure zone" and one for that from the "controlled zone". The final positioning of the treatment facilities will be reflected in the next design phase.

4.2.1.2.3.3.2 Production wastewater

Industrial wastewater is formed as acidic and alkaline wastewater in the production of demineralised water from the Chemical Water Treatment and water contaminated with petroleum products and oils.

The method and facilities for the collection and treatment of this water has been examined in detail for **Site 1.**

The discharge of the industrial wastewater will be carried out by means of a new channel directly to the Danube River or via a discharge into Hot Channel 1.

The global solution for the sewerage system will be the subject of a specific plan in the next design phase.

4.2.1.2.3.3.3 Rain water

A separate sewage system will be built for the disposal of rain water falling on the site. Subsequently, and following a mandatory radiation control, the water from the buffering arrester tanks will be discharged into the Danube River in carefully planned doses.

4.2.1.2.3.3.4 Cooling water from the technical water system

The cooling water taken from the Danube River is sent back using the Hot Channel (HC-1).

The conservative estimate for the expected quantity of 60m^3/s for the cooling of one reactor from the AES-92 and AES-2006 types is sent back to the Danube River as treated cooling water, amounting to approximately Q=1 892 160 000m^3/y. The estimated temperature above the raw water temperature will be up to T≤14.5°C.

The connection with Hot Channel 1 will require the construction of a new pipeline or channel from Site 3 to the open part of the old Hot Channel 1 (HC-1), as it is recommended to avoid any connection through the underground section of the hot channel.

4.2.1.2.3.4 Treatment facilities for non-radioactive wastewater

4.2.1.2.3.4.1 Treatment facilities for household wastewater

Two separate wastewater treatment plants have been planned for the household wastewater from the "pure zone" and the "controlled zone". For the household wastewater from the "pure zone", the treatment technological scheme includes facilities for mechanical and biological treatment.

The treatment facilities for this site will be like the ones for **Site 1.**

This kind of treatment is expected to bring the parameters of the treated wastewater in compliance with the regulatory requirements for the discharging of wastewater into the Danube River, which will be laid down in the discharge permit.

The screening and analysis carried out on a daily basis in the treatment complex are discussed in the sections on **Sites 1 and 2.**

In the next design phase it will be necessary to present current data on the quantities of household wastewater from the "pure zone" and the "controlled zone", as well as the quantities of the formed sludge from the treatment facilities.

4.2.1.2.3.4.2 Treatment facilities for wastewater from Chemical Water Treatment

The treatment of wastewater from Chemical Water Treatment facility is envisaged in a two-chamber neutralising pool.

After its neutralisation, the wastewater will be conveyed to the point of discharge into the Danube River.

In the next design phase it will be necessary to specify the quantity of acidic and alkaline water from the CWT facility, the time necessary for its neutralisation, the volumes of the neutralising pools, their positioning and everything related to this process.

4.2.1.2.3.4.3 Treatment facilities for wastewater contaminated with oils and petroleum products

Local treatment facilities for the elimination of petroleum products – mud/oil traps and grease arresters – will be built for the treatment of industrial wastewater from the diesel generator station, the oil plant and the transformer platforms. The facilities should utilize more advanced technologies and should meet the statutory requirements. It is imperative that exact parameters on the treatment facilities for petroleum-content wastewater are presented at the next design phase.

4.2.1.2.3.5 Major flows of non-radioactive wastewater

The wastewater from Site 3 will form the same major flows as in the case of **Sites 1 and 2.**

4.2.1.2.3.6 Wastewater characteristics

For the present there are no sufficient specific data to fully outline the wastewater characteristics, therefore, as in the case of **Site 1,** data by analogy will be used for this purpose. It is necessary to present exact data on the quantities and contamination load of non-radioactive wastewater at the next design phase.

The characteristics of wastewater resulting from the NNU and discharged into the Danube River must comply with the contamination requirements laid down for the Danube River.

The expected contamination levels presented here show that the individual emission limits for the Danube River – III-rd class of recipient water body – will not be exceeded.

The expected contamination levels and contamination loads for the cooling and industrial wastewater from the NNU, discharged into the Danube River, are presented in **Table 4.2-5** for **Site 1.**

No exceeded levels above the Individual Emission Limits are expected for the water from the Hot Channel, for which there is a permit issued by the Water Basin Management Directorate for the Danube Region – **Permit No. 13120037 / 22.11.2010.**

The wastewater from the NNU is not expected to have any heavy metal content above the Individual Emission Limits.

The expected contamination levels and contamination loads for the cooling and industrial wastewater resulting from the operation of the NNU (with an AP-1000 reactor), discharged in the Hot Channel, are presented in **Table 4.2-7** for **Site 1.**

No exceeded levels above the Individual Emission Limits are expected for the Hot Channel, for which there is a permit issued by the Water Basin Management Directorate for the Danube Region – **Permit No. 13120037 / 22.11.2010.**

As already mentioned above, data by analogy is used to determine the expected contamination loads. It is recommended to clarify in the next design phase all wastewater quantities by flows and their contamination level.

4.2.1.2.3.7 Radioactively contaminated industrial wastewater

The radioactively contaminated wastewater generated by the NNU will be similar to those released from the currently existing nuclear units. These estimates are presented in the section on **Site 1.**

Based on the information submitted, the expected wastewater characteristics will be identical to those for Site 1.

4.2.1.2.3.8 Expected impact

Wastewater discharge into the recipient water body, the Danube River, during operation is not expected to cause any significant changes in the qualitative composition of its water.

The efficient control and management of the treatment processes, and the continuous monitoring on the quality of water will guarantee that the emission limit values of the water discharged into the recipient water body – the Danube River – will be met and the quality of the aquatic ecosystem will be preserved.

During operation no irreversible negative impact of wastewater on the environment is expected.

- **Impact Scope**– local.
- **Impact Type** – direct, negative, low level of impact. Negative impact could be expected in case of improper operation of the treatment facilities or as a result of accidental releases.
- **Impact Characteristics –** continuous, long-term, cumulative, and reversible.

4.2.1.2.4 SITE 4

The main characteristic of this site is its small size and, depending on the type of reactor, the auxiliary construction facilities may need to be deployed separately from the actual site, which would necessitate the displacement of many facilities along the main path of the power plant. Furthermore, as it is situated the closest to the existing units in operation, it will be the one that could cause the greatest interactions with the active units.

For Site 4 the actual design will be adjusted to accommodate the area offered by the Client for the construction of the new power unit.

4.2.1.2.4.1 Water supply

4.2.1.2.4.1.1 Drinking and household water supply

The needs for drinking and household water during the operation period will be covered by the branch of the existing water-supply network of the Kozloduy NPP, like for the other sites, but for this one the branch will be shorter.

The necessary quantity of drinking water is the same as that for **Site 1.**

4.2.1.2.4.1.2 2. Provisionally pure water (non-drinking) for bathing, washing, toilets, etc.

The provisionally clean water for washing will be taken from the "Valyata" Pump Station, for which there is water abstraction permit, issued by the Water Basin Management Directorate for the Danube Region. The maximum water consumption rate for about 1 hour (after the shift) is about 20 l/s.

This water will also be supplied via a branch of the water main of the NPP for provisionally clean water, which will be shorter than the ones for the remaining sites, considering the positioning of Site 4 within the existing site of the NPP.

4.2.1.2.4.1.3 Technical water (non-drinking) for fire control purposes

The system will be developed and supplied in the same manner as for the other sites.

4.2.1.2.4.2 Technical water supply

Technical water supply provides cooling water (circulation water – for the condensers of the turbines; and technical water – for Chemical Water Treatment and for other purposes).

The type of water intake, the water inlet scheme form the Danube River and the return of spent water back to the river will be identical to the solutions suggested for **Sites 1.**

For the provision of technical water, considering the fact that the first four power units of the existing power plant have been decommissioned, there is some available capacity up to 80 m^3/s, so that the cooling water for the turbine condensers and the other systems of the IP will be partially supplied from the water freed up after their decommissioning, where the necessary quantity is considerably smaller than the available one and is fully guaranteed.

The necessary quantity of cooling water for an AP-1000 reactor is 114 000 m^3/h[33].

The reports from the Own Non-radiation Monitoring (ONM) of the Kozloduy NPP show that for instance after 2007 the utilised annual water quantity of fresh raw water from the Danube river varies at about 2 600 000 000m^3/y, which is $Q_{av.d.}$~7mil.m^3/day~82m^3/s. If we consider the required water quantity for this reactor, amounting to Q=40m^3/s and 4800m^3/d for technological purposes, as envisaged in the IP, then the annual volume of water drawn from the source for the purposes of the NNU is expected to be approximately Q=1 261 440 000 m^3/y. The total expected water quantity to be drawn from the river would be approximately Q=3 861 440 000 m^3/y together with the operating units 5 and 6. This quantity of water is close to the one drawn from the water body during the operation of units 3÷6 by 2006, after the decommissioning of units 1 and 2.

For this site the connection with the technical cooling water can be implemented via a connection with the cooling water intake for units 3 and 4 in the north corner of the site. The pipes of the cold channel must pass over the underground part of the hot channel. The connection between the existing CC-1 and this site will be the longest 75 m.

4.2.1.2.4.3 Sewerage network

The sewage system for the site of the new nuclear unit will be constructed as separate sub-systems for household wastewater, industrial wastewater and rain wastewater, like for the other sites.

4.2.1.2.4.3.1 Household wastewater

The household wastewater contamination level and contamination load for the different types of reactors is presented in **Table 4.2-8** for **Site 2.**

At this site the treatment of the household wastewater will also be identical to the solutions outlined for **Site 1.** Wastewater will be treated in a Treatment Facility, consisting of two

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[33] Letter No.416/13.05.2013 with PPP No.31/13.05.2013 by the Client.

treatment plants – one for the water from the “pure zone” and one for that from the “controlled zone”.

4.2.1.2.4.3.2 Production wastewater

Industrial wastewater is formed as acidic and alkaline wastewater in the production of demineralised water from the Chemical Water Treatment and water contaminated with petroleum products and oils.

The method and facilities for the collection and treatment of this water has been examined in detail for **Site 1.**

The discharge of the industrial wastewater will be carried out by means of a new channel directly to the Danube River or via a discharge into Hot Channel 1.

4.2.1.2.4.3.3 Rain water

A separate sewage system will be built for the disposal of rain water falling on the site (like for the other alternative sites). Subsequently, and following a mandatory radiation control, the water from arrester tanks will be discharged into the Danube River in carefully planned doses.

4.2.1.2.4.3.4 Cooling water from the technical water system

The cooling water taken from the Danube River is sent back using the Hot Channel (HC-1).

Due to the fact that the new hot channel (HC-2) is used only for units 5 and 6, the IP does not review the use of this channel for the NNU.

As it is recommended to avoid any connection through the underground section of the hot channel, the discharge of the cooling water must be done in the open part of HC-1, even though the underground section of the hot channel is in the north corner of the site.

4.2.1.2.4.4 Treatment facilities for non-radioactive wastewater

4.2.1.2.4.4.1 Treatment facilities for household wastewater

Two separate wastewater treatment plants have been planned for the household wastewater from the “pure zone” and the “controlled zone”. For the household wastewater from the “pure zone”, the treatment technological scheme includes facilities for mechanical and biological treatment.

The treatment facilities for this site will be like the ones for **Site 1.**

It is expected that the qualities of the treated wastewater would meet the statutory requirements for discharge into the Danube River.

In the next design phase it will be necessary to present current data on the quantities of household wastewater from the "pure zone" and the "controlled zone", as well as the quantities of the formed sludge from the treatment facilities.

4.2.1.2.4.4.2 Treatment facilities for wastewater from Chemical Water Treatment

The treatment of wastewater from Chemical Water Treatment facility is envisaged in a neutralising pool.

After its neutralisation, the wastewater will connected via low-pressure channels to the outlet channel for discharge into the Danube River.

It is necessary to specify, in the next design phase, the quantity of acidic and alkaline water from the CWT facility.

4.2.1.2.4.4.3 Treatment facilities for wastewater contaminated with oils and petroleum products

For the petroleum-content wastewater there are local treatment facilities envisaged for the removal of petroleum products – mud/oil traps. It is imperative that exact parameters on the treatment facilities for petroleum-content wastewater are presented at the next design phase.

4.2.1.2.4.5 Major flows of non-radioactive wastewater

Wastewater on Site 4 will form the same major flows as in the case of **Site 1**.

4.2.1.2.4.6 Wastewater characteristics

For the present there are no sufficient specific data to fully outline the wastewater characteristics, therefore, as in the case of **Site 1,** data by analogy will be used for this purpose. It is necessary to present exact data on the quantities and contamination load of non-radioactive wastewater at the next design phase.

The characteristics of wastewater resulting from the NNU and discharged into the Danube River must comply with the contamination requirements laid down for the Danube River.

The expected contamination levels presented here show that the individual emission limits for the Danube River – III-rd class of recipient water body – will not be exceeded.

For Site 4 the actual design will be adjusted to accommodate the area offered by the Client for the construction of the new power unit.

The expected contamination levels and contamination loads for the cooling and industrial wastewater resulting from the operation of the NNU (with an AP-1000 reactor), discharged in the Hot Channel, are presented in **Table 4.2-7** for **Site 1.**

The quantities of wastewater have been derived from the expected water volumes resulting from the operation of the AP-1000 reactor systems shown in the investment proposal, and the contamination level is taken from the data from the own monitoring programme of the Kozloduy NPP – water discharged into Hot Channel – 1 (accepted as analogous data for the NNU water with an AP-1000 reactor).

No exceeded levels above the Individual Emission Limits are expected for the Hot Channel, for which there is a permit issued by the Water Basin Management Directorate for the Danube Region – **Permit No. 13120037 / 22.11.2010.**

As already mentioned above, data by analogy is used to determine the expected contamination loads. It is recommended to clarify in the next design phase all wastewater quantities by flows and their contamination level.

4.2.1.2.4.7 Radioactively contaminated industrial wastewater

The radioactively contaminated wastewater generated by the NNU will be similar to that released from the currently existing nuclear units. These estimates are presented in the section on **Site 1.**

Based on the information submitted, the expected wastewater characteristics will be identical to those for Site 1.

4.2.1.2.4.8 Expected impact

During operation no irreversible negative impact of wastewater on the environment is expected.

- **Impact Scope**– local.
- **Impact Type** – direct, negative, low level of impact. Negative impact could be expected in case of improper operation of the treatment facilities or as a result of accidental releases.
- **Impact Characteristics** – continuous, long-term, cumulative, and reversible.

Conclusions

Based on the analysis of the expected impact during the operation of the NNU, the impact on surface water can be outlined as follows:

- **Impact Scope**– local.
- **Impact Type** – direct, negative, low level of impact. Negative impact could be expected in case of improper operation of the treatment facilities or as a result of accidental releases.
- **Impact Characteristics** – continuous, long-term, with minimal cumulative impact, reversible.

Based on the reviewed impact of the NNU investment proposal, we can categorically state that the impact of the non-radioactive wastewater on the receiving basin – the Danube River – during the operation will be local, continuous, reversible, but negligible.

4.2.1.3 Decommissioning

The decommissioning of the NNU is an operation that does not depend on the chosen site and type of reactor, therefore here this issue will be discussed in principle as a process which is going to happen once the operational life of the power unit has expired, namely 60 years, unless a decision has been taken to continue the operation of the power unit.

The decommissioning of a nuclear reactor is a complex endeavour involving a wide spectrum of issues, ranging from ending the active operation of the facility to its complete liquidation and the restoration of the industrial site as a terrain that can be used for other purposes.

The adopted decommissioning strategy will determine the selected alternative and the stages it will go through, taking into account the environmental impact. The design which will be developed for the implementation of the different stages of the process will review, analyse and evaluate all possible impact on the water ecosystem and the available methods to minimise that impact.

For instance, the stage preceding the decommissioning includes a number of documents that need to be prepared – plans and licenses, decommissioning the reactor fuel and transferring it to the Dry Spent Fuel Storage Facility (DSFSF), maintaining the systems necessary for the next stages, and conducting preparatory activities, such as: providing the necessary infrastructure for disassembly, reduction of the volume of plant and equipment, removal of operational RAW and conventional waste, deactivation, etc.

The performance of the preparatory operations related to the decommissioning is expected to generate non-radioactive wastewater (treated household, industrial and rain water). The facilities providing the supply of drinking water and water for technological purposes, as well as the facilities providing the treatment of this type of water, will continue to operate. During this period, the personnel engaged in these operations is not expected to differ considerably from the routine personnel for regular operations. The constructed treatment facilities will be sufficient and will have the unit to process the formed wastewater flows.

The estimates indicate that during this period the need for raw water from the Danube River will decrease substantially, due to the fact that cooling water will no longer be needed. The water supply for the needs of the CWT facility, necessary for all activities related to the decontamination of machinery, facilities, etc. could continue to operate in the same way. Increased water consumption can be predicted due to the increased operation of the laundries and bathrooms, and for the cleaning of floors and corridors.

No contamination of the Danube River with household and industrial wastewater is expected. The availability of constructed and operating treatment facilities is a mandatory condition for all stages of decommissioning, all the way to the final stage of recultivation.

Wastewater generation is also expected – as liquid RAW from the preparation and monitoring of the safe storage (SS) zone, which will also be treated in the existing facilities, and then subjected to volume reduction and safe storage in the special repositories designated for the purpose.

The liquid RAW generated before the stage of disassembly and decontamination, the water from the decontamination of unit materials, as well as the liquid waste from the special laundries and from the cleaning of floors and corridors, will be treated as pit water and will be processed in the already constructed existing facilities for the treatment of pit water. The secondary condensate will be disposed into the Danube River after treatment, decontamination and mandatory radiological control.

For an NPP with reactors of the latest generation, the disassembly process will be much easier than the one for the pressurized water power reactors currently in operation, on account of the smaller quantities of waste generated and released, which will reduce the quantity of demineralised water needed for decontamination. This condition is imposed as early as the design phase in the best interest of disassembly.

It can be estimated that the contamination level of wastewater will be considerably reduced in comparison with the operational period.

- ✓ **Impact Scope** – local.
- ✓ **Impact Type** – direct, negative, low level of impact. Negative impact could be expected in case of improper operation of the treatment facilities or as a result of accidental releases.
- ✓ **Impact Characteristics** – continuous, long-term, reversible after the decommissioning.

The existing non-radiation and radiation monitoring of the Kozloduy NPP, the NNU and the RAW SE will be continued throughout the decommissioning of the NNU. The advancement of knowledge over the years will provide new methods and opportunities for improvements to the monitoring process. This monitoring process will continue even after the closure and recultivation of the site, in accordance with the designated purpose.

In the final phase of closure and recultivation of the, after the demolishment of all water intake facilities drawing raw water from the river, the natural state of the coastline, disrupted during the years of operation, will be restored through appropriate engineering, technical and recultivational solutions. The project to be implemented will review the status and decide about the need for preservation, modernisation and subsequent operation of the constructed meliorative CWT facilities.

4.2.1.4 HYDROLOGY OF THE DANUBE RIVER

To analyse the alternative solutions for the construction and operation of the new nuclear unit, from the point of view of the impact on the Danube River water, here a brief description is presented of the four sites considered for its deployment.

SITE 1

The site is situated to the northeast of units 1 and 2 of the Kozloduy NPP, between the Outdoor Switchgears and the "Valyata" area, in the vicinity of the constructed cold and hot channels (further north). The design envisages the construction of an embankment for the purpose of raising the elevation level. An advantage is the connection with CC1 and HC-1, but the terrain divides the drainage channel in two. A disadvantage is the fact that the site is situated on the flooded terrace of the Danube River, and high water levels could cause a real danger of flooding and damage.

The humus loess layer will have to be removed in advance from the arable land, and the new facilities in this case will have embankment foundations.

SITE 2

The site is situated to the east of units 1 and 2 of the Kozloduy NPP site in the direction of the village of Harlets, to the south of the constructed cold and hot channels. The existing land has an elevation level of 37-38 m, and is hilly, with a considerable slope from the south to the north, more pronounced in the southeastern part of the site. Excavations are envisaged for the construction of a new nuclear unit. The cold and hot channels for the cooling system are situated In close proximity to the site.

SITE 3

The site is situated to the north of units 5 and 6 of the Kozloduy NPP, in the vicinity of the bypass road of the existing power plant. The surface of the site is flat, with an average altitude above sea level within the range 26.00-28.00 m and a slight slope to the north. The valley and the site are protected with a dike, reaching an absolute elevation level of +30.40 m. From the north the site is limited by the Danube River, the distance to the midstream of the river being 3.7 km, and from the south – by the slope of the watershed plateau. For the purposes of the site development, the construction envisages an embankment of at least 10 m in order to raise the elevation level to the 35.00 envisaged in the design. The present status of the terrain is more of marshland than of agricultural land. A disadvantage of this site is the marshing of a part of the terrain.

SITE 4

The site is situated to the west of units 3 and 4 of the Kozloduy NPP and of the Spent Fuel Storage Facility of the NPP, to the south of the cold and hot channels. The terrain houses the existing constructed service facilities – the Equipment storage facility, the Vehicle Repair Workshop, the Assembly Facility, etc. In order to utilise the site, the main underground communications of the NPP need to be reconstructed and displaced, and the aforesaid facilities need to be displaced to free up the area. It is situated at an elevation level approximately 36 m, and the new facilities will have excavation foundations.

4.2.1.4.1 During construction

The choice of the site is of major importance for the completion of the required construction and assembly works. The main risk factor in terms of safety is the possibility for flooding of the hollowed excavation during construction in the event of a wave of very high water passing along the Danube River. The hydrological regime of the river is described in **Section 3.2.1** but here once again, for convenience, we will present some of the key data related to the assessment of the potential significant impact resulting from events such as water quantities and water levels in the river.

Water quantities

The average multi-annual outflow at the "Oryahovo" WP for the period 1981-1986 r. e Q_{av}=5 847 m^3/s with a variation factor of C_v=0.18. It should be noted that the outflow of the Danube River for the multi-annual period varies within the range 0.18-0.20, which is an indicator of uniformity. The variation of the Danube River outflow has been determined to be greatest during the low-water months (August to January). It is most stable during the high water period (February – July). The annual river flow with 95% provision amounts to about 4300 m^3/s.

The minimum water quantities at different provision levels are shown in **Table 4.2-9**.

TABLE 4.2-9: AVERAGE ANNUAL MINIMUM WATER QUANTITIES IN THE DANUBE RIVER AT DIFFERENT PROVISION LEVELS FOR THE "ORYAHOVO" WATER-MEASURING POST

Provision, P%	of the Danube River, Q m^3/s
Minimum at Cv = 0.246	
99%	1444
97%	1558
95%	1666
90%	1804
Minimum at a confidence interval of 95%	
99%	1046
97%	1249
95%	1422
90%	1613

The maximum water quantities at different provision levels are shown in **Table 4.2-10.**

TABLE 4.2-10: AVERAGE ANNUAL MAXIMUM WATER QUANTITIES IN THE DANUBE RIVER AT DIFFERENT PROVISION LEVELS FOR THE "ORYAHOVO" WATER-MEASURING POST

Provision, P%	of the Danube River, Q m3/s
Maximum at Cv = 0.18	
0.01%	19309
0.1%	17572
1%	15606
5%	13981
Maximum at a confidence interval of 95%	
0.01%	21714
0.1%	19503
1%	17229

Figure 4.2-3 shows a comparison between the registered average annual water quantities at the Lom and Oryahovo stations for the period 2002 – 2012 (based on a letter by the Client No.438 from 17.05.2013 with PPP 34 from 17.05.2013 – data by the EAEMDR).

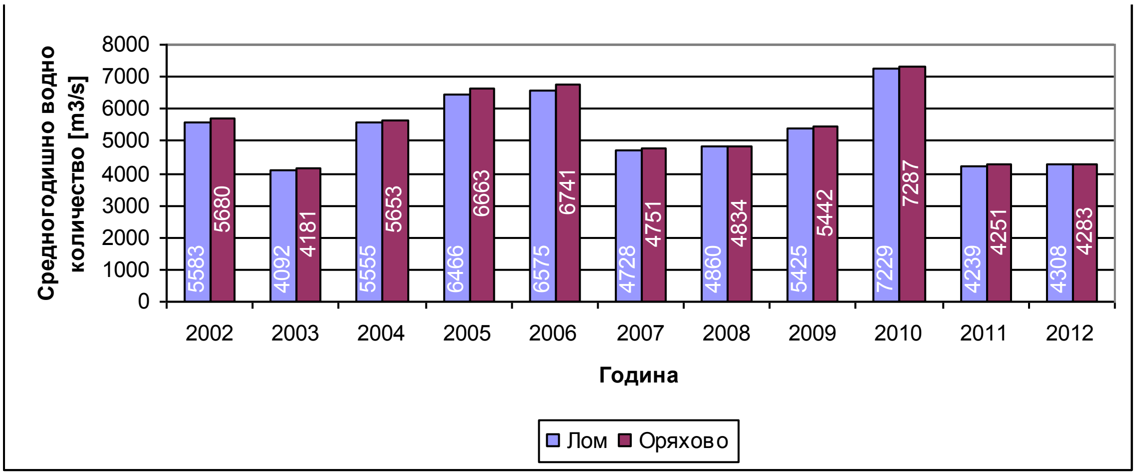


FIGURE 4.2-3: AVERAGE ANNUAL WATER QUANTITIES AT THE LOM AND ORYAHOVO WP FOR THE PERIOD 2002-2012

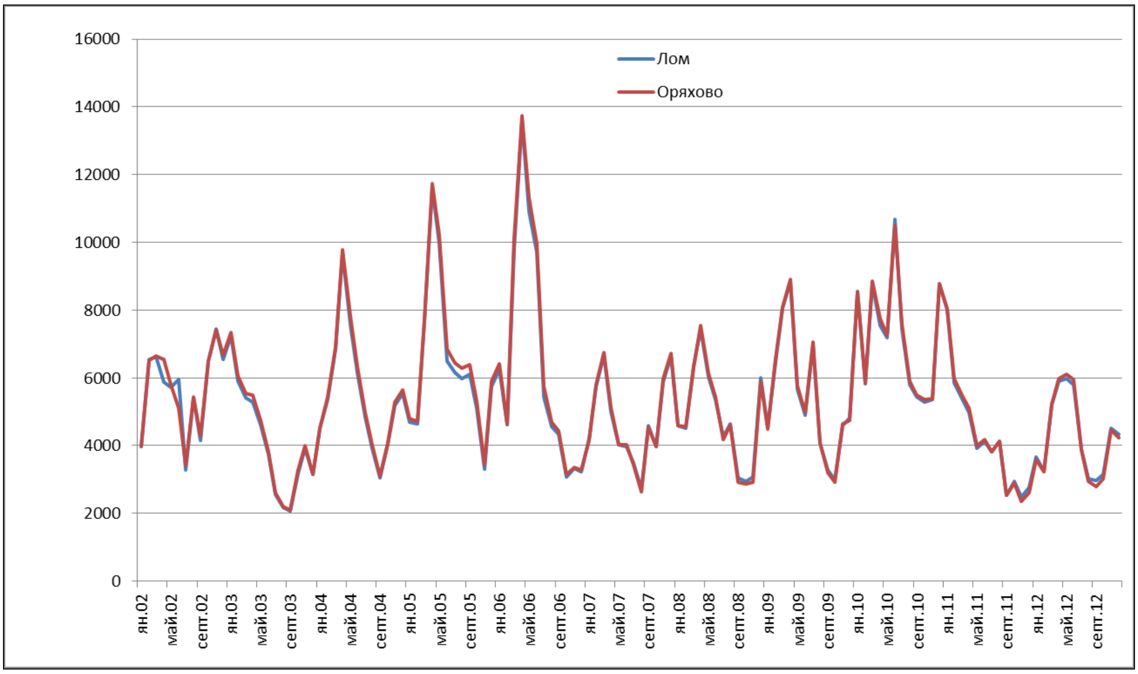


FIGURE 4.2-4: AVERAGE ANNUAL WATER QUANTITIES AT THE LOM AND ORYAHOVO WP FOR THE PERIOD 2002-2012

Figure 4.2-4 presents a comparison between the registered average daily water quantities at the Lom and Oryahovo stations for the same period. For the reviewed period it is difficult to establish any clear trend for change. Rather, we observe that there is a definite cyclical trend alternating between a low water-level period – 2002 and 2003, and a period of higher water quantities at the mid-point of the period, followed once again by a low water-level period in 2011 and 2012.

Water levels

The assessment of the water levels for different extreme situations is of primary importance for the safety of the power plant both during its construction and throughout its continued safe operation. An absolute elevation level of +35.00 according to the Baltic Elevation System is accepted as the ground zero (0.00) for the NPP site.

To determine the water levels of the river, the periods 1981-1985 for maximum water levels and 1937-1986 for minimum water levels have been used, based on data from the two outposts – Oryahovo and Kozloduy. For Kozloduy and Oryahovo the values presented are based on the Black Sea Elevation System, and for the BPS – on the Baltic Elevation System.

For the Kozloduy WP for the period 1981-1986 the highest water level was observed in March of 1981 – H=875 cm. The respective level for the Oryahovo WP was H=786 cm.

The second greatest maximum water level at the Kozloduy WP was H=825 cm in May of 1980, caused by the spring high water. The respective water level for Oryahovo was H=780 cm, once again for May of 1980.

During the summer and autumn low-water period, the lowest water level at the Kozloduy WP was H = 11 cm, observed in October of 1947, and at the Oryahovo WP it was H = -75 cm, observed for the same month.

During the reviewed period, the lowest water level at the Kozloduy WP was observed in January of 1954 – H = -2 cm, and at the Oryahovo WP it was respectively – H = -100 cm.

The average multi-annual water level for the Kozloduy WP is H=387 cm, and that for the Oryahovo WP is H=296 cm.

These characteristics with the water levels of water-measuring posts are presented in **Table 4.2-11** and **Table 4.2-12**.

TABLE 4.2-11: WATER LEVELS IN THE DANUBE RIVER AT DIFFERENT PROVISION LEVELS

Provision, P%	of the Danube River, H cm	of the Danube River, elevation level, m
Minimum for 1937-1986 at Cv = 1.41		
99%	-88	20.46
97%	-68	20.66
95%	-53	20.81
90%	-34	21.00
Maximum for 1941-1986 at Cv = 0.14		
0.01%	942	30.76
0.1%	886	30.20
1%	818	29.52
5%	758	28.92
10%	726	28.60

TABLE 4.2-12: WATER LEVELS IN THE DANUBE RIVER AT DIFFERENT PROVISION LEVELS AT THE RANGE OF THE KOZLODUY NPP SITE.

Provision, P%	Absolute elevation level of the Danube River, m
Minimum at Cv = 1.41	
99%	20.83
97%	21.06
95%	21.20
90%	21.39
Maximum at Cv = 0.14	
0.01%	31.08
0.1%	30.53
1%	29.86

For the range of the Kozloduy NPP, the water levels are presented at provision levels of 99-90% and from 0.01-1%. The results are presented in **Table 4.2-13** – the minimum value at provision level of 99% is 20.83 m, and the maximum value at provision level of 0.01% is 31.08 m.

TABLE 4.2-13: MAXIMUM WATER LEVELS IN THE DANUBE RIVER AT KM687 FROM THE DETAILED DESIGN.

Probability for exceeded values	1%	0.1%	0.01%
Water level	29.93	30.87	31.73

The updated technical justification of safety confirms the maximum water levels under a natural regime – **Table 4.2-14.**

TABLE 4.2-14: MAXIMUM WATER LEVELS IN THE DANUBE RIVER AT KM687 FROM THE SAFETY ANALYSIS REPORT..

Probability for exceeded values	1%	0.1%	0.01%
Water level	30.58	31.47	32.23

The maximum water levels in the Danube River branch next to the site of the Kozloduy NPP will be reached in the scenario with the destruction of the "Zhelezni Vrata" (Iron Gates) I and II hydroelectric power plants. Accounting for the overflow and destruction of the dykes, and for the accumulation of a part of the high tidal wave into the flooded plains, the maximum level will be 32.53 m. The scenario where this level would occurs would be the sudden and consecutive rupture of "Zhelezni Vrata" (Iron Gates) I and II hydro-electric complexes, with an overlay of the two waves and water volume of 10 000 m^3/s.[34]

The maximum water levels in the event of an overlay of low-probability events could be defined in the following way:

$$MWL = 32.53 + 0.1 + 0.30 = 32.93 \text{ m},$$

where to the highest elevation of water levels, caused of the destruction of the "Zhelezni Vrata" (Iron Gates) I and II hydro-electric complex, we are adding half of the expected height of the wind-generated waves of 0.30 m, and 0.10 m is the elevation of the water level resulting from intense rainfall in the section after the hydro-electric complex.

For the natural water of the Danube River, with probabilities of 10^{-5} to 10^{-7}, the estimated water levels are presented in **Table 4.2-15**.

TABLE 4.2-15: ESTIMATED WATER LEVELS IN THE NATURAL WATER OF THE DANUBE RIVER AT KM687.

Probability for exceeded values	10^{-5}	10^{-6}	10^{-7}
Water level	32.40	32.60	32.70

[34] Risk Inzhenerniy AD REL-1000-ST-001-2, 2013

Based on the water levels established in this way – for the normal and natural conditions of the Danube River, we can also estimate the combination of the two events – the natural extreme water levels at low probability (10^{-5} to 10^{-7}) and the rupture of the dam in the hydro-electric complex "Zhelezni Vrata" (Iron Gates) I and II (scenario 1). It must be noted that the combination of these two scenarios will lead to an event with very low probability. The estimated water levels are presented in **Table 4.2-16**.

TABLE 4.2-16: ESTIMATED WATER LEVELS IN THE WATER (SCENARIO 1) OF THE DANUBE RIVER AT KM687.

Probability for exceeded values	10^{-5}	10^{-6}	10^{-7}
Water level	32.98	33.26	33.42

Conclusion: We can see that even in the event of high waters with 10^{-7} probability of excess values combined with an overlap of catastrophic tides caused by the destruction of the dam of the "Zhelezni Vrata" (Iron Gates) I and II hydro-electric complex , the level of high waters will not exceed the elevation level of 33.42. This means that all four new sites proposed for the expansion of the Kozloduy NPP, which are planned to be constructed at elevation level of 35.00, will not be affected by flooding in the event of high waters. The existing protecting dikes, which have a peak elevation level of 32.00, would be overflown, which would lead to the flooding of the lowlands lying between them and sites 1 and 3. During the construction, before the completion of the construction works, there is a realistic danger of flooding, unless special measures are taken, related to the actual technology and sequence of the excavation and embankment works.

With high probability, we can expect the during the construction phase the need would arise for additional excavation works for the purpose of reinforcing the foundation under the new nuclear unit, which would result in an increased risk of flooding of the lowlands of the construction site, or at least of serious expenses for the draining of any flooding.

From the perspective of the safety of the new site, the advantage is on the side of the alternative sites 2 and 4, where the existing elevation level of the terrain is the highest and the maximum distance to from the dikes of the Danube River is the greatest. They have a natural safeguard against flooding even in the event of catastrophically high water levels of the Danube River. Site 2 has an additional advantage regarding the construction of the connection with the existing cold and hot channels.

4.2.1.4.2 During operation

The description of the expected water quantities and water levels is also valid for the operation period. Regarding the occurrence of catastrophically high water levels in the Danube River, all four sites will not be exposed to flooding. The analysis of the advantages and disadvantages of the reviewed sites clearly shows that the second site has least disadvantages, and at the same time, it brings in a lot of economic benefits.

To assess the impact of the water used from the Danube River for the cooling system, **Figure 4.2-5** shows the annual water volumes ($m^3.10^9$), passing through the ranges of the Lom WP and the Oryahovo WP during the period 2002-2012.

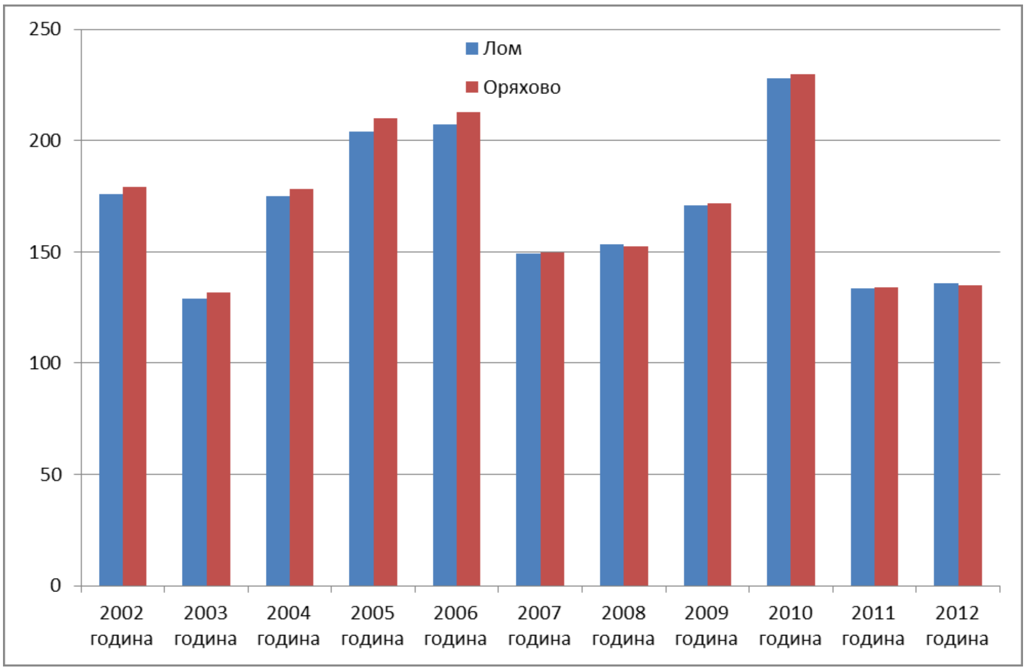


FIGURE 4.2-5: ANNUAL WATER VOLUMES ($M^3.10^9$) PASSING THROUGH THE RANGES OF THE LOM WP AND ORYAHOVO WP DURING THE PERIOD 2002-2012

Table 4.2-17 presents a comparison between the authorized water volumes and the ones actually used. We can see that the volume of the water used from the Danube River is about 53.21% of the authorized quantity, which is obviously due to the reduced capacity of the power plant.

When the Kozloduy NPP operated at its full capacity (3760 MW – with six running reactors in 2002 and capacity of the cold (intake) channel of 180 m^3/s, compared to the demonstrated maximum capacity of 200m^3/s), even in a year with very low water levels (99% provision), the Danube River water consumed by the NPP was very little – only 4.5 % of the river outflow.

TABLE 4.2-17: WATER AMOUNTS USED IN 2011, IN COMPARISON TO THE PERMITTED QUANTITIES

Water-abstraction point	Permitted quantity, [m^3]	Utilised quantity, [m^3]
Surface water from the Danube River	5 000 000 000	2 660 788 000

We can draw the conclusion that under the normal operation mode after the commissioning of the new unit, with a total average annual output of the NPP about 3000 MW, the necessary water quantity for the cooling system of the power plant will be about 3.5 %.

The irrecoverable water losses at the Kozloduy NPP have been estimated to be 0.00092% of the Danube River flow and 0.044 % of all the water used by the NPP, and the substantiated conclusion is that **the Kozloduy NPP does not affect the outflow of the Danube River**.

Conclusion: The abstraction of water for the cooling of the existing and the new reactors of the Kozloduy NPP in none of the considered 4 options for the site is expected to have any long-term, continuous, including cumulative and transboundary impact on the regime of the flowing water quantities of the Danube River, which is ensured through the use of the existing infrastructure – bank pump station, cold (intake) and hot (outlet) channels.

4.2.1.4.3 During decommissioning

We believe that regardless of choice of the specific site, the decommissioning of the new nuclear unit will not have any significant impact on the hydrological regime of the Danube River.

4.2.1.5 GENERAL CONCLUSION UNDER ITEM 4.2 – SURFACE WATER

The Impact on the surface water is identical for all four sites and throughout all implementation phases of the investment proposal. The choice of the most suitable site will be motivated by the easiest and most accessible solution for the connection with the Hot Channel (HC-1), leading all wastewater to the receiving basin, the Danube River, and allowing a form of discharge that employs an advanced monitoring system. The feasible options for the connection with the Cold Channel (CC-1) supplying water from the Danube River to the NNU should also be considered, as well as the probability of having the site flooded by high waters. Other decisive factors are the lack of already constructed hydrotechnical facilities within the site, and the level of groundwater.

Based on these criteria, the most suitable site under the "surface water" component is Site 2.

Site 2 is situated on the first unflooded terrace of the Danube River. The implementation of the reviewed IP will require minor earthwork (excavation and embankment). That territory currently houses a few small buildings, situated in at one end, which could be used as auxiliary buildings during the construction phase.

The connection with the Hot Channel will be short and easy, since it is situated on the northern border of **Site 2**.

The connection with the existing Cold Channel will also not be long – about 75 m. The position of the new pipes of the cold channel will have to pass over the underground part of the hot channel. The supply of circulation water can be implemented via the reuse of the existing CPS for units 1 and 2.

Based on the analysis and assessment made for the alternative site options and the different types of nuclear reactors that can be installed therein, **Site 2** is positively identified as the most suitable in the following regards:

Scope, characteristics and type of the impact – local, direct, negative, with low impact level, temporary and limited, provided the regulatory requirements and planned measures are strictly observed during construction, and direct, positive, with low to medium impact level, limited, long-term, with minimum cumulative impact, and irreversible, but limited if regulatory requirements and relevant measures for the operation phase are observed. Negative impact could be expected in case of improper operation of the treatment facilities or as a result of accidental releases during the operation or decommissioning stages. After the decommissioning – continuous, long-term, and reversible.

No transboundary impact is expected with regard to the component "Surface waters".

The conducted analysis on the non-radioactive household, industrial and cooling wastewater, as well as on the necessary raw water from the Danube River for the NNU reveals the differences among the three reactors under consideration with regard to the necessary quantities of raw water, with the AP-1000 reactor needing the smallest amount, but all three reactor types do not require greater fresh water quantities than the ones envisaged in the water abstraction permit. The water quantity made available after the decommissioning of units 1÷4 is more than sufficient for the NNU, regardless of the type of equipment.

Regarding the conventional wastewater, from the contamination loads introduced by the overall flow of wastewater via HC-1 into the Danube River, for all reactor types no exceeding of the Individual Emission Limits is expected from the joint operation of the new nuclear unit and the existing units 5 and 6 at the Kozloduy NPP site.

4.2.2 GROUNDWATER

4.2.2.1 FORECAST MIGRATION OF RADIONUCLIDES INTO THE SUBSOIL OF THE PROJECT SITES FOR CONSTRUCTION OF A NEW NUCLEAR UNIT AT THE KOZLODUY NPP SITE AND THE ADJUCENT TERRITORIES

Kozloduy NPP – New Build EAD provided a report on "MODELING THE MIGRATION OF RADIONUCLIDES IN THE SUBSOIL OF THE SITES" by: assoc. prof. d-r N. Stoyanov and prof. DGS M. Galabov, 2013, REL-1000-ST-005-E-1. This report is an integral part of the project: "RESEARCH AND DETERMINING THE LOCATION OF THE PREFERRED SITE FOR

CONSTRUCTION OF NEW NUCLEAR UNIT AT THE KOZLUDUY NPP SITE AND THE ADJUCENT TERRITORIES, RI/DI-1000.

The report presents data of the forecast behaviour and migration of the radionuclides in the subsoil of the sites proposed for the construction of NNU at Kozloduy NPP.

Assessments on the risk of contaminating the geological environment and groundwater during the operation of the NNU of Kozloduy NPP have been made based on the assumption that as a result of outflow of technological water and flooding of the concrete foundation of the reactor room, radionuclides of different type and different activity will be infiltrated into the subsurface space.

Based on data from the regular monitoring carried out at the territory of the plant the radionuclides included in the liquid emissions includes a broad range of isotopes, including: ^{51}Cr, ^{54}Mn, ^{58}Co, ^{59}Fe, ^{60}Co, ^{65}Zn, ^{95}Zr, ^{95}Nb,^{103}Ru, ^{106}Ru, ^{110}Ag, ^{122}Sb, ^{124}Sb, ^{125}Sb, ^{131}I, ^{134}Cs, ^{137}Cs, ^{140}Ba, ^{140}La, ^{141}Ce, ^{144}Ce, ^{89}Sr, ^{90}Sr, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Am, ^{242}Cm, ^{243}Cm и ^{244}Cm.

Based on detailed analysis on the characteristics and behaviour of the different isotopes, some „key" radionuclides of major significance have been chosen out of the whole range of radionuclides:

- ⇒ Cesium (^{137}Cs)
- ⇒ Strontium (^{90}Sr)
- ⇒ Cobalt (^{60}Co)
- ⇒ Americium (^{241}Am)
- ⇒ Plutonium (^{239}Pu)
- ⇒ Tritium (^{3}H).

The chosen six „key" radionuclides have different rate of decay and different sorbability (retention) in the geological environment. The initial assumption is that the modelling of their behaviour will give an overall picture of the potential spread of the isotopes related to the operation of the reactors into the subsoil space and into groundwater.

Tritium is "marking" isotope distinctive for its actually zero sorbability. In other words, this is an isotope moving at a maximum speed in the filtration flow, i. e. with the actual speed of water.

The research and analysis done covers all components (parts) of the migration field, i.e. of the space where radionuclides are likely to migrate in operational conditions of the nuclear power unit. According to the conservative scenario, simulated in mathematical models, the migration field will include three major components:

- the engineering protective barriers at the foundation of the reactor room (concrete substructure and construction embankments);
- the non-saturated zone embracing the space from the edge of the concrete foundation to the level of groundwater, the so-called aeration zone (formally the engineering barriers are part of the non-saturated zone);

- the aqueous part of the massif (aquifers), i.e. the migration into groundwater.

- The migration of all six key radionuclides is researched in the first two components (the protective barriers and the aeration zone). The research results show that practically all radionuclides are retained within the framework of the non-saturated zone and in a very limited part of the aqueous zone. Only ^{3}H and to a certain extent ^{90}Sr migrate comparatively more intensively (but with very low activity rates) into groundwater, hence an estimate is made about their penetration and spread into the aquifers.

4.2.2.1.1 Conceptual modelling positions

The main starting points for modelling the migration processes for each of the four sites are the following.

- Migration of radionuclides through the aeration zone and the engineering barriers is modelled by means of two-dimensional (2D) models, and the possibilities for their distribution in the groundwater – by means of three-dimensional (3D) models. The resulting two-dimensional solutions were used as input data for the developing of the three-dimensional ones.
- The modelling area in the two-dimensional models covers the sections passing through the central part of each site – south-north direction (in the direction of the groundwater flow). The modelling area in the three-dimensional models covers the entire region from the Danube River, based on the fact that the river is a potential receiver of the groundwater, respectively of the pollutants in them.
- The hydro-geological units and the engineering barriers are represented in full correspondence to their main features: geometrical (width, length or distribution area), physical (density, porosity), filtration (filtration coefficient) and migration (distribution, dispersity and molecular diffusion coefficients). In the aeration zone in addition are also set the specific to the non-saturated area parameters: natural humidity, coefficient of moisture conductivity and the connection between the suction potential and the humidity $\psi=f(\theta)$.
- The vertical infiltration feeding is calculated and set according to the climate, geological (soil) and technogenic conditions at the relevant site.
- The mass transfer mechanism is set in its fullest possible completion, that is: convectional and diffusion transfer accompanied by mechanical dispersion (longitudinal and transverse), sorption, radioactive disintegration, dilution, etc.
- The following conservation assumptions that simplify the modelling are adopted: the infiltration flow through the engineering barriers and on the areas outside the source of pollution (the reactor) is evenly distributed; the activity of each radionuclide is equal and homogeneously distributed on the entire area of the concrete foundation of the reactor; during the migration processes there is no interaction detected between the separate radionuclides.

- The geometry, size and special location of the reactor foundations for each site are given for guidance in the models since at present there is no information for the specific technology and future Master plan of the sites;
- In the estimate calculations it is accepted that the nuclear power plant functions for a period of 60 years but the migration calculations cover a period of 10000 years due to the expected extended presence of radionuclides in the subsurface area.
- The behaviour of the "key" radionuclides (^{137}Cs, ^{90}Sr, ^{60}Co, ^{241}Am, ^{239}Pu and ^{3}H) is stimulated in the mathematical models, which gives a complete idea of the possible distribution of radionuclides in the subsoil and groundwater.
- The results are given as "relative activity", i. e. activity A_i at a given time t_i and place of the initial (input) activity of the respective radionuclide A_0. In this case along the entire area of the concrete foundation of the reactor the value $A_0=1$ is taken as the initial activity.

For illustration and analysis of the results from the model calculations are chosen a given number of "typical" ("observational") points from the massif, situated at different depths under the upper edge of the concrete foundation. Based on the same scheme there are such points away from the concrete foundation at the side of the expected distribution of the radionuclides. For each point is given the change of activity of the specific radionuclide in time A=f(t). The results of the three-dimensional modelling in the aquifers are given as contours of the relative activity of the radionuclide at different times.

4.2.2.1.2 Geometrical, filtration and sorption features of the geological environment

The potential media for the spread of radionuclides into subsurface space includes all low rank hydrogeological units formed in the geological intersection to a depth of 50-60 m. The considerations also cover the adjacent to the four sites territory to the nearest potential receiving basin of contaminants – the Danube River. There are two basic geological complexes within the spatial boundaries thus delineated:

- quaternary complex, consisting of loess materials (loess, sand loess, and loess clays), old alluvial terraces (clays, sands and gravels), first non-flooding and flooding terrace of the Danube River (gravels and sands);
- neogene complex represented by the sediments of the Brusartsi Formation (clays, sandy clays and sands).

Within the two geological complexes 11 layers can be separated, defined as low rank all units: eight in the quaternary complex and three – in the neogene complex. These layers, that are relatively uniform in their lithological composition, filtration capacities and migration features, have complex spatial forms and different presence within the reviewed territory. Generally their boundaries coincide with the boundaries of the lithological and engineering-geological variations, defined based on historical data and based on the detailed research carried out at the four sites.

The low rank hydrogeological units (layers) are situated in depth in the following sequence:

- Layer 1. Dusty and sandy loess
- Layer 2. Clay loess
- Layer 3. Loess clay and clay sand
- Layer 4. Alluvial rubble and rubble clay (old terraces)
- Layer 5. Alluvial clays
- Layer 6. Alluvial gravel and sand (non-flooding and flooding terrace of the Danube River)
- Layer 7. Alluvial rubble and sand (flooding terrace of the Danube River)
- Layer 8. Alluvial rubble (flooding terrace of the Danube River)
- Layer 9. Clay with sand layers (Brusartsi Formation)
- Layer 10. Clay (Brusartsi Formation)
- Layer 11. Small sand (Brusartsi Formation)

Based on precise analysis and interpretation of the results from the research activities carried out on the territory of Kozloduy NPP both for the construction of the acting capacities and for the four potential sites, and based on the analysis of the collected historical data of the research carried out by the Geological Institute at BAS, University of Mining and Geology "St. Ivan Rilski", SD Akvater, and other companies specialized in research, in the region of the NPP and "Radiana" Site were defined the geometry, spatial borders, hydro-dynamic and migration characteristics of the **above-defined 11 layers.**

The boundaries of the low rank hydrogeological units for the separate sites are illustrated on schematic intersections and block-diagrams employed in the developed mathematical models by the request of "NPP Kozloduy –NC" EAD.

Table 4.2-18 presents the average values of width, density ρ_n, dry density ρ_d, porosity n and penetrability (filtration coefficient) *k* of each layer.

The geological environment has the ability to sorb (retain) part of the radionuclide flow. In this aspect the low rank hydrogeological units (layers) represent **natural barriers** that prevent the migration of radionuclides into the subsoil.

TABLE 4.2-18: PHYSICAL AND HYDRODYNAMIC CHARACTERISTICS OF THE LOW RANK HYDROGEOLOGICAL UNITS (LAYERS)

Layer Number	Geological Index	Lithological Description	Width from- to-, m	Density ρ_n, kg/m^3	Dry density ρ_d, kg/m^3	Porosity n, -	Filtration Coefficient k, m/d
1	eolQp$^{2-3}$	Dusty and sandy loess	5-10	1850	1510	0.40	1.5
2	eolQp$^{2-3}$	Clay loess	2-4	1930	1550	0.43	0.2
3	eol-alQp^2	Loess clay and clay sand	2-5	2000	1570	0.43	0.25
4	alQp^1	Alluvial rubble and rubble clay (old terraces)	1-3	2050	1730	0.36	7.5
5	alQh	Alluvial clays	3-7	1980	1600	0.41	0.02
6	alQh	Alluvial gravel and sand (non-flooding and flooding terrace)	5-9	2050	1710	0.38	30.0
7	alQh	Alluvial rubble and sand (flooding terrace)	6-8	2100	1760	0.37	80.0
8	alQh	Alluvial rubble (flooding terrace)	3-5	2150	1780	0.35	120.0
9	brN$_2$	Clay with sand layers (Brusartsi Formation)	>30	2030	1630	0.40	0.1
10	brN$_2$	Clay (Brusartsi Formation)	3-10	2010	1620	0.41	0.005
11	brN$_2$	Small sand (Brusartsi Formation)	1-8	2080	1750	0.36	2.5

TABLE 4.2-19: AVERAGE VALUES OF THE DISTRIBUTION COEFFICIENT KD* OF THE LOW RANK HYDROGEOLOGICAL UNITS (LAYERS) AND ENGINEERING BARRIERS REGARDING THE "KEY" RADIONUCLIDES ^{137}CS, ^{90}SR, ^{60}CO, ^{241}AM, ^{239}PU AND ^{3}H

Radionuclide	Coefficient of Disintegration γ	NATURAL BARRIERS (LAYERS)					
		Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	Layer 6
		Dusty and sandy loess	*Clay loess*	*Loess clay and clay sand*	*Rubble clay and rubble*	*Dusty and sandy clays*	*Gravel and sand*
		m^3/kg	m^3/kg	m^3/kg	m^3/kg	m^3/kg	m^3/kg
^{137}Cs	6.29E-05	0.20	0.25	0.23	0.14	0.25	0.11
^{90}Sr	6.64E-05	0.07	0.12	0.14	0.075	0.056	0.010

^{63}Co	3.60E-04	0.18	0.42	0.65	0.11	0.65	0.15
^{241}Am	4.39E-06	10.00	20.00	20.00	20.00	20.00	6.00
^{239}Pu	7.87E-08	0.11	0.21	0.16	0.15	0.15	0.12
^{3}H	1.56E-04	0.00	0.00	0.00	0.00	0.00	0.00

TABLE 4.2-19: CONTINUE

Radionuclide	NATURAL BARRIERS (LAYERS)					ENGINEERING BARRIERS	
	Layer 7	Layer 8	Layer 9	Layer 10	Layer 11	Barrier 1	Barrier 2
	Rubble and sand	*Rubble*	*Clay with sand layers*	*Clay*	*Small sand*	*Concrete foundation*	*Rubble embankment*
	m³/kg	m³/kg	m³/kg	m³/kg	m³/kg	m³/kg	m³/kg
^{137}Cs	-	-	0.40	0.41	0.10	0.48	0.43
^{90}Sr	0.009	0.008	0.20	0.23	0.04	0.015	0.009
^{63}Co	-	-	0.22	0.21	0.08	0.37	0.15
^{241}Am	-	-	30.0	30.00	8.00	3.27	0.60
^{239}Pu	-	-	0.56	0.58	0.10	0.58	0.10
^{3}H	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 4.2-19 presents the average values of the sorption (retaining) characteristics of the layers represented by the distribution coefficient Kd regarding the "key" radionuclides (^{137}Cs, ^{90}Sr, ^{60}Co, ^{241}Am, ^{239}Pu and ^{3}H).

4.2.2.1.3 Features of the engineering barriers

The assessment of the possible distribution of radionuclides in the subsoil is carried out by the request of "NPP Kozloduy-NC" EAD at the conservative hypothesis that under the conditions of operation of the reactor the technological water from the first loop systematically floods the concrete foundation. Under this scenario the engineering barriers against liquid emissions, respectively radionuclides, into the geological base are two – concrete foundation and rubble embankment.

4.2.2.1.3.1 Concrete foundation

The research was made, when there was no defined final nuclear technology to be used at the site of the NNU of Kozloduy NPP and respectively no clear basic parameters of the building constructions. There is an indicative assessment of the nuclides transfer into the subsoil phenomenon, and as per the expert assessment were adopted the following parameters necessary for the research: the concrete foundation has the following parameters: 2500 m²; absolute elevation of the building elevation „0" – 36.0 m; absolute elevation "upper edge" of the foundation 30.0 m; foundation width – 2.5 m. These characteristics, with accuracy sufficient for the research purposes, reflect the parameters of the reactor building of the nuclear plants potentially possible for realization at the NNU site.

The adopted working hypothesis that "the foundation is flooded with technological water through the entire period of exploitation of the new reactor (60 years) with the relative activity of the "key" radionuclides along the entire area of the foundation being A_0=1, is a highly conservative consumption, since it presupposes drastic non-compliance with the operation and monitoring technology of the site. The adopted geometric scheme is identical for all the sites and cannot impact the accuracy of the comparative assessment of the retaining (protective) abilities of the geological environment.

4.2.2.1.3.2 Rubble embankment

In line with the lower than the adopted elevation "0" absolute elevations of the terrain of Site 1 (about 25 m) and Site 3 (about 30 m) a construction rubble embankment is modelled at these two sites in the research. For the construction of the embankment will be used rubbles from the contemporary bed of the Danube River.

The model researches do not consider removal of the weak soils and construction of loess-concrete cushions under the concrete foundation since these and all other questions related to the foundation and construction of NNU are not yet developed into conceptual or detailed designs. Only at the modelling of the low sites (Site 1 and Site 3) it is adopted that the area between the terrain elevation and "lower edge" of the foundation elevation or to "0" elevation will be filled by an embankment of river rubble (due to the unevenness of the terrain this embankment under the foundation of Site 1 varies in the range of 2-3 m). Due to the absence of loess-concrete cushion all forecasts and assessments are much more conservative.

Table 4.2-20: Physical and hydrodynamic characteristics of the engineering barriers

Engineering Barrier	Width, m	Density ρ_n*, kg/m³	Dry density ρ_d , kg/m³	Porosity n, -	Filtration Coefficient k**, m/d
Concrete Foundation	2.50	2400	1910	0.01	0.001
Rubble Embankment	2-3	2100	1750	0.36	20.0

* *The adopted density corresponds to "heavy construction concrete". For the migration of radionuclides through it more significant are the values of the coefficient of distribution Kd, characterizing the sorption (see below), while the density changes insignificantly and its values do not change significantly the conditions of the passing of isotopes through the concrete.*

** *The adopted water permeability of the concrete (k=10^{-3} m/d) is two levels higher than the project one. The indicators of water impermeability of the used concrete – W6 and W4 (under GOST 26633-91) – approximately correspond to filtration coefficients of 10^{-5} to 10^{-6} m/d. I. e. water permeability of the concrete slabs is adopted with a serious reserve, allowing for some imperfections and defects in their realization.*

The spatial parameters and the geometry of the engineering barriers are illustrated on schematic intersections and block-diagrams employed in the developed mathematical models.

Error! Reference source not found. presents the values of their average width in m, density ρ_n, dry density ρ_d, porosity n and filtration coefficient *k*.

Table 4.2-19 presents the values of their retaining characteristics, expressed by the distribution coefficient K_d.

4.2.2.1.4 Modelling the migration of radionuclides through the engineering barriers and the aeration zone of the four sites

4.2.2.1.4.1 Input data

The specific natural features and assets of each of the four sites imply certain differences in the conditions for migration of radionuclides into subsoil and groundwater.

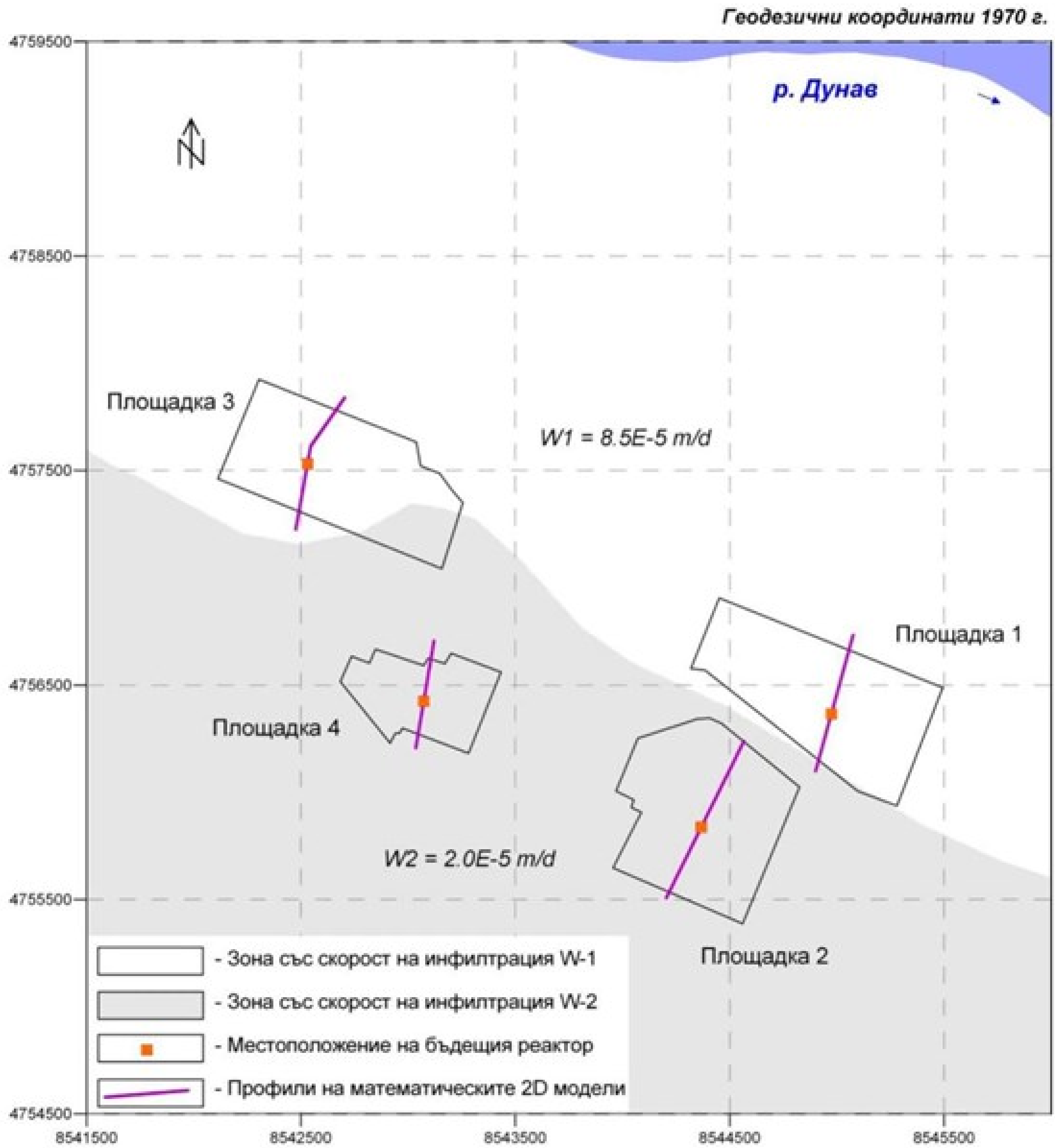


FIGURE 4.2-6: SCHEME WITH THE LOCATION OF THE PROFILES OF THE MATHEMATICAL 2D MODELS OF THE FUTURE REACTOR (POTENTIAL POLLUTION SOURCE)

Legend: Geodesic coordinates 1970
From top to bottom: Zone with infiltration speed W-1
Zone with infiltration speed W-2
Location of the future reactor
Profiles of the mathematical 2D models

Some of the more important ones are related to certain differences in the structure of the geologic foundation, the low rank hydrogeological units and engineering barriers, the thickness of the non-saturated zone (the aeration zone) under the concrete foundation (or its absence), etc. These specific aspects are reflected in the 2D mathematical models developed for each site.

The models have been developed by profiles passing through the central parts of the sites in South-North direction (**Figure 4.2-6**). The determined borders of the low rank hydrogeological units and of the engineering barriers (concrete foundation and construction embankment) in the intersections of these profiles are based on the drawn engineering-geological intersections.

4.2.2.1.4.2 Results

Two-dimensional mathematic model of Site 1

The groundwater level in the region is determined at elevation 25 m. Width of the aeration zone under the concrete foundation is about 2.5 m. Its main part is formed in the constructed rubble embankment. The general direction of the groundwater flow is to the northeast.

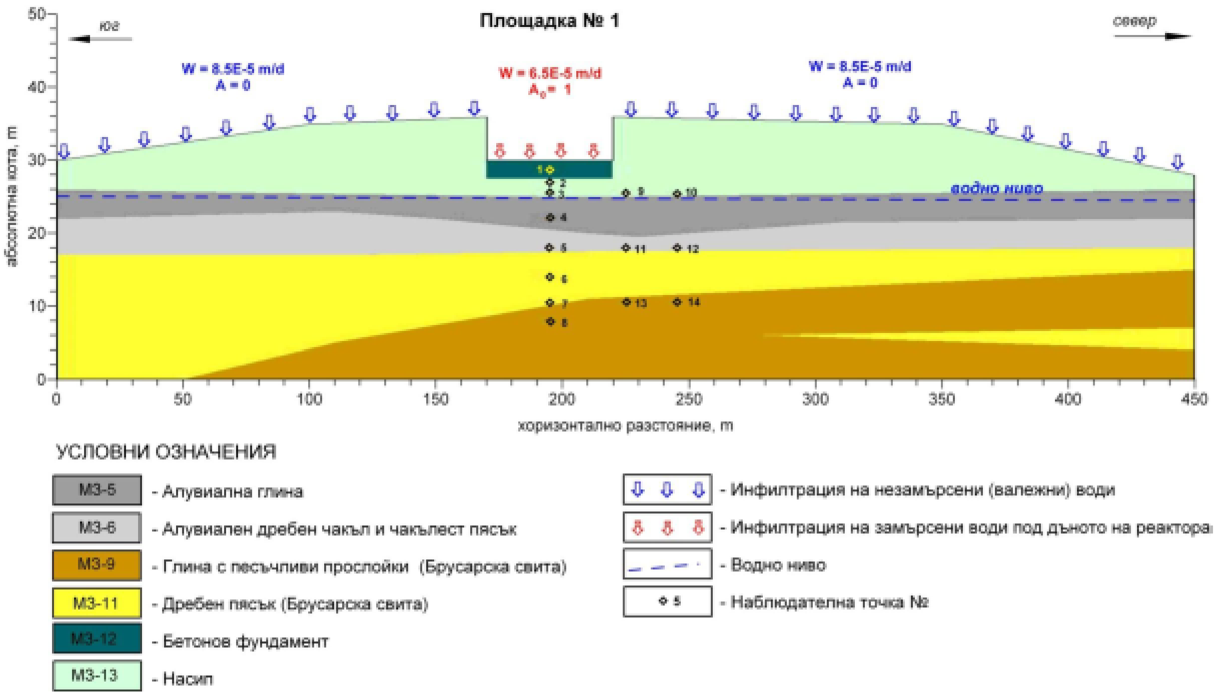


FIGURE 4.2-7: MATHEMATICAL 2D MODEL OF THE CONDITIONS OF MIGRATION OF RADIONUCLIDES IN THE SUBSOIL AREA OF SITE 1

Legend: on the left, from top to bottom: MZ-5 – Alluvial clay
MZ-6 – Alluvial gravel and gravel sand
MZ-9 – Clay with sand layers (Brusartsi Formation)
MZ-11 – Small sand (Brusartsi Formation)
MZ-12 – Concrete foundation
MZ-13 – Embankment
On the right, from top to bottom: Infiltration of non-contaminated (rain) water
Infiltration of contaminated water under the bottom of the reactor
Water level
Monitoring point №

14 monitoring points were chosen for illustration and analysis of the results from the model calculations in the mathematical 2D model (see **Figure 4.2-7**). Part of these points is

located at depths of 1.25, 3.0, 4.5, 8.0, 12.0, 16.0, 19.5 and 22.0 m under the upper edge of the concrete foundation. The point at 1.25 m depth is located in the middle of the foundation, the point at 3.0 m depth is immediately under the lower edge of the foundation, and the point at 4.5 m depth is immediately above the groundwater level. The remaining monitoring points are located away from the foundation at horizontal distance 5 and 25 m in the direction of the expected distribution of radionuclides and at depths of 4.5, 12.0 and 19.5 m.

Two-dimensional mathematic model of Site 2

The groundwater level in the region of the site is determined at 9.3 m of the ground surface (at elevation of 26.7 m). Width of the aeration zone under the concrete foundation is very small – about 0.8 m. The general direction of the groundwater flow is to the northeast.

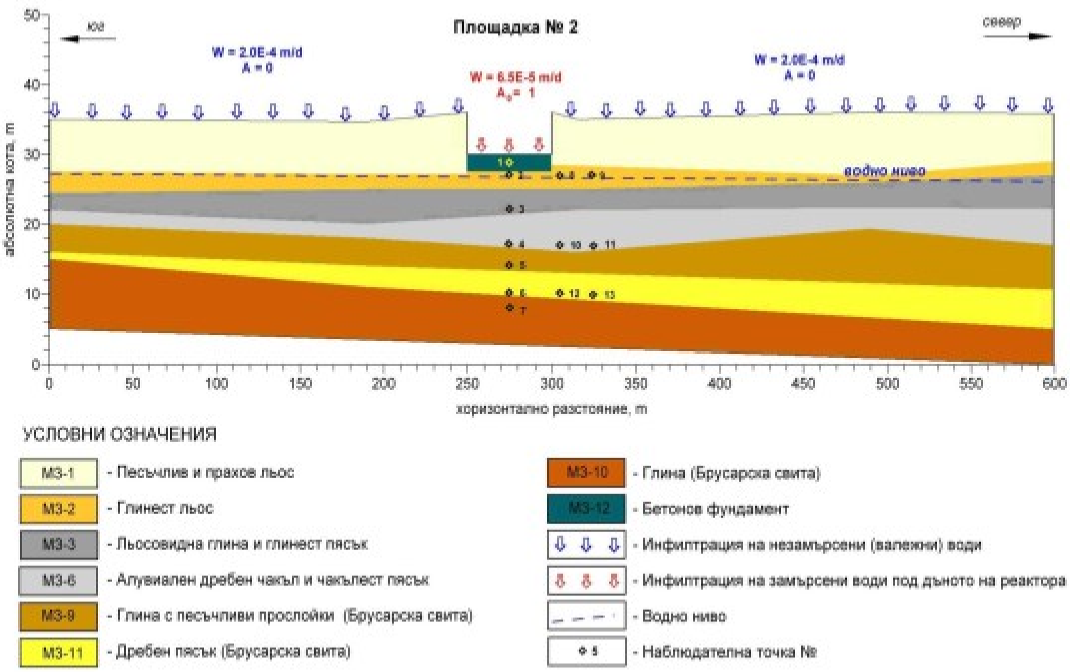


FIGURE 4.2-8: MATHEMATICAL 2D MODEL OF THE CONDITIONS OF MIGRATION OF RADIONUCLIDES IN THE SUBSOIL AREA OF SITE 2

Legend: on the left, from top to bottom: MZ-1– Dusty and sandy loess
MZ-2 – Clay loess
MZ-3 – Loess clay and clay sand
MZ-6 – Alluvial gravel and gravel sand
MZ-9 – Clay with sand layers (Brusartsi Formation)
MZ-11 – Small sand (Brusartsi Formation)
On the right, from top to bottom: MZ-10 – Clay (Brusartsi Formation)
MZ-12 – Concrete foundation
Infiltration of non-contaminated (rain) water
Infiltration of contaminated water under the bottom of the reactor
Water level
Monitoring point №

14 monitoring points were chosen for illustration of the results from the model calculations in the mathematical 2D model (see **Figure 4.2-8**). The first seven points are located at depths of 1.25, 3.0, 8.0, 13.0, 16.0, 20.0 and 22.0 m under the upper edge of the concrete foundation. The point at 1.25 m depth is located in the middle of the foundation, the point at 3.0 m depth is immediately above the groundwater level. The remaining monitoring points are located away from the foundation, at horizontal distance 5 and 25 m in the direction of the expected distribution of the isotopes and at depths of 3.0, 13.0 and 20.0 m.

Two-dimensional mathematic model of Site 3

The groundwater level in the region is determined at elevation 25 m. Width of the aeration zone under the concrete foundation is about 2.3 m. It is formed in the sandy loess (layer 1). The general direction of the groundwater flow is to the northeast.

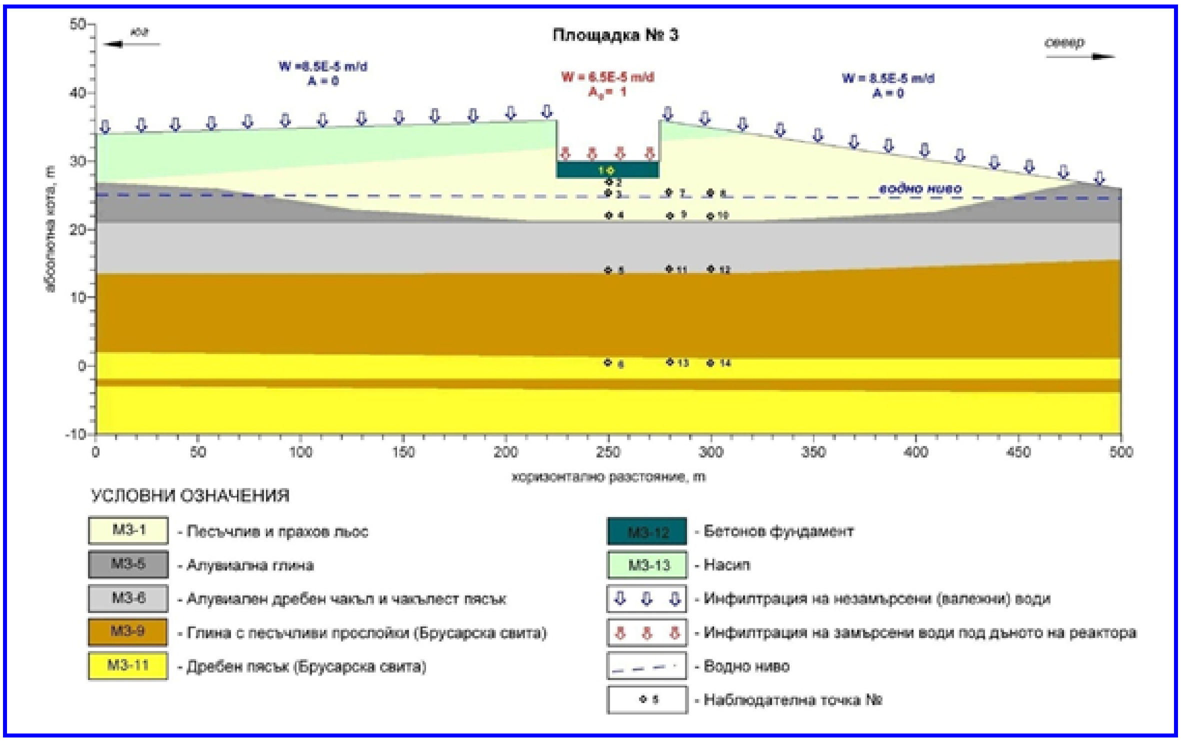


FIGURE 4.2-9: MATHEMATICAL 2D MODEL OF THE CONDITIONS OF MIGRATION OF RADIONUCLIDES IN THE SUBSOIL AREA OF SITE 3

Legend: on the left, from top to bottom: MZ-1– Dusty and sandy loess
MZ-5– Alluvial clays
MZ-6 – Alluvial gravel and gravel sand
MZ-9 – Clay with sand layers (Brusartsi Formation)
MZ-11 – Small sand (Brusartsi Formation)
On the right, from top to bottom: MZ-12 – Concrete foundation
MZ-13 – Embankment
Infiltration of non-contaminated (rain) water
Infiltration of contaminated water under the bottom of the reactor
Water level
Monitoring point №

14 monitoring points were chosen for illustration and analysis of the results from the model calculations in the mathematical 2D model (see **Figure 4.2-9**). The first six points are located at depths of 1.25, 3.0, 4.5, 8.0, 16.0 and 29.5 m under the upper edge of the foundation. The point at 1.25 m depth is located in the middle of the foundation, the point at 3.0 m depth is immediately under the lower edge of the foundation, and the point at 4.5 m depth is immediately above the groundwater level. The remaining monitoring points are located away from the foundation at horizontal distance 5 and 25 m in the direction of the expected distribution of radionuclides and at depths of 4.5, 8.0, 16.0 and 29.5 m.

Two-dimensional mathematic model of Site 4

The geological base under the reactor is auriferous. The groundwater level region is determined at elevation 28.2 m, i. e. it is 0.7 m above the lower edge of the concrete foundation. The general direction of the groundwater flow is to the northeast.

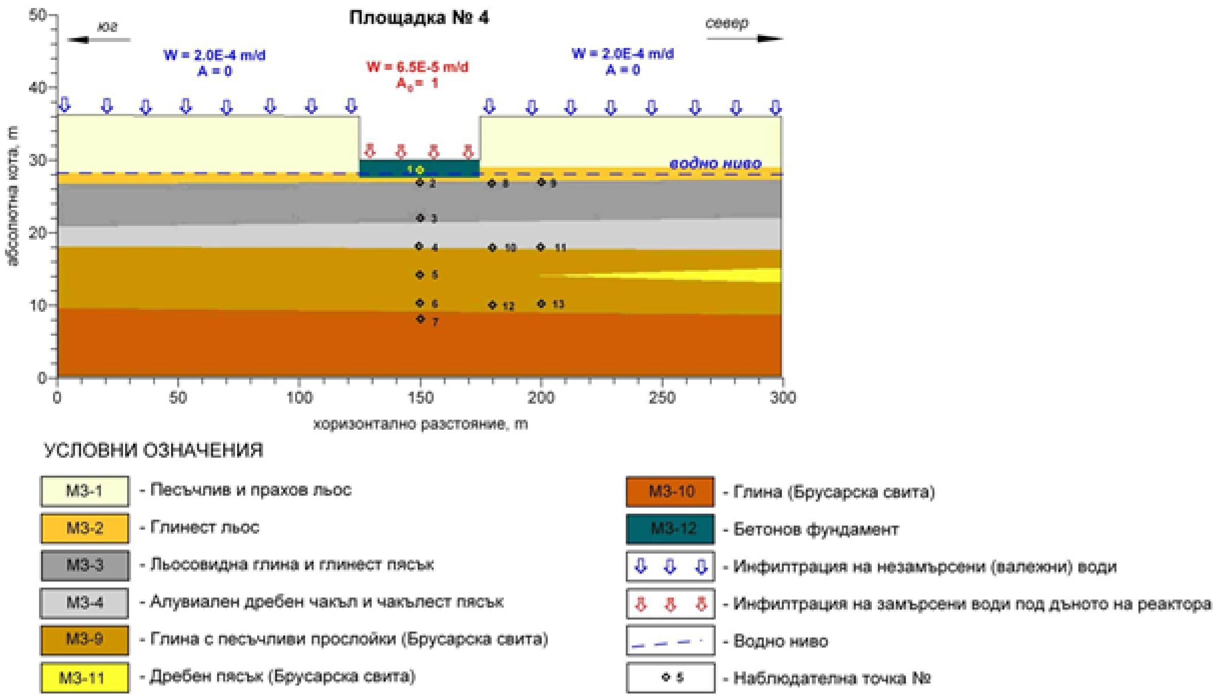


FIGURE 4.2-10: MATHEMATICAL 2D MODEL OF THE CONDITIONS OF MIGRATION OF RADIONUCLIDES IN THE SUBSOIL AREA OF SITE 4

Legend: on the left, from top to bottom: MZ-1– Dusty and sandy loess
MZ-2 – Clay loess
MZ-3 – Loess clay and clay sand
MZ-4 – Alluvial rubble and rubble clay
MZ-9 – Clay with sand layers (Brusartsi Formation)
MZ-11 – Small sand (Brusartsi Formation)
On the right, from top to bottom: MZ-10 – Clay (Brusartsi Formation)
MZ-12 – Concrete foundation
Infiltration of non-contaminated (rain) water
Infiltration of contaminated water under the bottom of the reactor
Water level
Monitoring point №

13 monitoring points were chosen for illustration and analysis of the results from the model calculations in the mathematical 2D model (see **Figure 4.2-10**). The first seven points are located at depths of 1.25, 3.0, 8.0, 12.0, 16.0, 20.0 and 22.0 m under the upper edge of the foundation. The point at 1.25 m depth is located in the middle of the foundation, immediately above groundwater level, and the point at 3.0 m depth is under the water level. The remaining monitoring points are located away from the foundation at horizontal distance 5 and 25 m in the direction of the expected distribution of the isotopes and at depths of 3.0, 12.0 and 20.0 m. Actually all monitoring points, except for the point in the concrete foundation, are located within the auriferous area.

4.2.2.1.5 Modelling the migration of radionuclides in the water aquifers and drainage zones that are potentially threatened with contamination

The conjecture for a potential radionuclide migration into the groundwater in the area of the four sites is made by employing a three-dimensional (3D) mathematical simulation of the conditions for substance transmission. For this purpose, one basic filtration 3D model and four migration 3D models have been developed.

The basic filtration 3D model simulates the structure of the groundwater flow in the area of the four sites under consideration and their adjacent territory to the Danube River, which is a potential receiver of the radionuclides that have penetrated in the groundwater. The specific hydrogeological conditions and all external impacts have been taken into account. The modelled structure of the filtration field has been used as a basis for the development of the migration models.

The migration 3D models are computer simulations of the potential spread of the radionuclides penetrating from the corresponding site into the aquifers for a period of 10 000 years. They served to produce an estimate about the migration of **^{3}H** and **^{90}Sr,** as the solutions obtained by means of the two-dimensional models show that the remaining "key" isotopes are retained within the non-saturated zone or in a very limited part of the aqueous zone. In this respect, **^{3}H** and **^{90}Sr** are viewed as sufficiently indicative for the assessment of the contamination risk of aquifers and the nearest to NNU receiving waters.

4.2.2.1.5.1 Conceptual model

The mathematical three-dimensional models were developed under the following output conditions:

Modelling area

- ✓ As a layout it covers the region of the four sites and the adjacent territories between the slope side of the loess complex and the Danube River – see **Figure 4.2-6**.
- ✓ As an intersection it covers all low rank hydrogeological units (layers) in the composition of the quaternary and neogene complex to 40-50 m of depth.

Hydrogeological units

Quaternary complex

- ⇒ Layer 1. Dusty and sandy loess
- ⇒ Layer 2. Clay loess
- ⇒ Layer 3. Loess clay and clay sand
- ⇒ Layer 4. Alluvial rubble and rubble clay (old terraces)
- ⇒ Layer 5. Alluvial clays
- ⇒ Layer 6. Alluvial gravel and sand (non-flooding and flooding terrace)
- ⇒ Layer 7. Alluvial rubble and sand (flooding terrace of the Danube River)
- ⇒ Layer 8. Alluvial rubble (flooding terrace of the Danube River)

Neogene complex

- ⇒ Layer 9. Clay with sand layers (Brusartsi Formation)
- ⇒ Layer 10. Clay (Brusartsi Formation)
- ⇒ Layer 11. Small sand (Brusartsi Formation)

Geometry and spatial borders of the bottoms and tops of the low rank hydrogeological units are defined based on a precise analysis of the results of the detailed drilling and geophysical surveys carried out at the four sites, as well as based on the information of the hydrogeological surveys carried out in the region of the Power plant for the last 30-40 years.

Hydrogeological parameters

The adopted calculation values for the three-dimensional models of the physical, filtration, and migration characteristics of the low rank hydrogeological units are presented in the text above.

Structure of the groundwater flow

It is entirely controlled by the fluctuations of the levels of the Danube River and by the draining channels (draining system). The complied piezometric maps at high and low level of the Danube River show the following regularities:

- ✓ At times of low level the entire groundwater flow is directed towards the river.
- ✓ At times of high level the groundwater flow in the northern half of the flooding terrace is directed from the river to the layer, respectively to the draining channels, and in the non-flooding terrace and in the southern part of the flooding terrace the flow keeps its north-northeast direction.

The direction of the groundwater flow, the gradients and speed at the low standings in the Danube River create highly favourable conditions for accelerated movement of the isotopes that entered the layer towards the river. Therefore in the calibration of the main filtration model with a significant engineering reserve was used the piezometric map at low river levels.

Boundary conditions

- The Danube River. It is the main factor controlling the structure of the filtration field. The river is also considered as the first potential receiver of radionuclides contaminated groundwater from the NNU.
- Draining channels. They are the main factor for the reduction of groundwater level in times of high levels of the Danube River and to a great extend they determine the structure of the filtration field. They are not of great significance in times of low levels of the river.

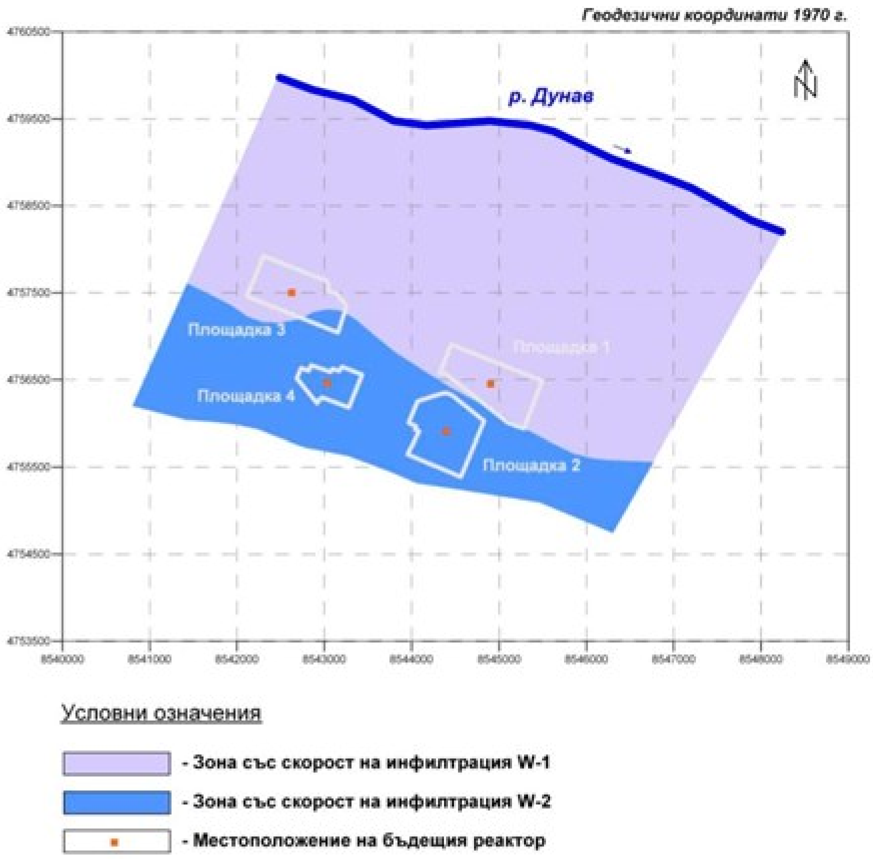


FIGURE 4.2-11: ZONING AS PER THE VALUE OF INFILTRATION FEED

Legend: from top to bottom: Zone with infiltration speed – W-1
Zone with infiltration speed – W-2
Location of the future reactor

- Infiltration feed by precipitation. In the modeling area based on the different water permeability of the covering layers, two zones are separated – northern zone with speed of infiltration W1=8.5E-5 m/d and southern zone with speed of W2=2.0E-4 m/d (see Fig. 4.2.2.1-13.). The infiltration flow I is calculated as per Bredencamp formulae, respectively: for permeable soils I=0.3 (P - 313) and for less permeable soil I=0.2 (P - 313). With annual precipitation of P=556 mm/a the infiltration calculated for the northern half of the modelling area, where the covering layer is made of less permeable alluvial clays (layer 5), is I=31 mm/a. For the southern half, where the surface is dominated by the more permeable sandy loess (layer 1), the infiltration is I=71 mm/a - **Figure 4.2-11**.

- ✓ Groundwater flow on the southern border of the modelling area. It is formed by the groundwater in the sandy layers of Brusartsi Formation (layers 9 and 11), gravel-clay sediments at the old alluvial terraces (layer 4) and the loess complex (layers 1 and 3). It is drained underground in the gravel-sandy materials of the non-flooding terrace (layer 6).

Source of pollution

- ✓ This is the infiltration flow entering the entire area of the plane projection of the concrete foundation of the reactor building over “the glass mirror”, marking the border between the aeration zone and the auriferous zone.
- ✓ The infiltration speed is permanent and equals the speed of Wp=26 m/d of polluted water passing through the concrete foundation adopted in the two-dimensional models.
- ✓ It is adopted that the initial activity of the researched radionuclides (^{3}H and ^{90}Sr) on the entire area of the above-defined area source of pollution is a variable. It is described by the forecast solutions of the relative activity change of ^{3}H and ^{90}Sr in time A=f(t) in the two-dimensional models of each site in the monitoring points located immediately next to the groundwater level. These functional dependencies are adopted as income date in the 3D models developed below.

4.2.2.1.5.2 Formation of three-dimensional (3D) models

Main filtration 3D model

The filtration model is a three-dimensional structure of the groundwater flow in the region of the modelling area. In its development are taken into account the specific hydrogeological conditions and all external impacts, including the hydraulic conditions for pollutants penetration under the bottom of the designed energy unit. The main points in its formation are the following:

- ✓ The filtration 3D model is made according to the provisions set out in the conceptual model and software package MODFLOW.
- ✓ The modelling area covers the four sites under consideration and their adjacent territories to the Danube River (**Figure 4.2-12**). The overall area of the model is about 23.7 km^{2}.

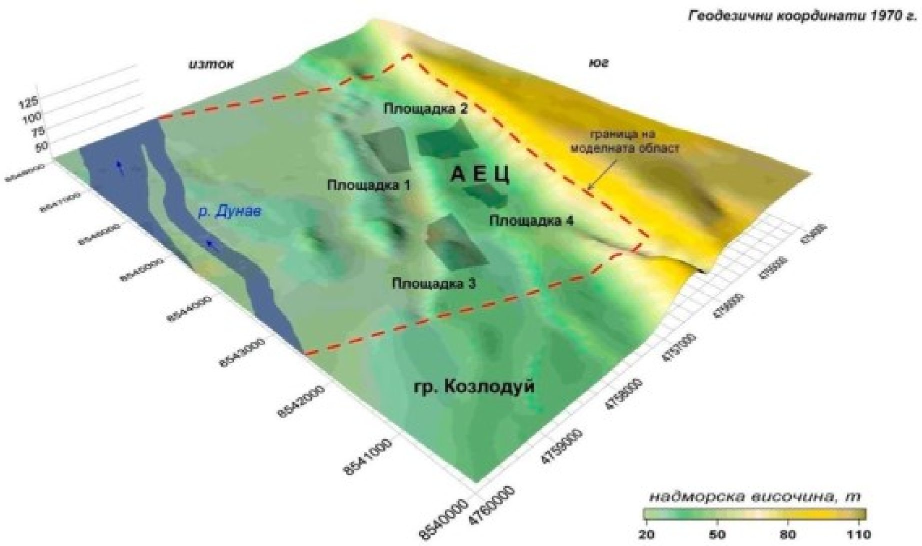


FIGURE 4.2-12: GEOMORPHOLOGIC PECULIARITIES IN THE SITE REGION. BORDERS OF THE MODELING AREA

✓ The modelling layers and zones simulate fairly accurate the spatial distribution of the low rank units determined in the hydrogeological intersection - **Table 4.2-21** and **Figure 4.2-13.**

TABLE 4.2-21: FILTRATION FEATURES AND MIGRATION CHARACTERISTICS OF THE MODELING LAYERS AND ZONES IN THE THREE-DIMENSIONAL MATHEMATICAL MODELS

Modelling layer	Modelling zone	Layer №	Filtration Coefficient *k*, m/d	Dry density ρ_d, kg/m³	Longitudinal dispersion α_L, m	Diffusion coefficient D_M, m²/d
ML-1	MZ-1.1	1,2,3	0.25	1550	0.003	1.5E-4
	MZ-1.2	5	0.02	1600	0.005	1.5E-4
ML-2	MZ-2.1	4	7.5	1730	0.015	1.2E-4
	MZ-2.2	6	30.0	1710	0.025	1.0E-4
	MZ-2.3	7	80.0	1760	0.030	1.0E-4
	MZ-2.4	8	120.0	1780	0.070	1.0E-4
ML-3	MZ-3.1	9	0.1	1630	0.010	2.5E-4
	MZ-3.2	11	2.5	1750	0.050	1.0E-4
ML-4	MZ-4.1	10	0.005	1620	0.015	2.5E-4
	MZ-4.2	11	2.5	1750	0.050	1.0E-4
ML-5	-	9,10	0.1	1630	0.010	2.5E-4

- MZ-1.1 – loess complex (layers 1, 2 and 3);
- MZ -1.2 - alluvial clay in the flooding and non-flooding terrace (layer 5);
- MZ -2.1 - alluvial rubble and rubble clay in the old terraces (layer 4);
- MZ -2.2 - alluvial gravel with sand in the non-flooding and flooding terrace (layer 6);
- MZ -2.3 - alluvial gravel with sand in the flooding terrace (layer 7);
- MZ -2.4 - alluvial gravel in the flooding terrace (layer 8);
- MZ -3.1 и MZ -4.1 - clay with sand layers and clay in the Brusartsi Formation (layers 9 and 10);
- MZ -3.2 и MZ -4.2 – small sand in the Brusartsi Formation (layer 11);

– alluvial clay in the non-flooding and flooding terrace (layer 5);

– ML-5 - clay with sand layers in the Brusartsi Formation (layers 9 and 10).

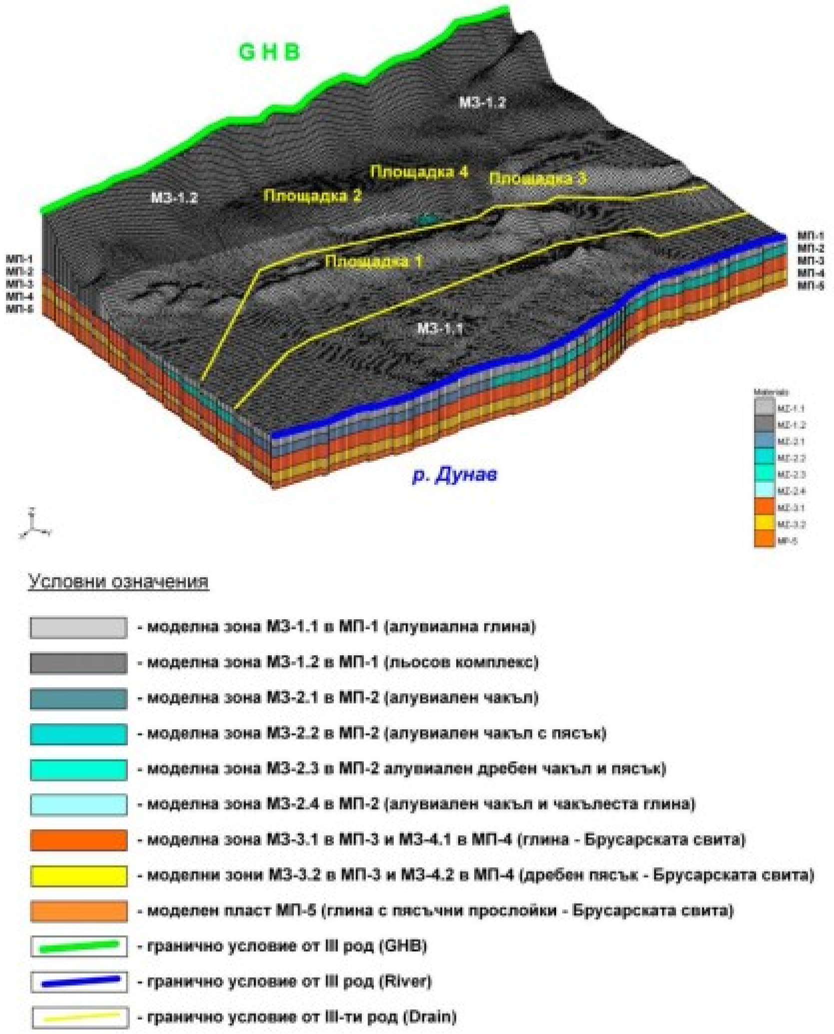


FIGURE 4.2-13: GEOMETRY OF THE MODELING LAYERS AND ZONES. BOUNDARY CONDITIONS

Legend: from top to bottom
Modeling zone MZ-1.1 in ML-1 (alluvial clay)
Modeling zone MZ-1.2 in ML-1 (loess complex)
Modeling zone MZ-2.1 in ML-2 (alluvial rubble)
Modeling zone MZ-2.2 in ML-2 (alluvial rubble with sand)
Modeling zone MZ-2.3 in ML-2 (alluvial gravel with sand)
Modeling zone MZ-2.4 in ML-2 (alluvial rubble and rubble clay)
Modeling zone MZ-3.1 in ML-3 and MZ-4.1 in ML-4 (clay - Brusartsi Formation)
Modeling zone MZ-3.2 in ML-3 and MZ-4.2 in ML-4 (small sand - Brusartsi Formation)
Modeling layer ML-5 (clay with sand layers – Brusartsi Formation)
Boundary condition of III type (GHB)
Boundary condition of III type (River)
Boundary condition of III type (Drain)

✓ The spatial discretization of the modeling area was made using a uniform orthogonal grid with 180 rows, 230 columns and 5 modeling layers – ML-1, ML-2, ML-3, ML-4 AND

ML-5. 12 modelling zones are determined in the modelling layers (**Figure 4.2-14**, **Figure 4.2-15, Figure 4.2-16** and **Figure 4.2-17**), distributed as follows:

- ML-1 includes modelling zones MZ-1.1 and MZ-1.2;
- ML-2 includes modelling zones MZ-2.1, MZ-2.1, MZ-2.1 and MZ-2.4;
- ML-3 includes modelling zones MZ-3.1 and MZ-3.2;
- ML-4 includes modelling zones MZ-4.1 and MZ-4.2.

✓ The relief and the hypsometric levels of the restrictive surfaces (the s. c. bottoms and tops) of the modelling layers and zones consider the morphological peculiarities of the terrain and the spatial forms and low rank units (see **Figure 4.2-18**, **Figure 4.2-19**, **Figure 4.2-20**, **Figure 4.2-21**, **Figure 4.2-22** and **Figure 4.2-23**). The Earth surface is set as the top of ML-1.

✓ The physical, hydrodynamic and migration characteristics are permanent within the determined modelling layers and zones. They are set in accordance with the values adopted for each layer and zone. For filtration coefficient in all modelling layers is taken the relation applied in modelling – *kx=ky=10kz*.

✓ The regional flow is modelled by simulating flow run off on part of the external boundaries of the modelling area under the GHB (*General Head Boundary*) scheme. In the cells along these boundaries it is adopted that the pressure equals the initially set pressure. The permeability used along the boundary is calculated in accordance with modelling layer width and the filtration coefficient in the layer or zone, where the respective modelling cell falls in. the Danube River is simulated as a three-dimensional object with the respective geometry and hydraulic characteristics. It is set with the boundary condition of III type (*River*). The adopted values of the river levels from west to east (downstream) are in the range of elevation 21.9 m to elevation 21.5 m, i. e. equal the water stands at times of low water.

✓ The draining channels are set as three-dimensional objects in the first modelling layer with the assumption that there is a direct hydraulic relation between them and the various lithological formations containing them. The geometry and the hydraulic characteristics of the facilities are adopted in accordance with their actual sizes, coordinates and constructive peculiarities. They are set with the boundary condition of III type (*Drain*). The adopted values of the levels from west to east in the southern channel are in the range of elevation 24.0 m to elevation 23.0 m, and in the northern channel from elevation 22.6 m to elevation 21.6 m.

✓ The infiltration feeding is set in the first modelling layer with the boundary condition of recharge (*Recharge*). Two zones with different infiltration speed are defined: northern zone - W1=8.5E-5 m/d and southern zone - W2=2.0E-4 m/d.

✓ The calibration of the main filtration model is done in accordance with the piezometric map drafted at low level of the Danube River.

✓ The formed filtration model determines the spatial distribution of the pressures, gradients and speed of groundwater in the region of the four sites and the territory to the first potential receiver – the Danube River. It is adopted as a basis for the development of the migration models.

Migration 3D models

The migration models are a three-dimensional simulation of the conditions for radionuclides movement in the aquifers within the reach of the potential source of pollution (the future NNU at Kozloduy NPP) to the first potential receiver – the Danube River.

Eight migration models were made, which present a long-term forecast for each of the four sites regarding the dispersion of the key radionuclides ^{3}H and ^{90}Sr after their possible entry into the groundwater under the foundation (described below). The precise location of the potential source of pollution (the foundation) for each site is presented on **Figure 4.2-6.**

The summary of the working schemes and input data used for the making of each of the eight migration models is as follows:

- They are composed by means of the program MT3D-MS (Zheng and Bennett, 1995; Zheng and Wang, 1998, etc.), using the above spatial discretization. As input data are used the gradients, speed and water quantities received through the filtration model.
- The computation scheme takes into account the convective transfer, irreversible elimination (radioactive decay), reversible elimination (sorption), mechanical dispersion, molecular diffusion and mixing.
- The presented values of the dry density p_d, longitudinal dispersion a_i and the coefficient of diffusion DM are set in the modelling layers. The values of the coefficient of distribution K_d in the migration models are set in accordance with the values of the different soil types in relation to the key radionuclides ^{3}H and ^{90}Sr and are given in **Table 4.2-22**.
-

TABLE 4.2-22: DIFFERENT SOIL TYPES IN RELATION TO KEY RADIONUCLIDES ^{3}H AND ^{90}Sr

Site	Site 1		Site 2		Site 3		Site 4	
Isotope	^{3}H	^{90}Sr	^{3}H	^{90}Sr	^{3}H	^{90}Sr	^{3}H	^{90}Sr
Migration model No.	MM-1	MM-2	MM-3	MM-4	MM-5	MM-6	MM-7	MM-8

- The area of the of the concrete foundation plane projection on the boundary between the non-auriferous and the auriferous zone is set as an area source. The relative activity of ^{3}H and ^{90}Sr, set based on this area, changes in time in accordance with the forecast solutions obtained by the two-dimensional models A=f(t) in the monitoring points under the center of the foundation to the groundwater level – monitoring point № 2 for Site 2 and Site 4 and monitoring point № 3 for Site 1 and Site 3.
- The projected time in the models simulating the migration of the relatively more stable ^{90}Sr is 10000 years, while the projections for the short-lived ^{3}H are for a period of 3000 years.

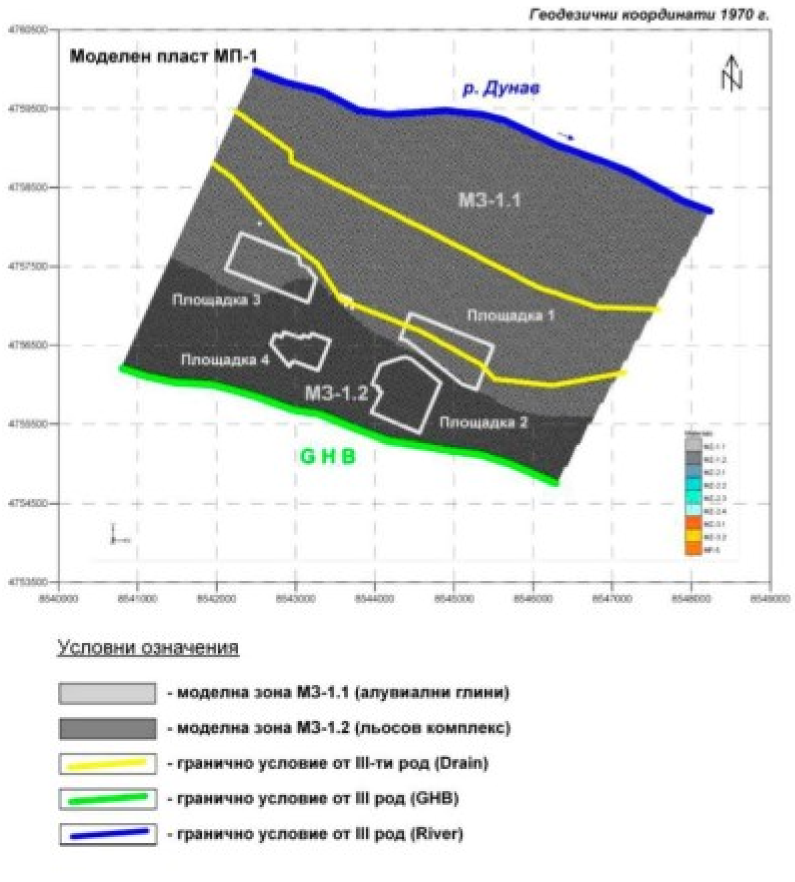


FIGURE 4.2-14: MODELING ZONES AND BOUNDARY CONDITIONS IN ML-1

Legend: from top to bottom:
Modeling zone MZ-1.1 (alluvial clay)
Modeling zone MZ-1.2 (loess complex)
Boundary condition of III type (Drain)
Boundary condition of III type (GHB)
Boundary condition of III type (River)

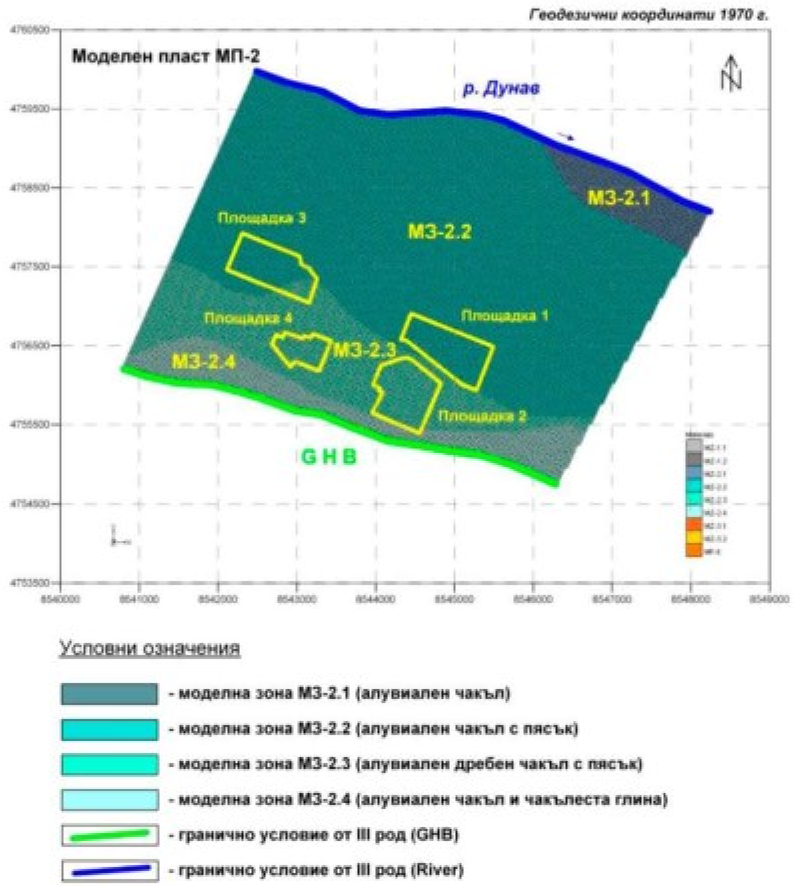


FIGURE 4.2-15: MODELING ZONES AND BOUNDARY CONDITIONS IN ML-2

Legend: from top to bottom:
Modeling zone MZ-2.1 (alluvial rubble)
Modeling zone MZ-2.2 (alluvial rubble with sand)
Modeling zone MZ-2.3 (alluvial gravel with sand)
Modeling zone MZ-2.4 (alluvial rubble and rubble clay)
Boundary condition of III type (GHB)
Boundary condition of III type (River)

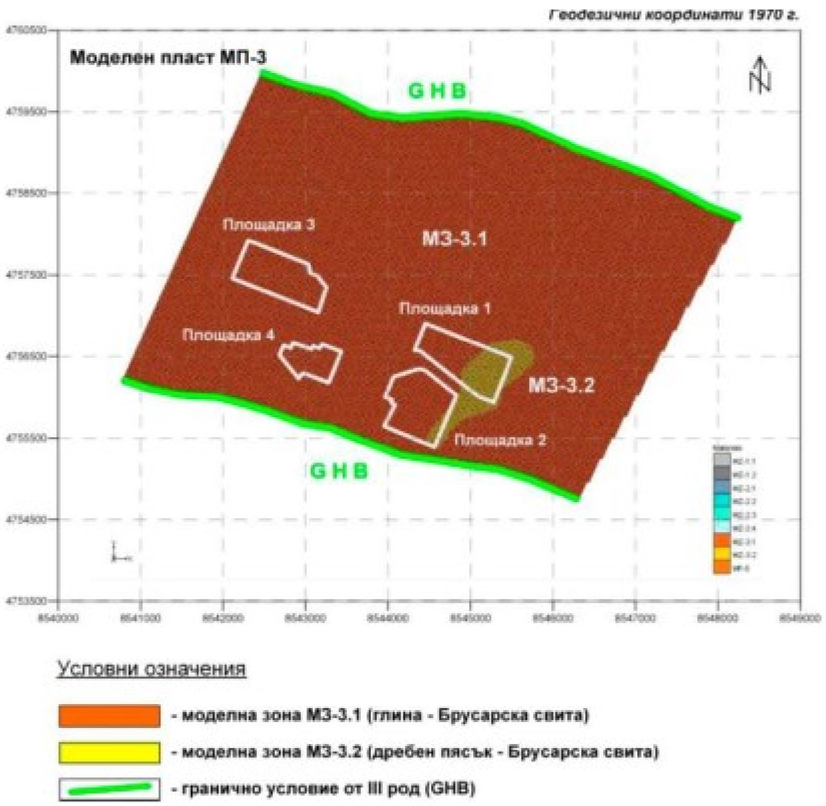


FIGURE 4.2-16: MODELING ZONES AND BOUNDARY CONDITIONS IN ML-3

Legend: from top to bottom:
Modeling zone MZ-3.1 (clay - Brusartsi Formation)
Modeling zone MZ-3.2 (small sand - Brusartsi Formation)
Boundary condition of III type (GHB)

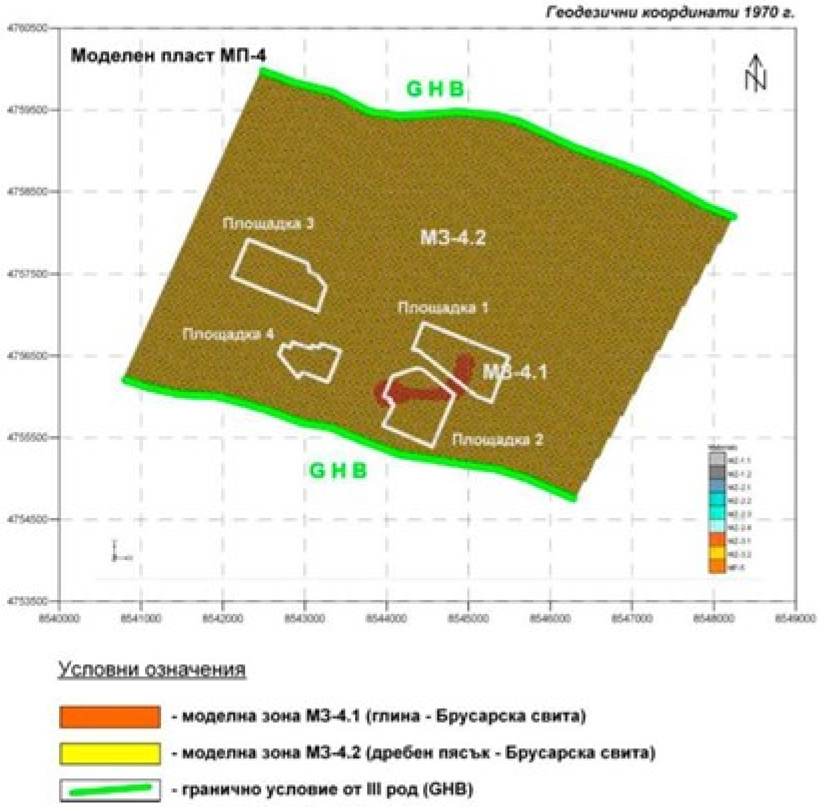


FIGURE 4.2-17: MODELING ZONES AND BOUNDARY CONDITIONS IN ML-4

Legend: from top to bottom:
Modeling zone MZ-4.1 (clay - Brusartsi Formation)
Modeling zone MZ-4.2 (small sand - Brusartsi Formation)
Boundary condition of III type (GHB)

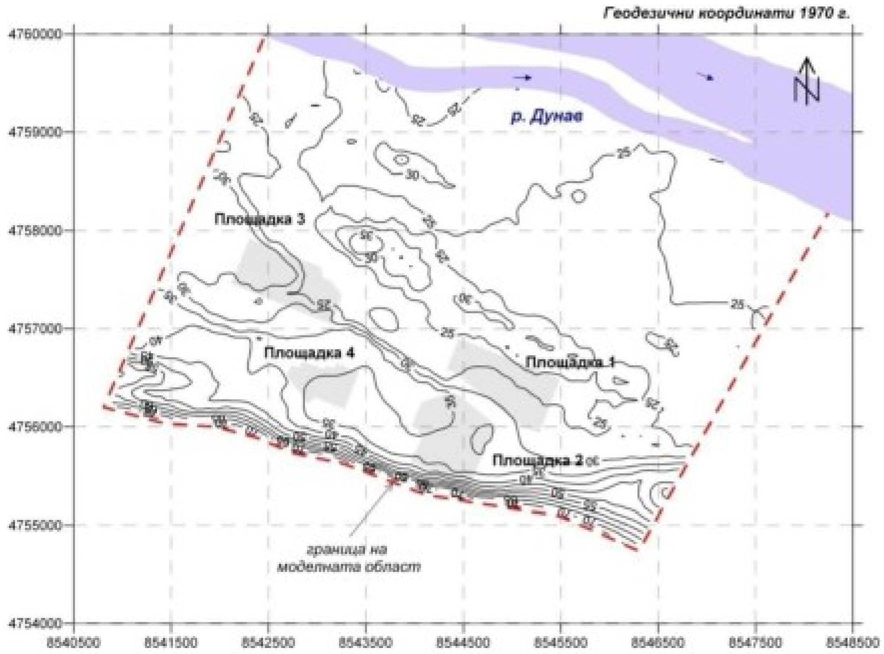


FIGURE 4.2-18: RELIEF OF THE TOP OF MODELING LAYER ML-1

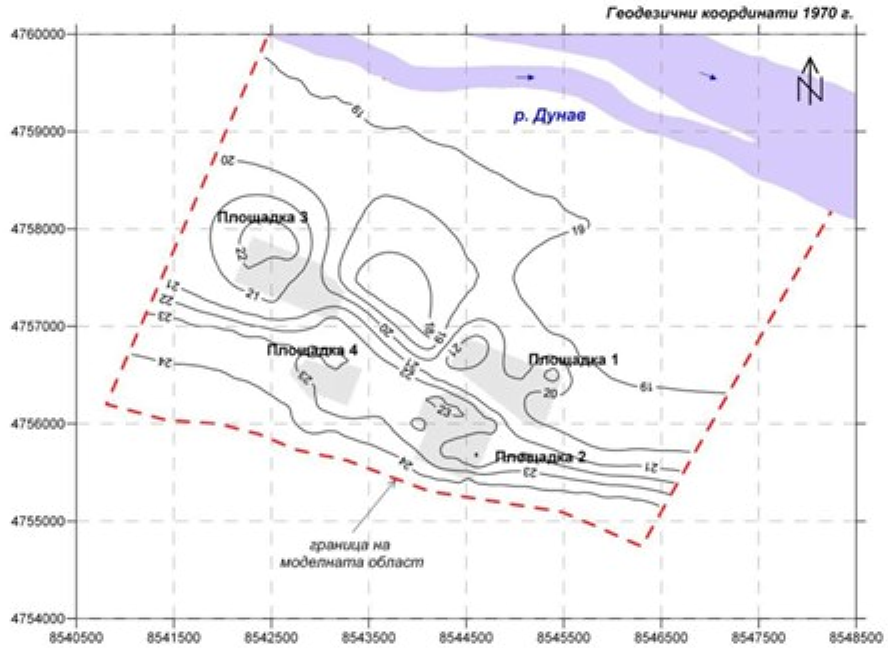


FIGURE 4.2-19: RELIEF OF THE BOTTOM OF MODELING LAYER ML-1

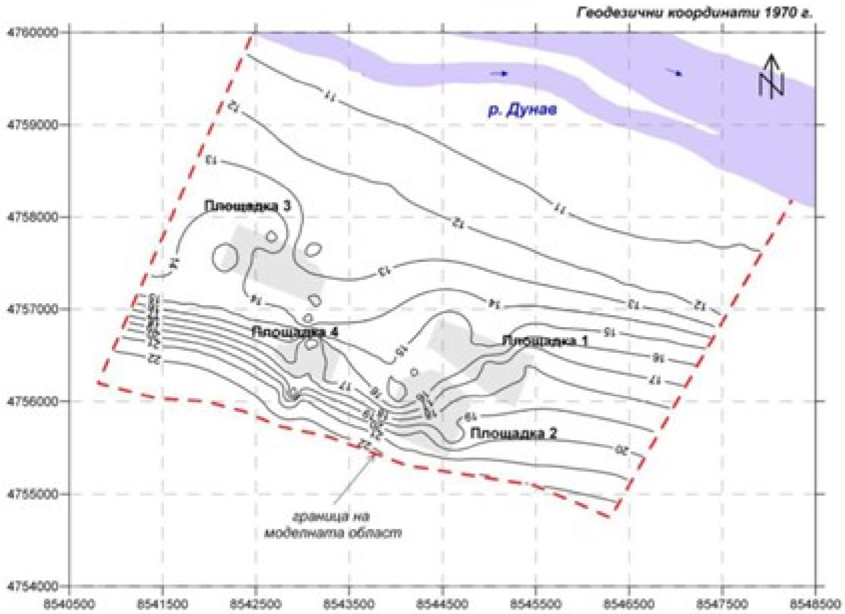


Figure 4.2-20: Relief of the top of modeling layer ML-2

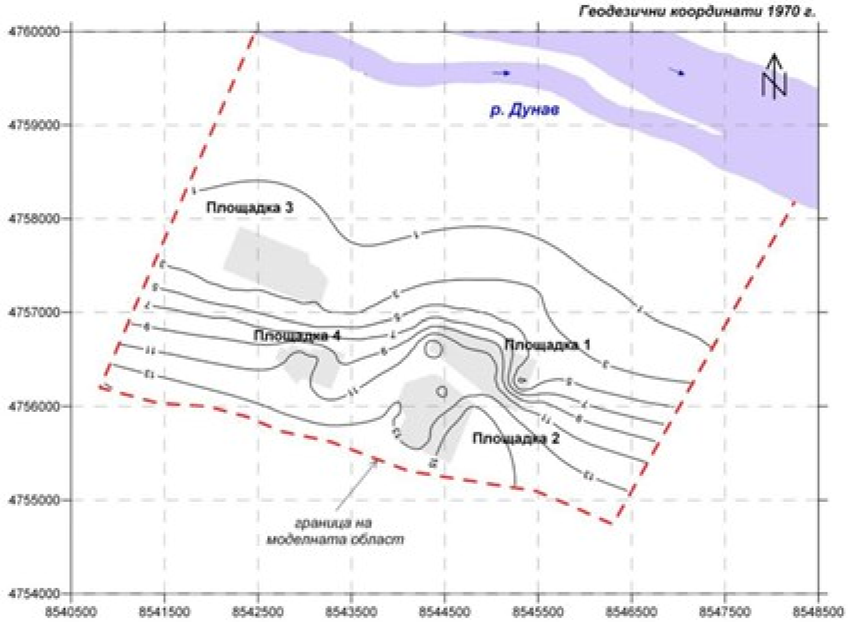


Figure 4.2-21: Relief of the bottom of modeling layer ML-3

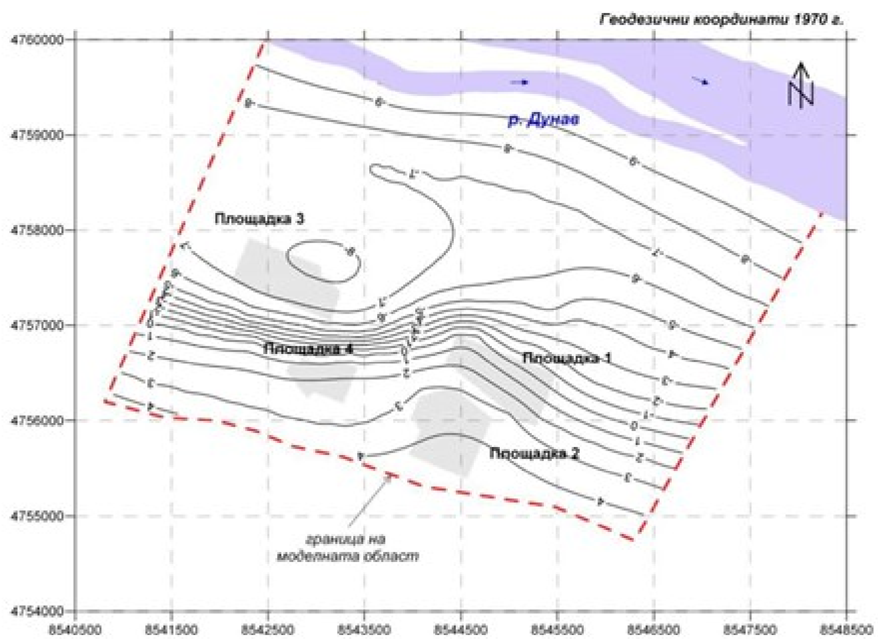


FIGURE 4.2-22: RELIEF OF THE TOP OF MODELING LAYER ML-4

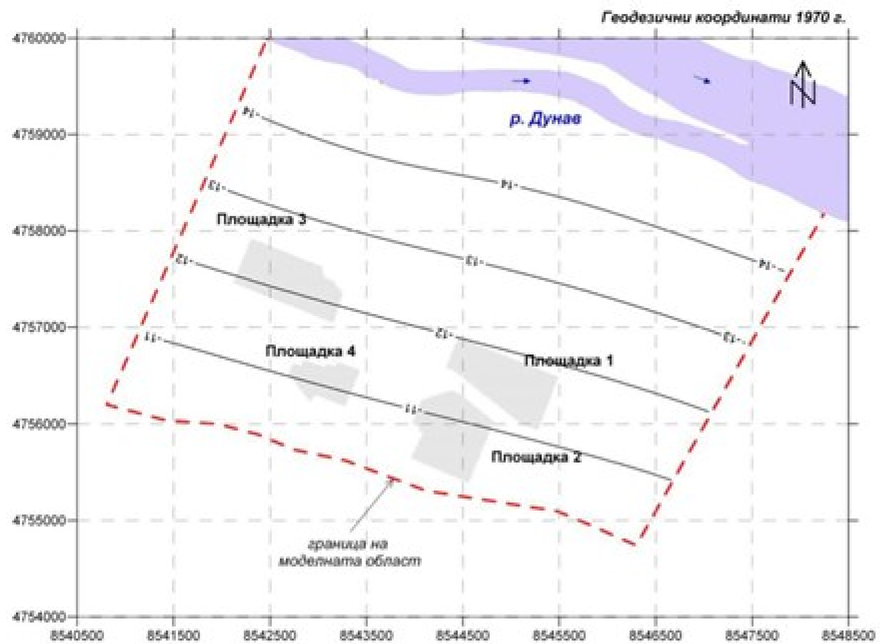


FIGURE 4.2-23: RELIEF OF THE BOTTOM OF MODELING LAYER ML-5

4.2.2.1.5.3 Results of the mathematical modelling

Structure of the groundwater flow

Figure 4.2-24 presents the structure of the filtration field in the region of the four sites and the territory to the first water receiver the Danube River obtained through the filtration 3D model. The obtained good conformity between the actual (real) and modelled piezometry is proof of its sufficient reliability and of the reliability of the obtained solutions.

The modelling solution presented in **Figure 4.2-24** shows that within the modelling area the groundwater flow is directed to northeast. Water from the loess complex, the old terraces and the Brusartsi Formation are drained in the non-flooding and flooding terraces after which the groundwater flow is directed to northeast – to the Danube River. It is to be expected that the radionuclides coming to the region of the four sites will affect the groundwater in the non-flooding and flooding terraces. In depth, reaching the neogene clay cushion, radionuclides will gradually start migrating laterally following the direction of the groundwater flow to north-northeast – towards the Danube River.

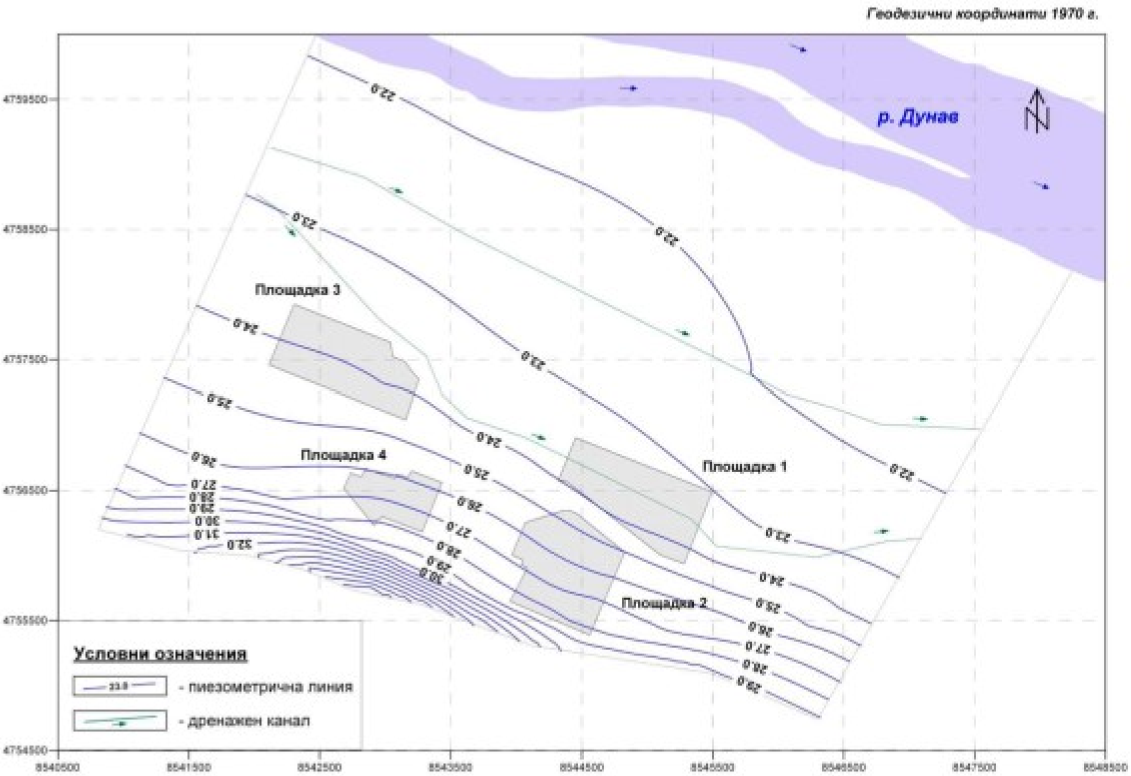


FIGURE 4.2-24: MAIN FILTRATION 3D MODEL. STRUCTURE OF THE GROUNDWATER FLOW IN THE QUATERNARY AQUIFER (THE TERRACE OF THE DANUBE RIVER)

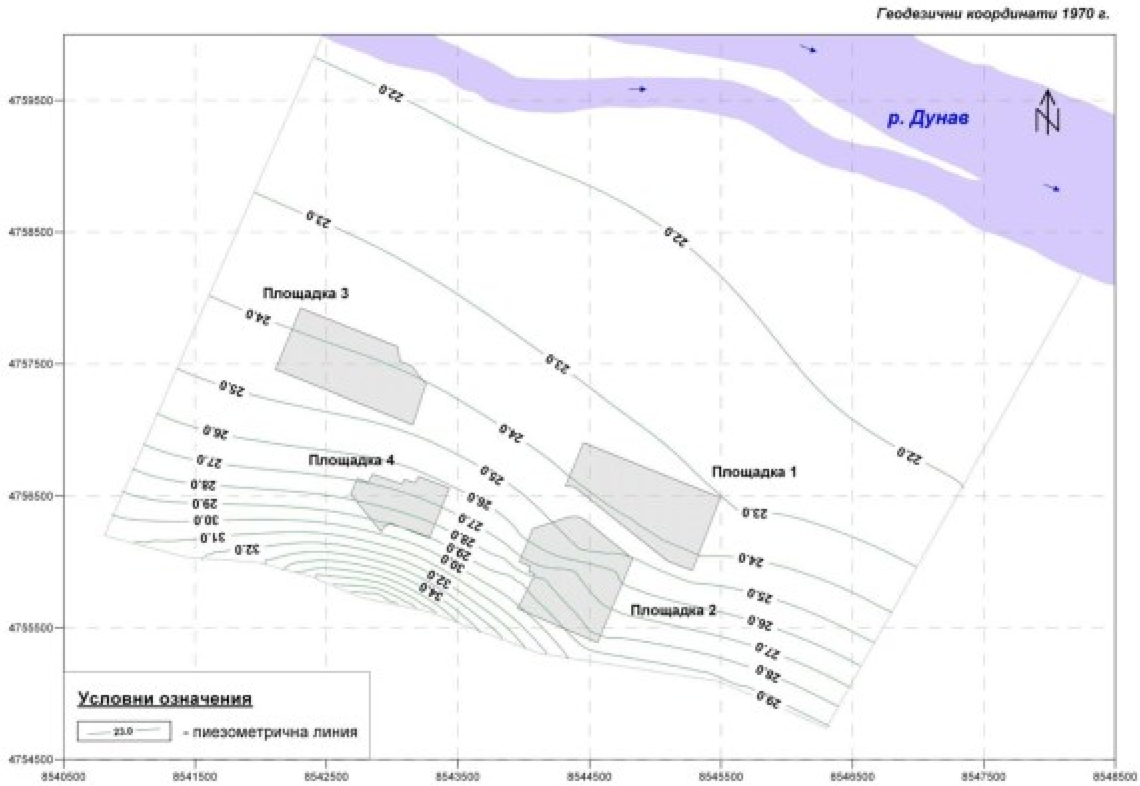


FIGURE 4.2-25: MAIN FILTRATION 3D MODEL. STRUCTURE OF THE GROUNDWATER FLOW IN THE NEOGENE AQUIFER (BRUSARTSI FORMATION)

Water balance of the four sites

The main filtration 3D model defines the water balance of the hydrogeological units in the region of the four sites under consideration. In the developed filtration model the quaternary horizon is simulated by modelling layers ML-1 and ML-2, while the neogene horizon – by modelling layers ML-3, ML-4 and ML-5.

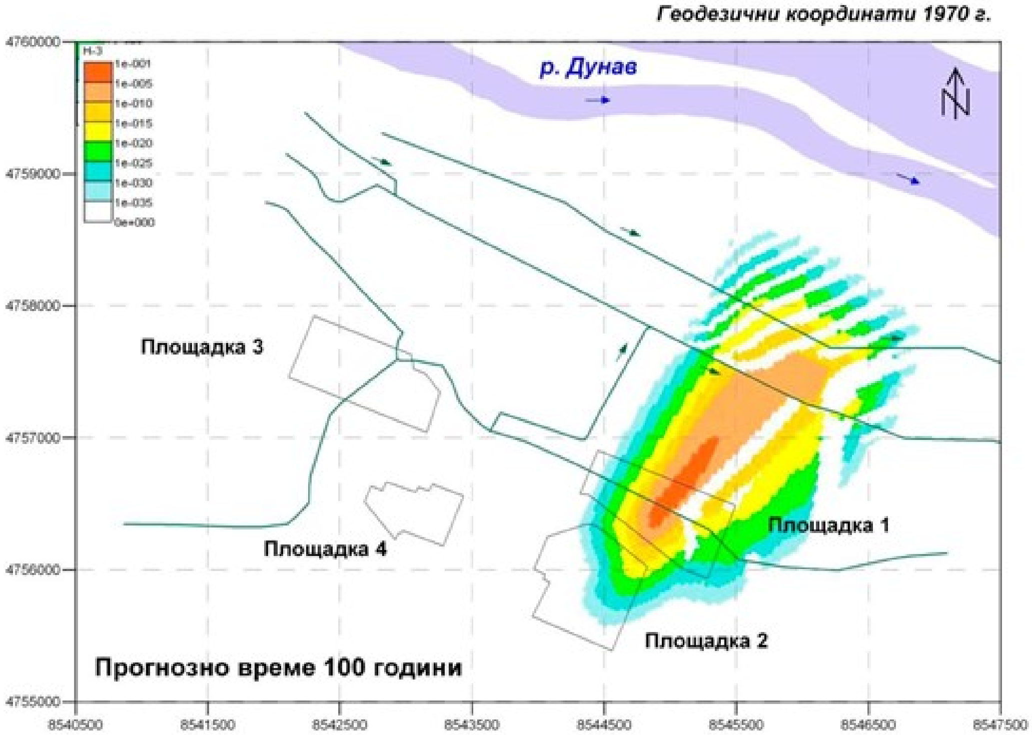
Migration of ^{3}H and ^{90}Sr into the groundwater

The results of the migration models used for the projected migration of ^{3}H and ^{90}Sr into the quaternary alluvial horizon, formed in the pebbles of the non-flooding and flooding terraces (layers 6, 7 and 8), are presented in series of figures - from **Figure 4.2-26** to **Figure 4.2-45**. The forecast solutions of the four sites illustrate the distribution of ^{3}H at four time moments – 100, 500, 1000 and 3000 years, while the solutions for ^{90}Sr are related to six time moments – 100, 500, 1000, 3000, 5000 and 10000 years after it enters the aquifer.

The modelling solutions for all sites show that the relative activity of the relatively short-lived isotope ^{3}H after about 3000 years will be quite insignificant (it is lower than 1E-40). The same tendency is observed in the migration projections for the more long-lived ^{90}Sr but after a more prolonged period of 10000 years.

For the forecast period the researched radionuclides migrate only within the quaternary aquifer (modelling layer ML-2) that forms the modern river terraces (layers 6, 7 and 8). They move in the direction of the groundwater flow to north-northeast – towards the first water receiver the Danube River. For less than 100 years the short-lived and actually non-absorbent isotopes (^{3}H) incoming from Site 1 and Site 3 reach the river. The same isotopes incoming from Site 2 and Site 4 will reach the river after about 200-300 years. In all cases, however, the relative activity of ^{3}H will be lower than 1E-10, i. e. the alleged activity range of this isotope in the first receiver will be much lower than the admissible limits. Meantime, the longer living but adsorbent by the filtration environment isotopes (^{90}Sr) incoming from the four sites have a very restricted distribution in the quaternary aquifer and would not reach the Danube River.

In depth, the migration of ^{3}H and ^{90}Sr is restricted by the thick and actually water impermeable neogene clays (layers 9 and 10), as well as by the higher hydraulic pressures in the auriferous sandy layers of the Brusartsi Formation (layer 11).



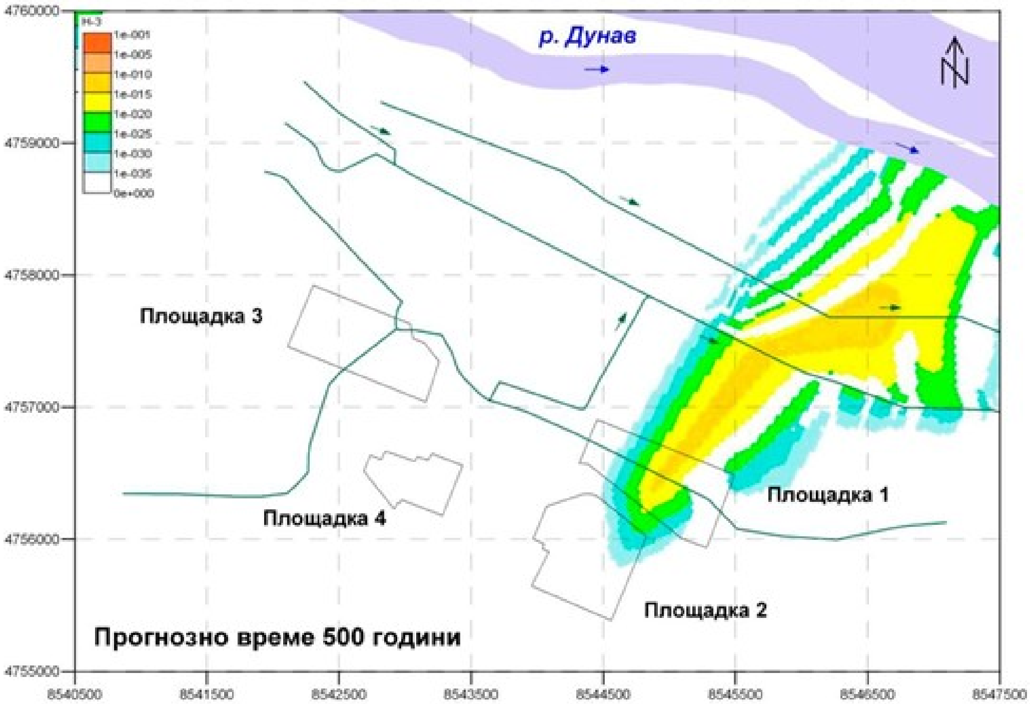


FIGURE 4.2-26: FORECAST MIGRATION OF ^{3}H ISOTOPE AT PROJECTED TIME OF 100 AND 500 YEARS AFTER ITS ENTRY INTO THE GROUNDWATER IN THE REGION OF SITE 1. MIGRATION MODEL MM-1

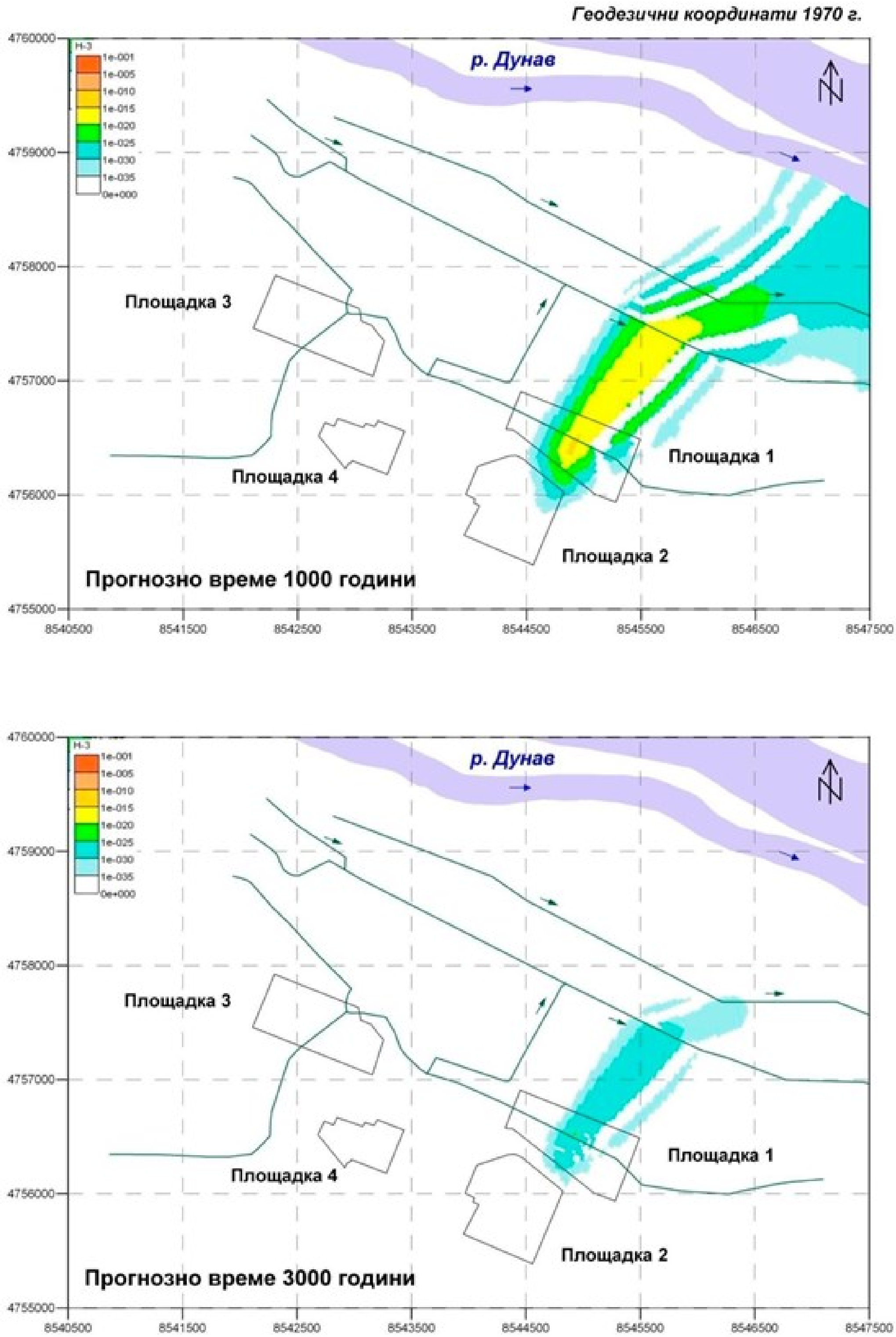


FIGURE 4.2-27: FORECAST MIGRATION OF ^{3}H ISOTOPE AT PROJECTED TIME OF 1000 AND 3000 YEARS AFTER ITS ENTRY INTO THE GROUNDWATER IN THE REGION OF SITE 1. MIGRATION MODEL MM-1

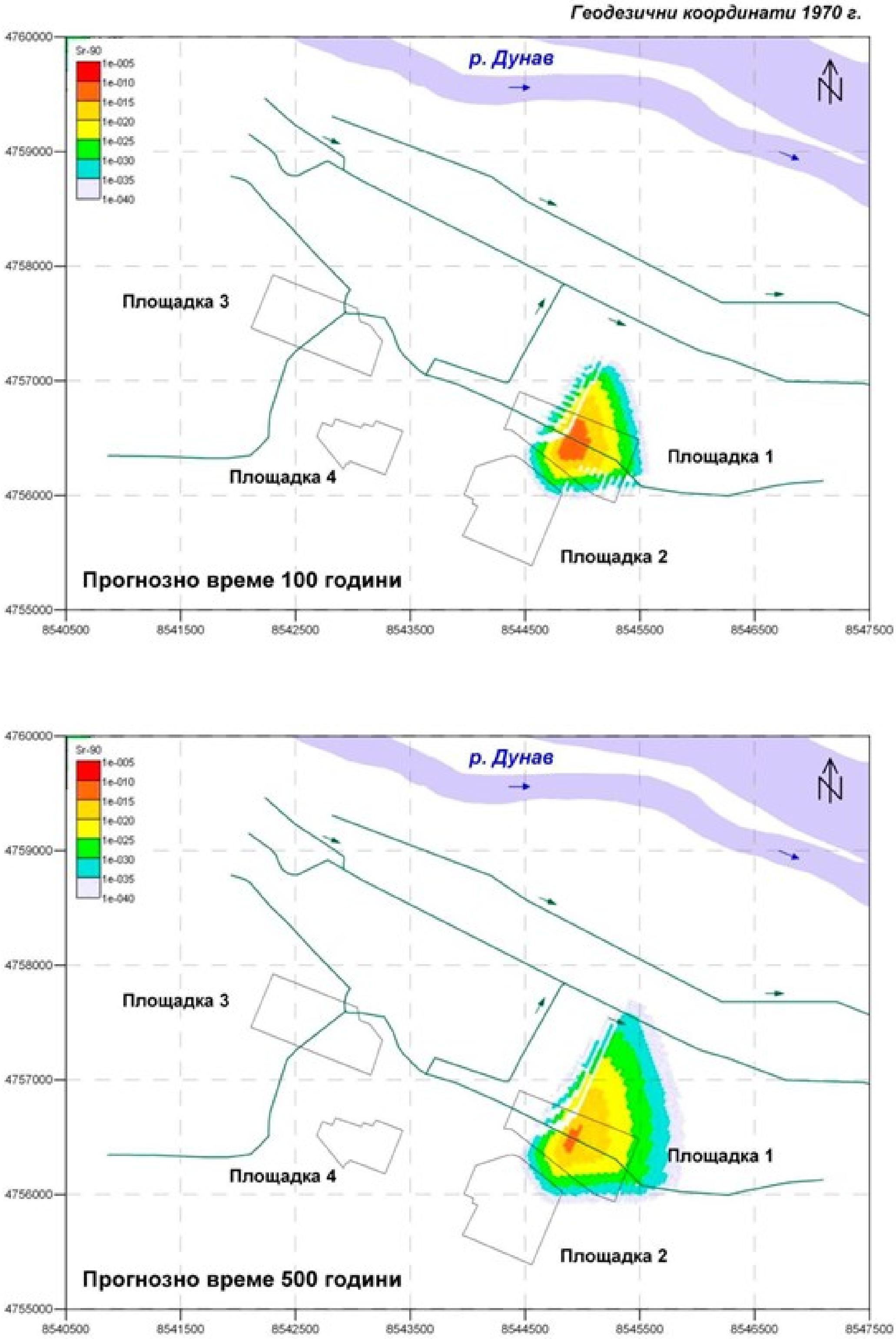


FIGURE 4.2-28: FORECAST MIGRATION OF ^{90}SR ISOTOPE AT PROJECTED TIME OF 100 AND 500 YEARS AFTER ITS ENTRY INTO THE GROUNDWATER IN THE REGION OF SITE 1. MIGRATION MODEL MM-2

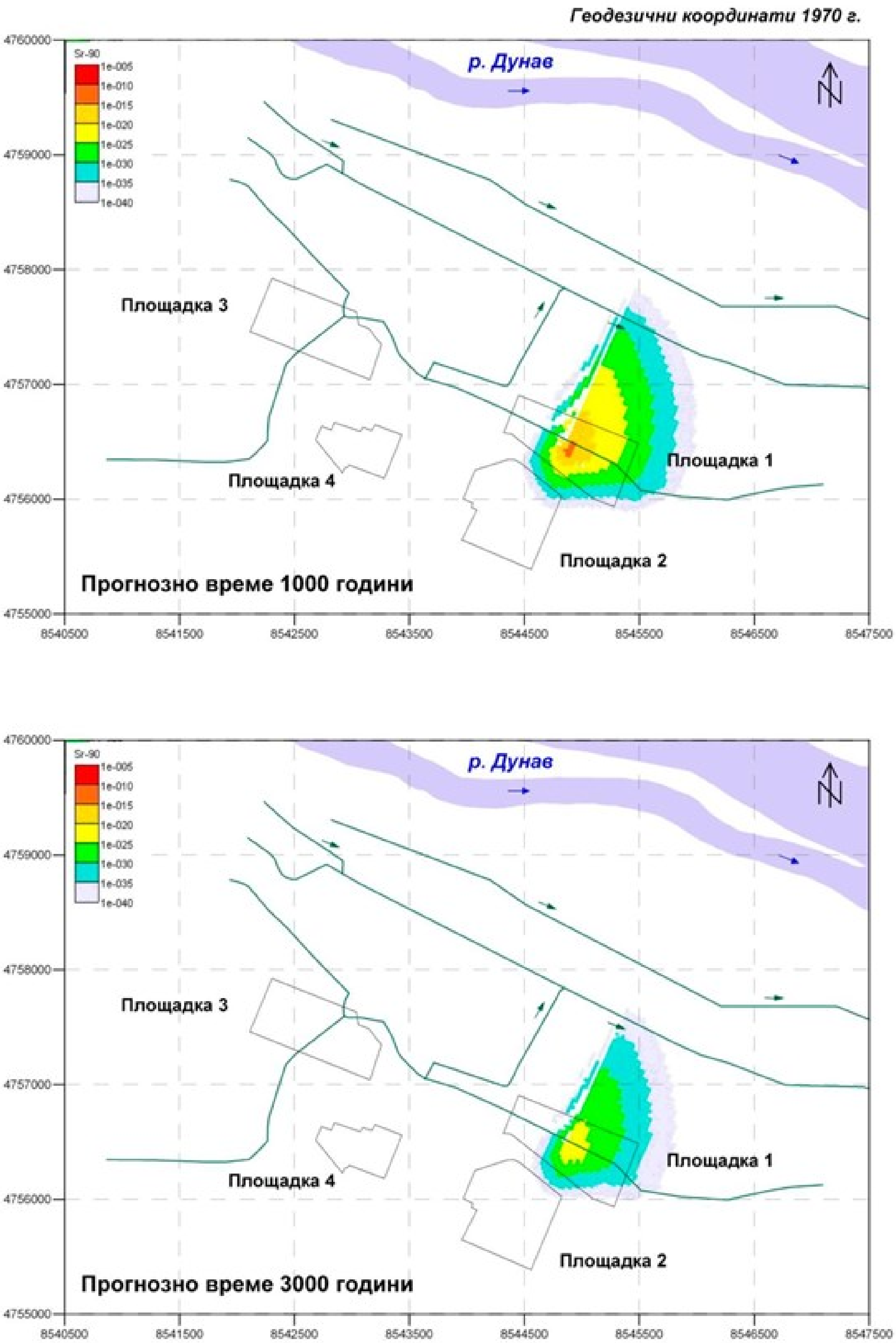


FIGURE 4.2-29: FORECAST MIGRATION OF ^{90}Sr ISOTOPE AT PROJECTED TIME OF 1000 AND 3000 YEARS AFTER ITS ENTRY INTO THE GROUNDWATER IN THE REGION OF SITE 1. MIGRATION MODEL MM-2

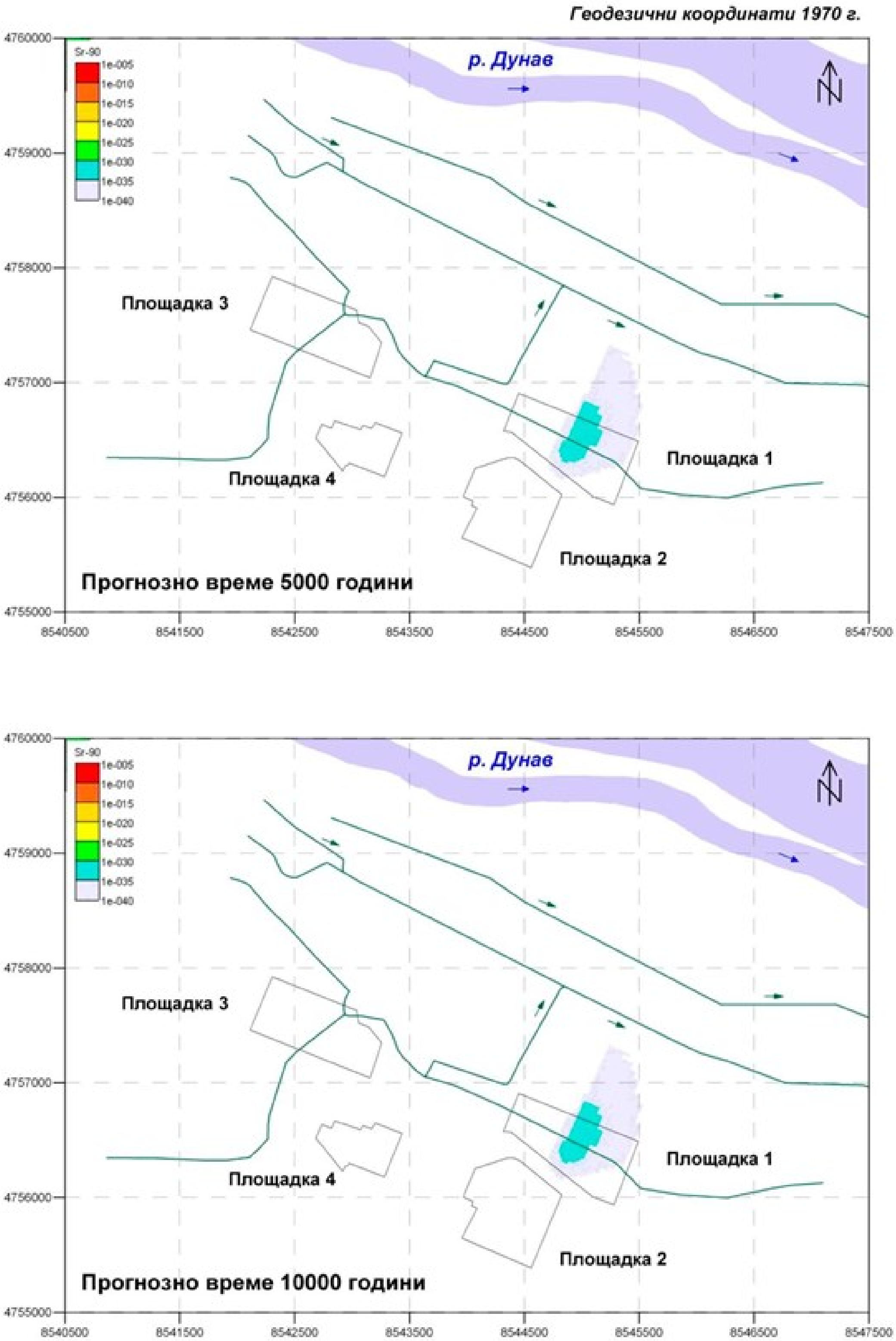


FIGURE 4.2-30: FORECAST MIGRATION OF ^{90}SR ISOTOPE AT PROJECTED TIME OF 5000 AND 10000 YEARS AFTER ITS ENTRY INTO THE GROUNDWATER IN THE REGION OF SITE 1. MIGRATION MODEL MM-2

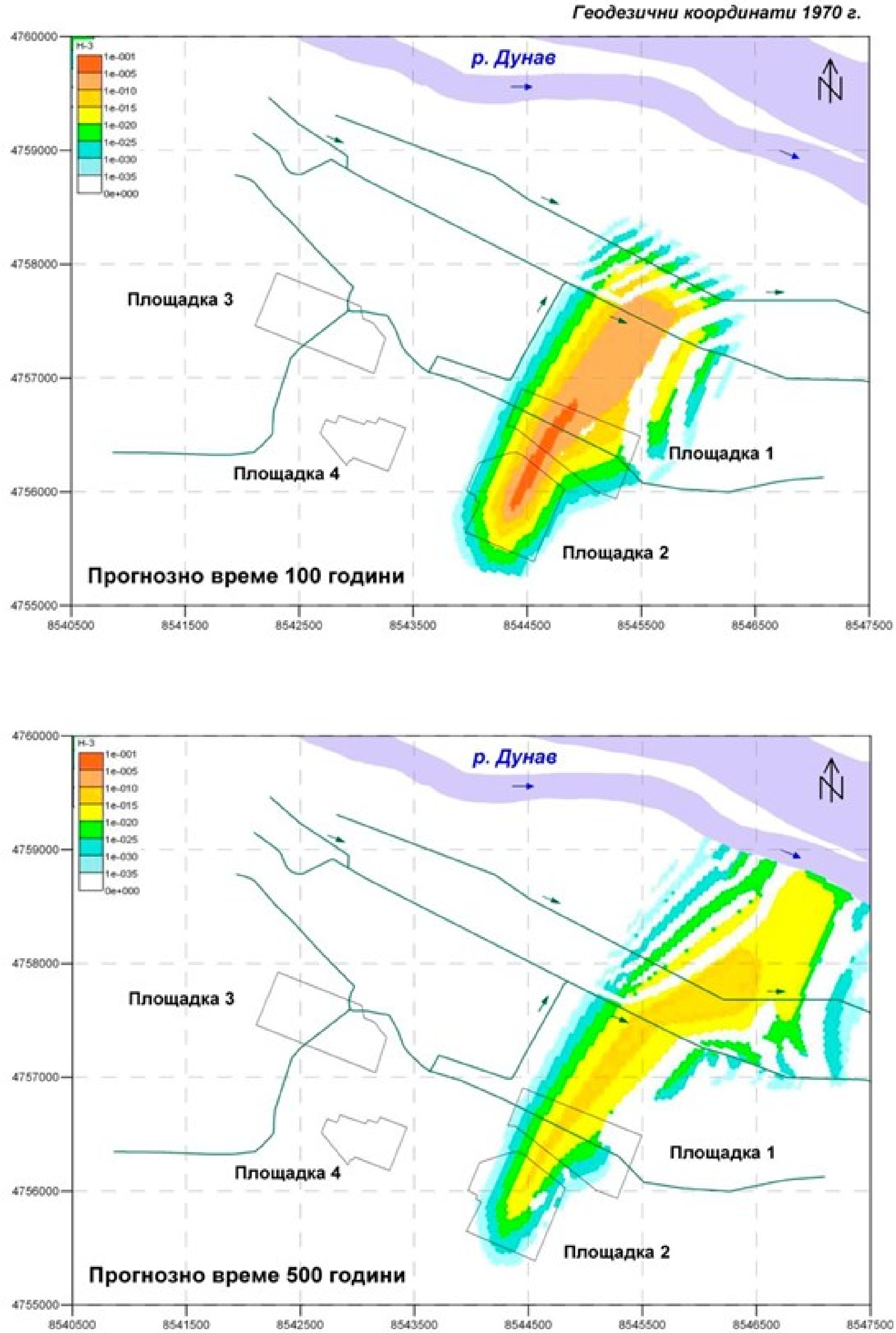
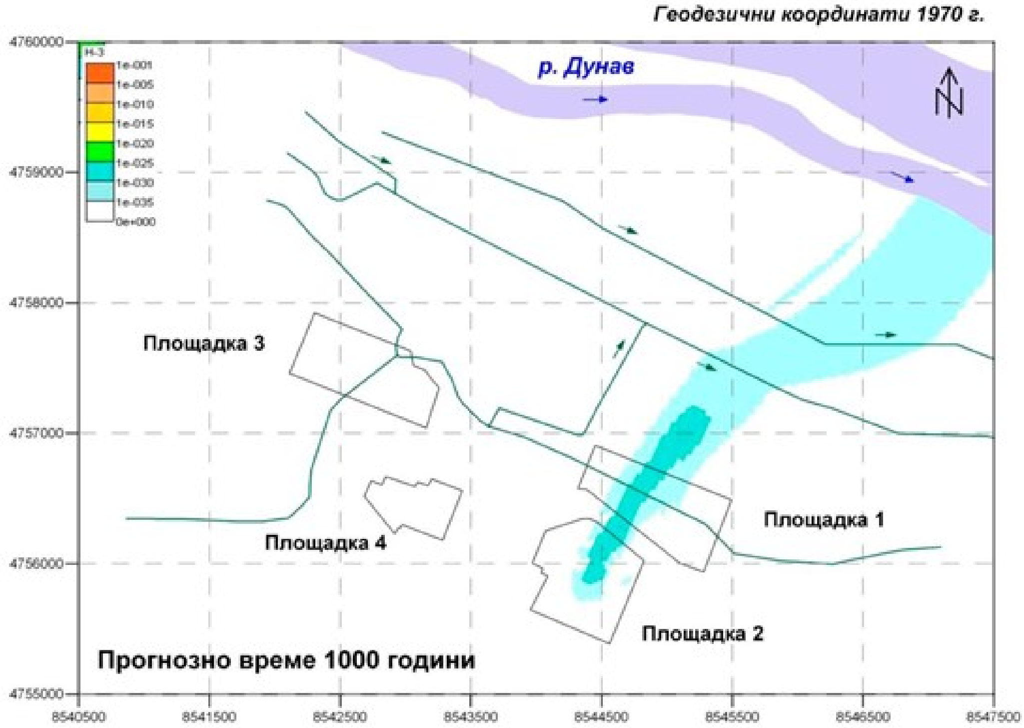


FIGURE 4.2-31: FORECAST MIGRATION OF ^{3}H ISOTOPE AT PROJECTED TIME OF 100 AND 500 YEARS AFTER ITS ENTRY INTO THE GROUNDWATER IN THE REGION OF SITE 2. MIGRATION MODEL MM-3



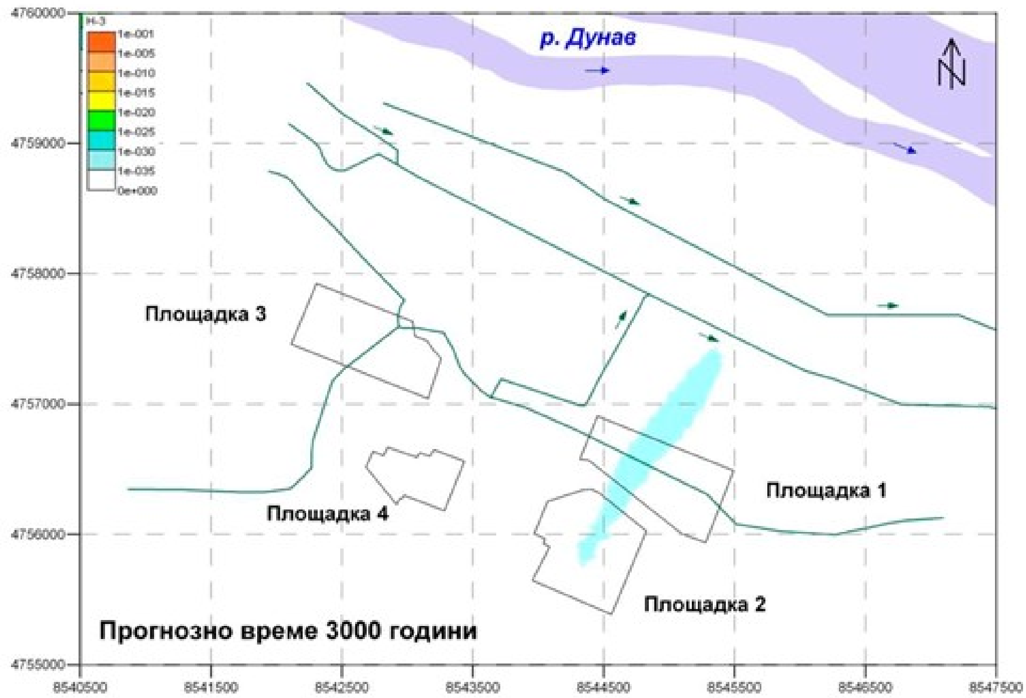


FIGURE 4.2-32: FORECAST MIGRATION OF ^3H ISOTOPE AT PROJECTED TIME OF 1000 AND 3000 YEARS AFTER ITS ENTRY INTO THE GROUNDWATER IN THE REGION OF SITE 2. MIGRATION MODEL MM-3

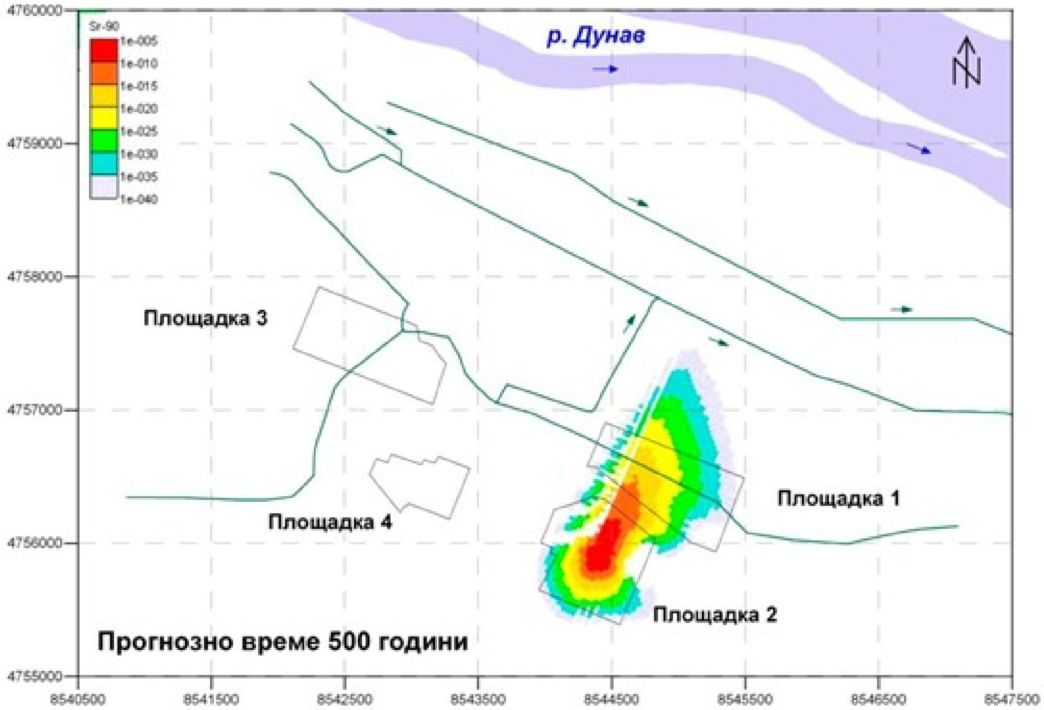


FIGURE 4.2-33: FORECAST MIGRATION OF ^{90}SR ISOTOPE AT PROJECTED TIME OF 100 AND 500 YEARS AFTER ITS ENTRY INTO THE GROUNDWATER IN THE REGION OF SITE 2. MIGRATION MODEL MM-4

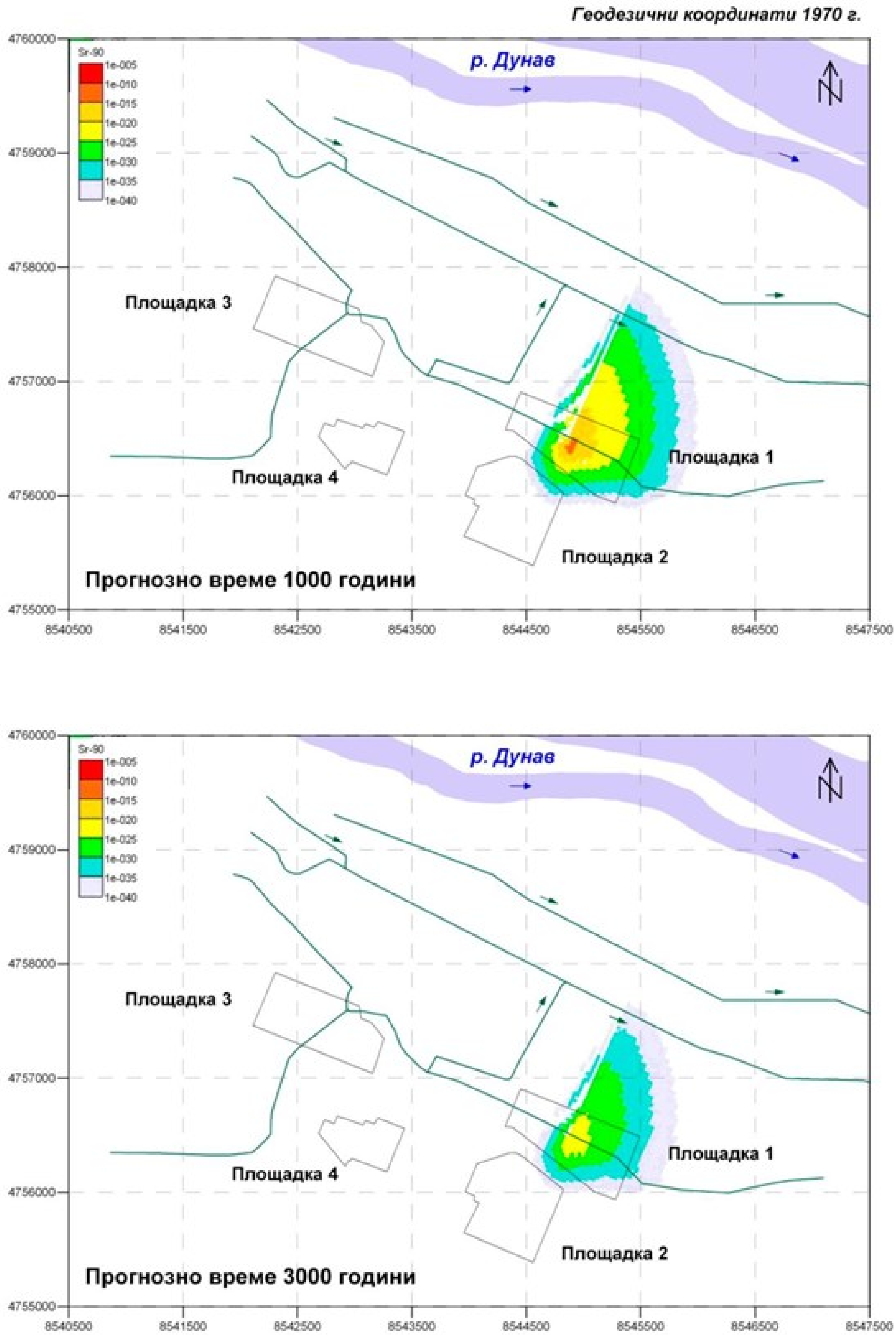


FIGURE 4.2-34: FORECAST MIGRATION OF 90SR ISOTOPE AT PROJECTED TIME OF 1000 AND 3000 YEARS AFTER ITS ENTRY INTO THE GROUNDWATER IN THE REGION OF SITE 2. MIGRATION MODEL MM-4

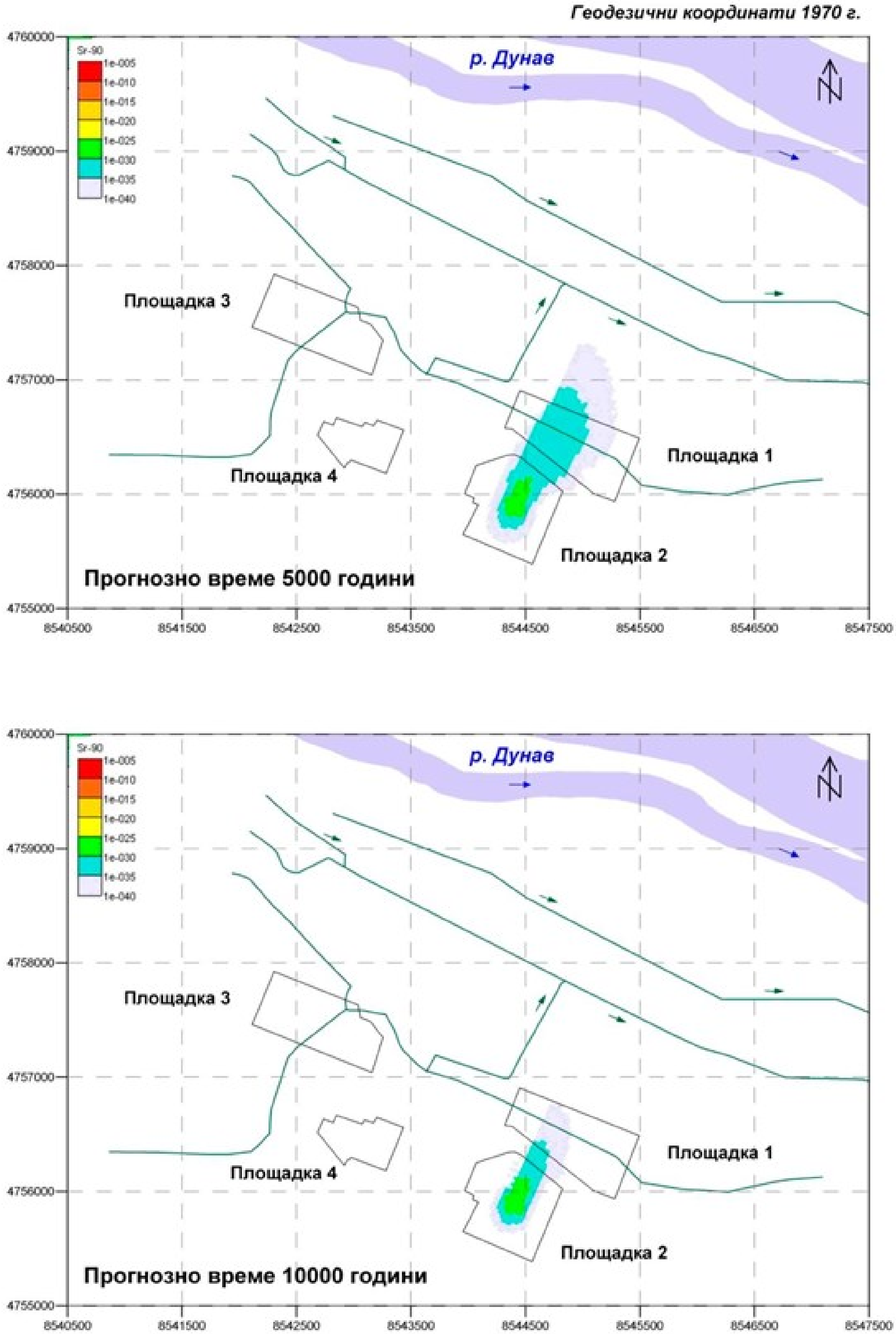
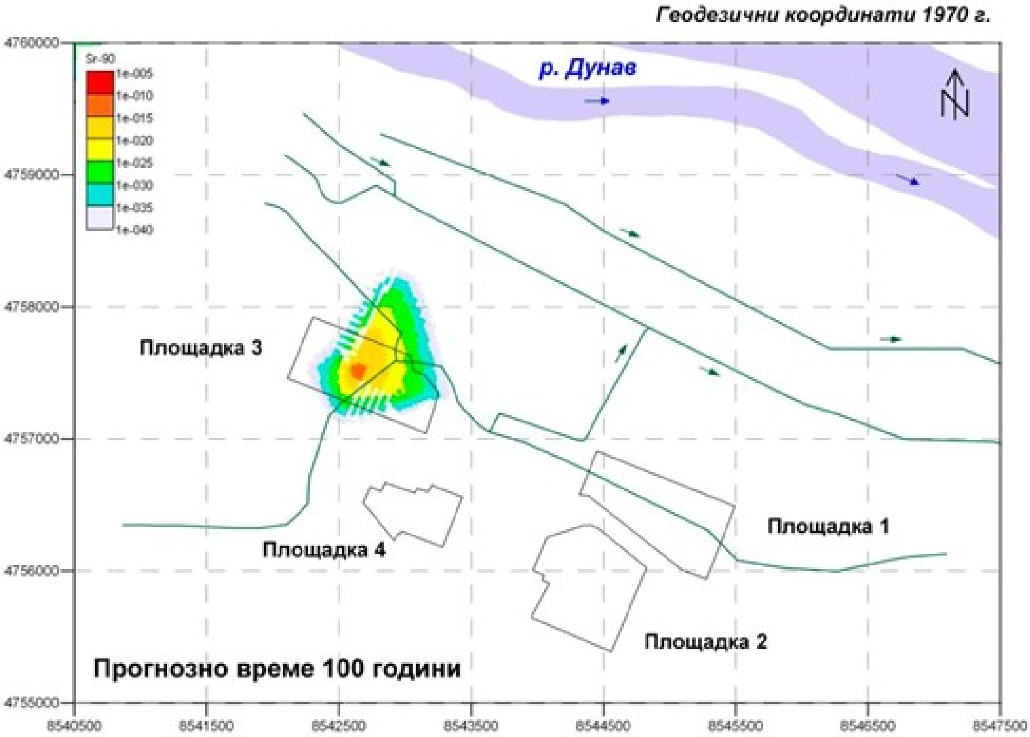


FIGURE 4.2-35: FORECAST MIGRATION OF ^{90}SR ISOTOPE AT PROJECTED TIME OF 5000 AND 10000 YEARS AFTER ITS ENTRY INTO THE GROUNDWATER IN THE REGION OF SITE 2. MIGRATION MODEL MM -4

FIGURE 4.2-36: FORECAST MIGRATION OF ^{3}H ISOTOPE AT PROJECTED TIME OF 100 AND 500 YEARS AFTER ITS ENTRY INTO THE GROUNDWATER IN THE REGION OF SITE 3. MIGRATION MODEL MM-5

FIGURE 4.2-37: FORECAST MIGRATION OF ^{3}H ISOTOPE AT PROJECTED TIME OF 1000 AND 3000 YEARS AFTER ITS ENTRY INTO THE GROUNDWATER IN THE REGION OF SITE 3. MIGRATION MODEL MM-5



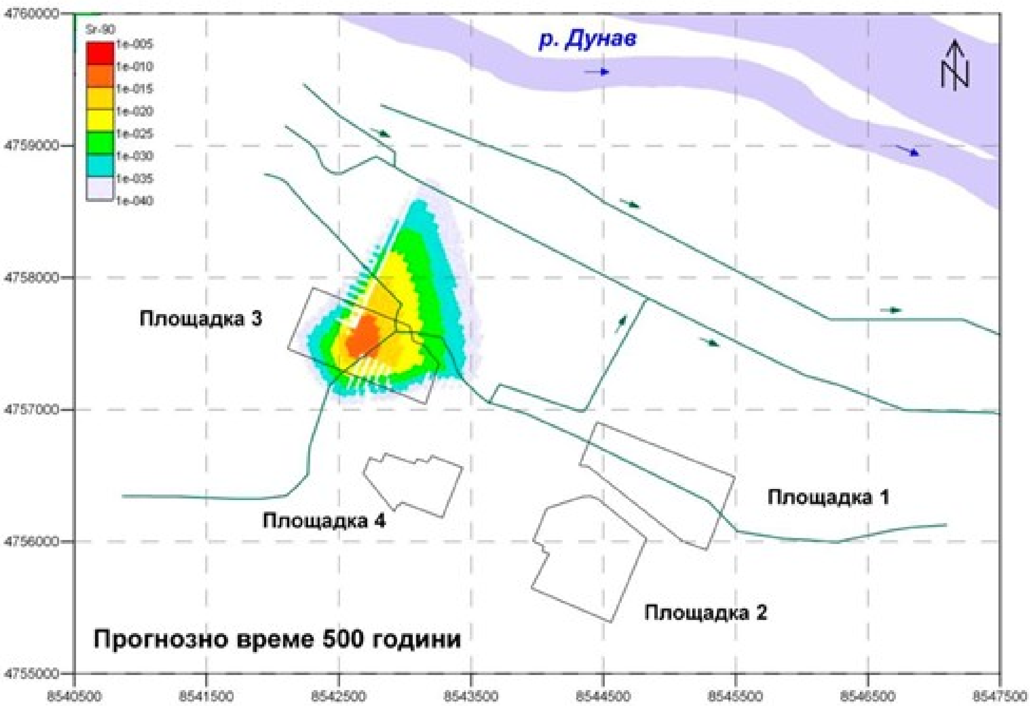


FIGURE 4.2-38: FORECAST MIGRATION OF ^{90}SR ISOTOPE AT PROJECTED TIME OF 100 AND 500 YEARS AFTER ITS ENTRY INTO THE GROUNDWATER IN THE REGION OF SITE 3. MIGRATION MODEL MM-6

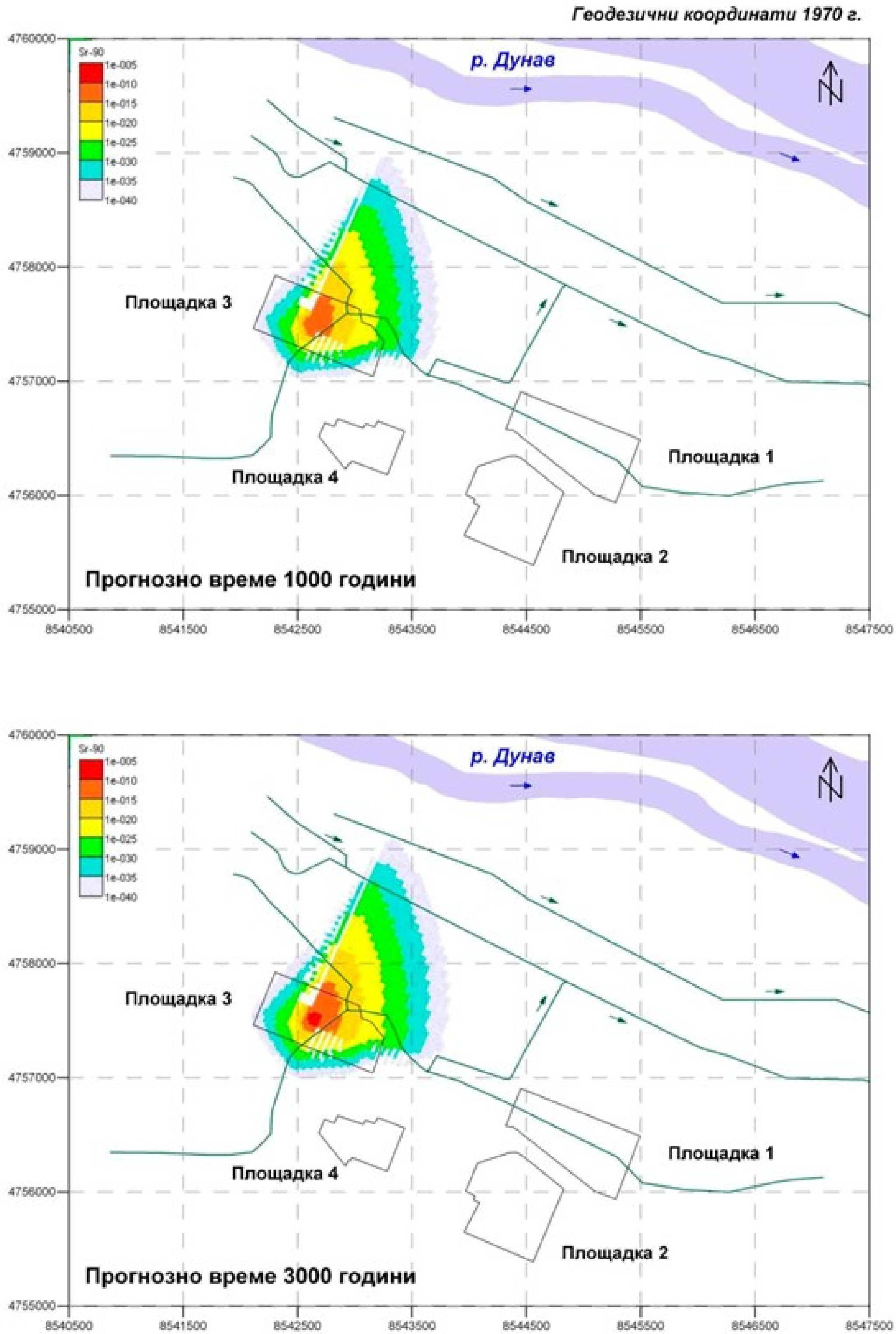


FIGURE 4.2-39: FORECAST MIGRATION OF ^{90}Sr ISOTOPE AT PROJECTED TIME OF 1000 AND 3000 YEARS AFTER ITS ENTRY INTO THE GROUNDWATER IN THE REGION OF SITE 3. MIGRATION MODEL MM-6

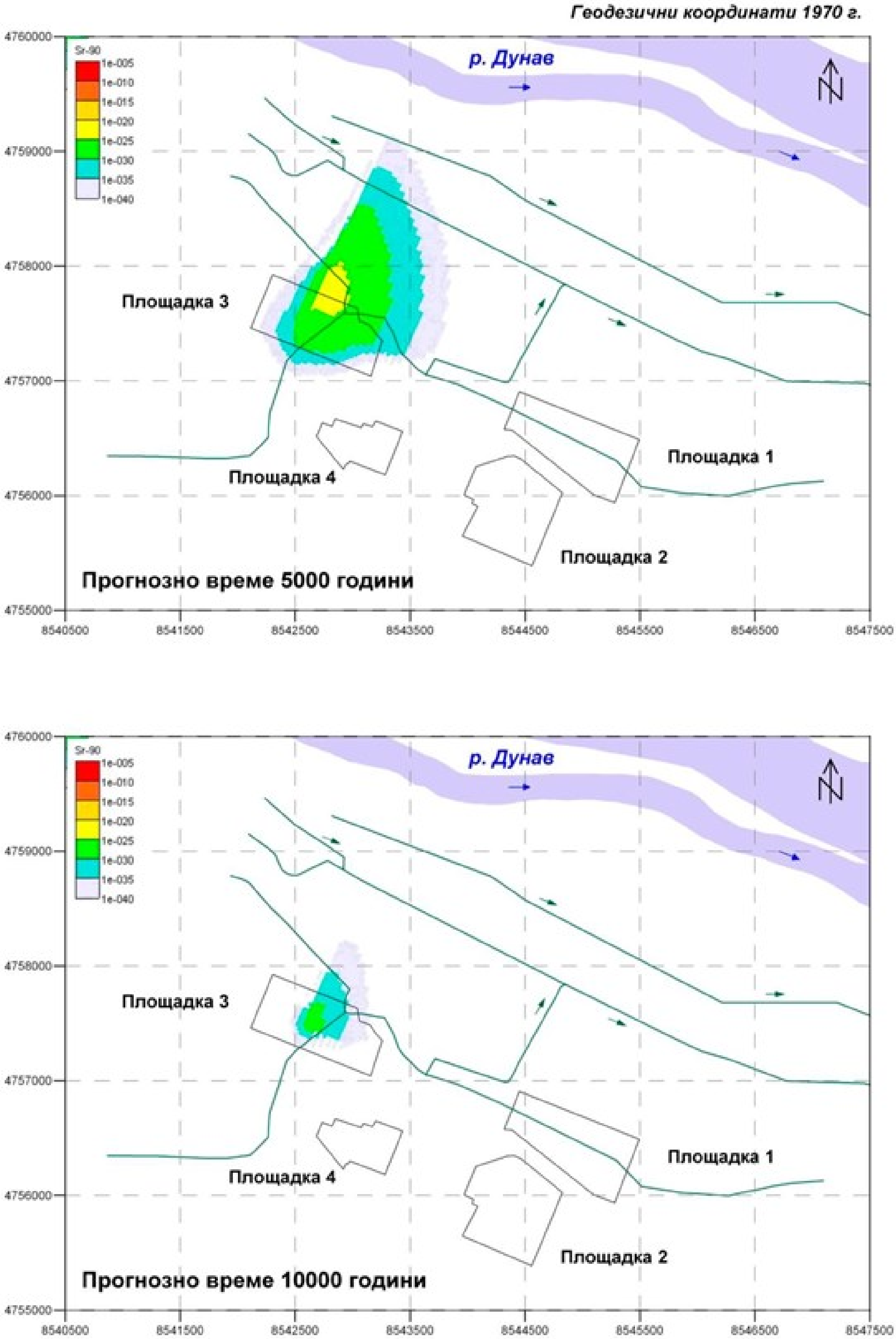


FIGURE 4.2-40: FORECAST MIGRATION OF ^{90}SR ISOTOPE AT PROJECTED TIME OF 5000 AND 10000 YEARS AFTER ITS ENTRY INTO THE GROUNDWATER IN THE REGION OF SITE 3. MIGRATION MODEL MM-6

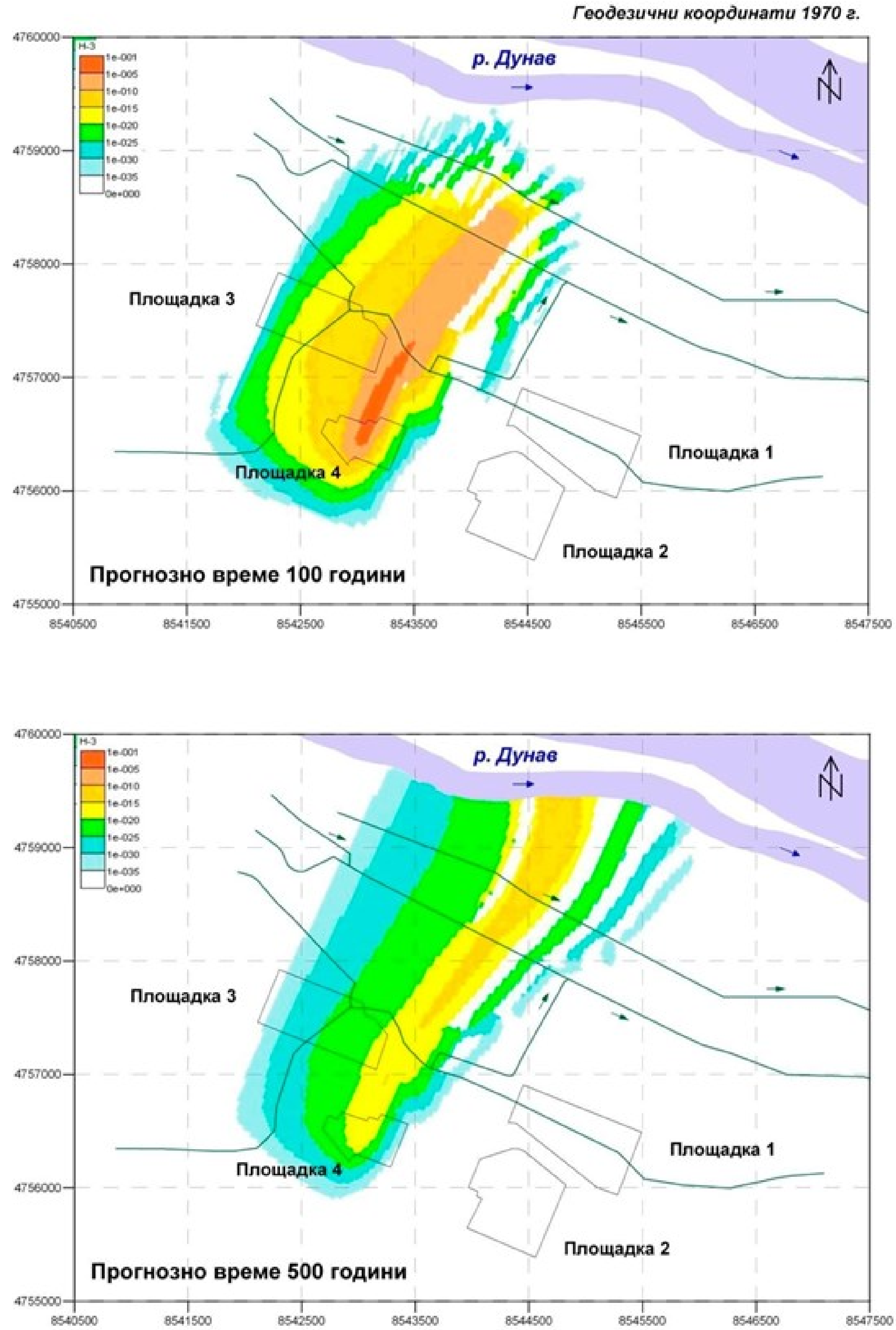


FIGURE 4.2-41: FORECAST MIGRATION OF ^{3}H ISOTOPE AT PROJECTED TIME OF 100 AND 500 YEARS AFTER ITS ENTRY INTO THE GROUNDWATER IN THE REGION OF SITE 4. MIGRATION MODEL MM-7

FIGURE 4.2-42: FORECAST MIGRATION OF ^{3}H ISOTOPE AT PROJECTED TIME OF 1000 AND 3000 YEARS AFTER ITS ENTRY INTO THE GROUNDWATER IN THE REGION OF SITE 4. MIGRATION MODEL MM-7

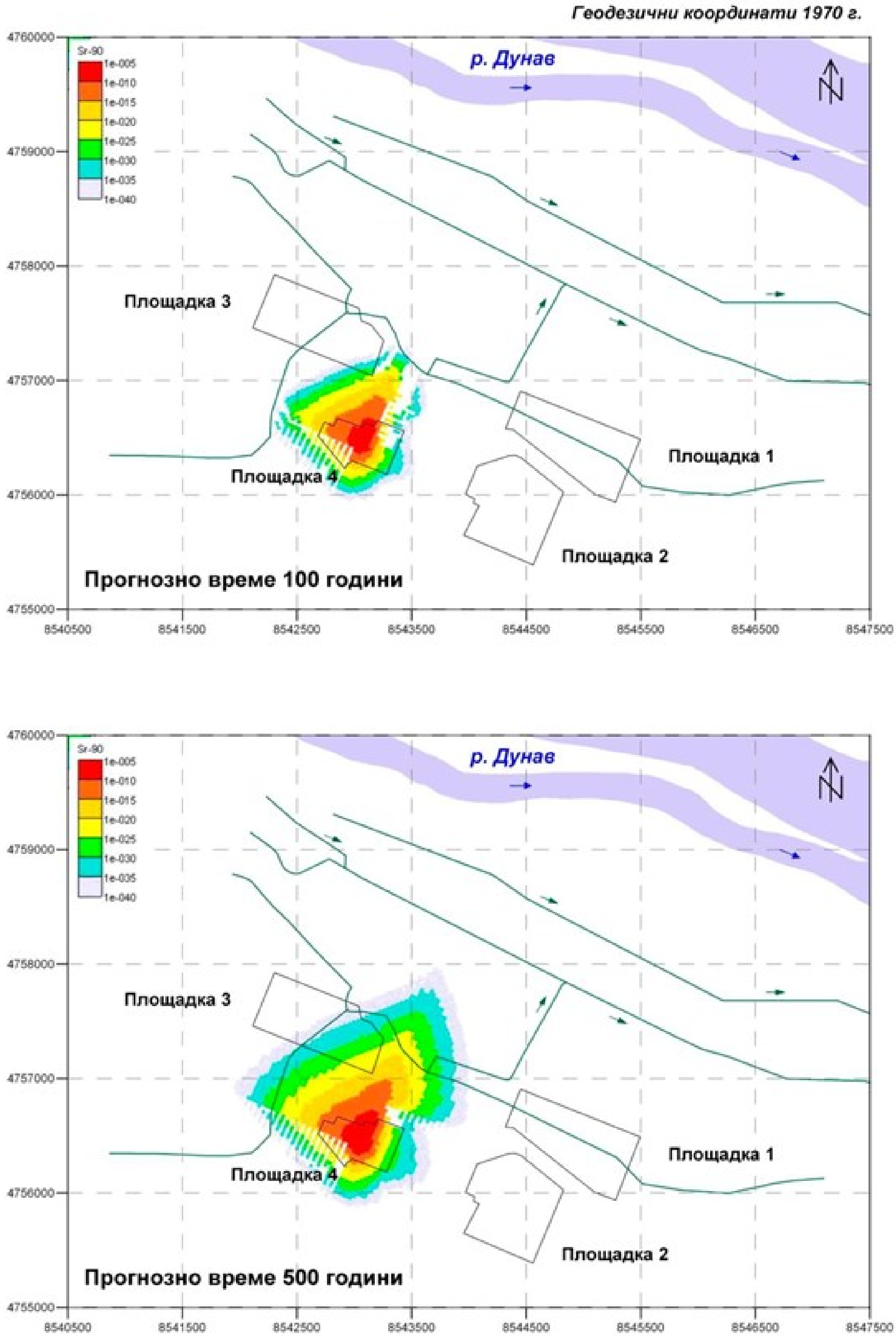


FIGURE 4.2-43: FORECAST MIGRATION OF ^{90}Sr ISOTOPE AT PROJECTED TIME OF 100 AND 500 YEARS AFTER ITS ENTRY INTO THE GROUNDWATER IN THE REGION OF SITE 4. MIGRATION MODEL MM-8

FIGURE 4.2-44: FORECAST MIGRATION OF ^{90}Sr ISOTOPE AT PROJECTED TIME OF 1000 AND 3000 YEARS AFTER ITS ENTRY INTO THE GROUNDWATER IN THE REGION OF SITE 4. MIGRATION MODEL MM-8

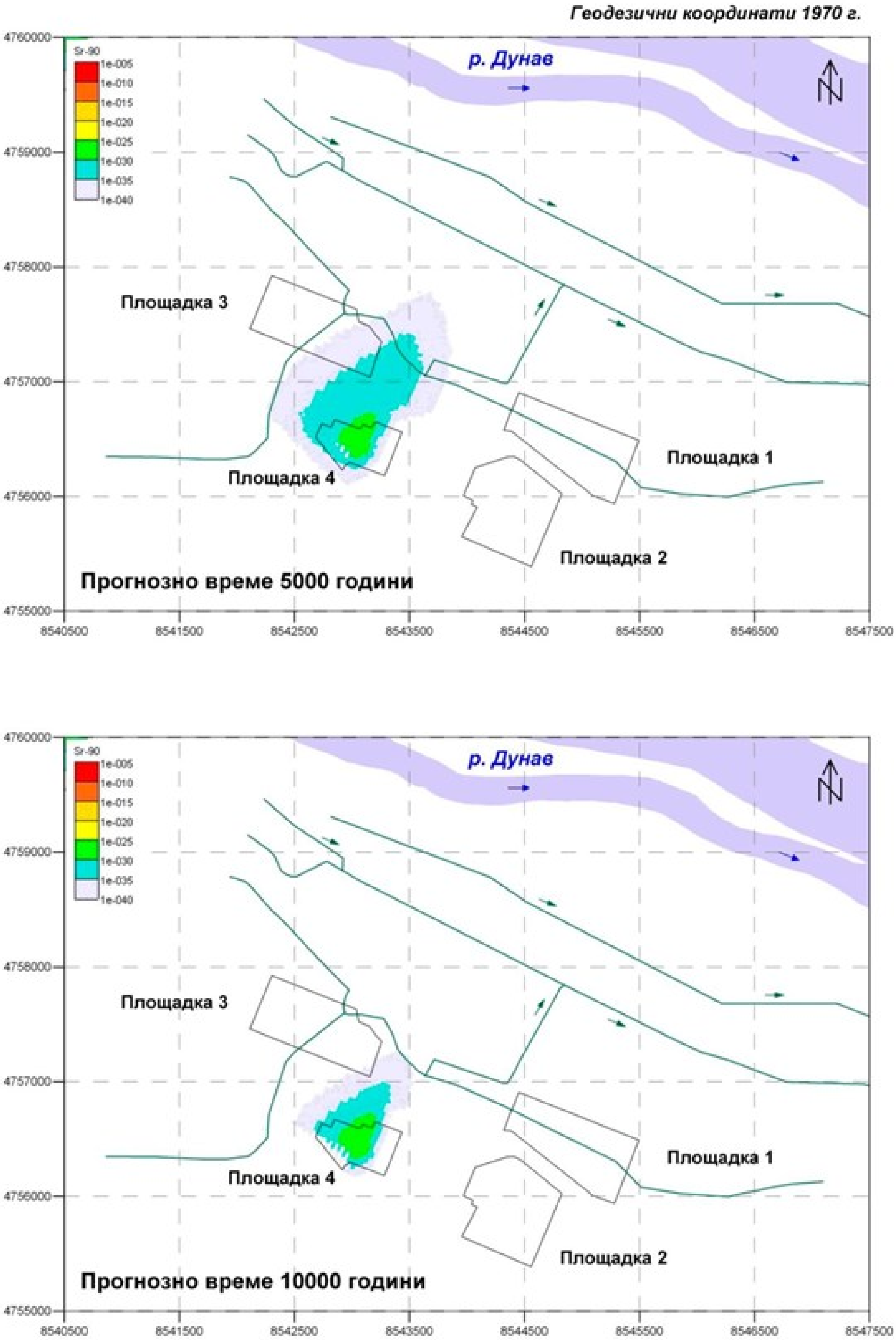


FIGURE 4.2-45: FORECAST MIGRATION OF ^{90}SR ISOTOPE AT PROJECTED TIME OF 5000 AND 10000 YEARS AFTER ITS ENTRY INTO THE GROUNDWATER IN THE REGION OF SITE 4. MIGRATION MODEL MM-8

4.2.2.1.5.4 Key findings and conclusions

By summarizing the received results from the mathematical modelling of the radionuclides migration from the four sides under consideration the following more important findings and conclusions can be drawn:

- The estimates have been projected for a period of 10 000 years. This period is sufficiently long and actually goes far beyond the foreseeable future.
- The migration of radionuclides into subsoil and groundwater and the differences in their spread pattern are determined mostly by the sorption characteristics (retainment) of the corresponding radionuclide in the geologic environment and its decay rate through time. From this point of view, the chosen „key" radionuclides represent a quite diverse "bunch" of isotopes with quite dissimilar decay rates and largely different with regard to their sorption characteristics. The combinations of these properties contribute to the wide representative quality of the research done.
- The results are shown through the values of "relative activity rate" (the relation between the "current" and initial (input) activity of the given isotope), i.e. the decline of activity rates in time and space. This is done, since at this early stage of design the initial activities of the radionuclides in the reactor building are not completely clear.
- Among all isotopes the most "active" is tritium – ^{3}H, which is practically non-adsorbent. Its spread depends only on the permeability of the medium (the filtration rate, respectively) and on its decay rate in the migration process.
- The remaining considered radionuclides (^{137}Cs, ^{90}Sr, ^{60}Co, ^{241}Am, ^{239}Pu) have various properties – some (such as ^{242}Am for example) are long-lived, but highly adsorbent, while others (such as ^{90}Sr for example) are less adsorbent but they are more rapidly disintegrating. The multiple and multi-variant investigations revealed a very important result, namely: out of all radionuclides (with the exception of tritium), the largest range of distribution and outreach is displayed by ^{90}Sr. The other radionuclides (throughout the forecast period of 10 000 years) have more narrow distribution. Consequently, the figures herein show specifically the spread of strontium in groundwater.
- An important barrier for the spread of radionuclides is the substructure platform of the reactor and the aeration zone beneath it (the non-saturated zone between the bottom side of the slab and the groundwater level). Even here the isotopes activity is significantly reduced – in most cases by 3-5 up to 10-15 times. Tritium is the only exception.
- One very important finding of the studies is worth noting. The spreading of all radionuclides marks a peak "maximum" (different in time and place for the different radionuclides and sites), followed by a gradual "shrinking" of the contaminated zone. For all studied radionuclides (without tritium) however, even with the accepted very low values of relative activity (10^{-10}-10^{-40}), the outreach of contamination **never reaches the Danube River**.

- Only tritium could reach the Danube River in the first centuries with relative activity between 10^{-10} and 10^{-30}, after which for it also follows shrinking of "the trail" and further reduction of the activity. This estimate implies certain reserves because the calculations have been done for low-level water in the Danube River. In high water periods the underground flow to the Danube is "blocked" (its direction is temporarily reverse), so that the time it takes for the tritium to reach the river will be much longer than the one shown, and accordingly, the activity rate of the isotope will be still lower.

Expected impact

4.2.2.1.6 During construction

Site 1

Drainage channels pass through Site №1, including the Main drainage canal /MDC/, which is receiver of wastewater from EP-1 and part of the water from EP-2 from the active site of Kozloduy NPP. Its entire reconstruction /shifting/ is necessary for the absorption of this site. The site is located in the flooding terrace of the Danube River, terrain elevation of 25.0-26.0 m, with high groundwater. For reaching the project elevation of the site and the functioning of the future NNU an efficient dewatering system should be designed and implemented.

The design of the dewatering system should envisage measures for the used water discharge into the Danube River water body. In order to realize the implementation of the dewatering system and used water discharge it is necessary to regulate the procedures pursuant to Ordinance № 1 of 10 October 2007 – for research, usage and preservation of groundwater in force since 30.10.2007 (Promulgated in SG, No. 87 of 30 October 2007, amended in SG, No. 2 of 8 January 2010, amended and supplemented in SZ, No. 15 of 21 February 2012).

During the construction of the IP for NNU groundwater contamination is possible through direct filtration of domestic-faecal wastewater, rain water with high content of suspended solids and grease (from the construction equipment), construction wastewater, water from cleaning the construction site, etc.

In order to prevent these local and time-restricted negative impacts, the main sewerage collectors and sewerage network will be constructed at the so called "controlled zone" and "clean zone", as well as WWTP for the domestic-faecal wastewater, which will serve the NNU during exploitation.

Prior to the construction of sewerage and WWTP portable facilities /chemical toilets/ will be used.

Dewatering system. The presence of high groundwater will necessitate the construction of dewatering system at the site, which should be permanently working both during construction and in the period of operation.

The monitoring on the quantity and quality of used groundwater both during construction and operation should be summarized to the reports of the internal monitoring system at Kozloduy NPP.

Advantages:

- ✓ Suitable area for the site construction, possibility to organize a construction site, proximity of the "double channel" allowing lower investments for the implementation.

Disadvantages:

- ✓ Reconstruction of the existing drainage channels, danger of unwanted filtration and direct impact upon groundwater, massive filling and excavation works to reach the elevation of the main operational site, direct impact upon groundwater as a result of construction works and their organization.
- ✓ Construction of dewatering system, requiring both significant costs for its regulation and construction and significant costs for the water abstraction, discharge and provision fees, as well as monitoring surveillance control.

Site 2

Groundwater level in the area of Site 2 is from 8.0 to 10 m from the surface.

The site is located in the non-flooding terrace of the Danube River and there is sufficient area for forming the necessary construction zone and the adjacent infrastructure related to the construction process.

During the construction of the IP for NNU groundwater contamination is possible through direct filtration of domestic-faecal wastewater, rain water with high content of suspended solids and grease (from the construction equipment), construction wastewater, water from cleaning the construction site, etc.

In order to prevent these local and time-restricted negative impacts, the main sewerage collectors and sewerage network will be constructed at the so called "controlled zone" and "clean zone", as well as WWTP for the domestic-faecal wastewater, which will serve the NNU during exploitation.

Prior to the construction of sewerage and WWTP portable facilities /chemical toilets/ will be used.

Dewatering system. Groundwater in the region of this site is located lower, at a greater depth, however, for the protection of NNU and provision of the requirements for safety operation of all buildings and facilities it is necessary to construct and have an operational dewatering system.

The monitoring on the quantity and quality of used groundwater both during construction and operation should be summarized to the reports of the internal monitoring system at Kozloduy NPP. The design of the dewatering system should envisage measures for the used water discharge into the Danube River water body. In order to realize the implementation of the dewatering system and used water discharge it is necessary to regulate the procedures pursuant to Ordinance № 1 of 10 October 2007 – for research, usage and preservation of groundwater in force since 30.10.2007 (Promulgated in SG, No. 87 of 30 October 2007, amended in SG, No. 2 of 8 January 2010, amended and supplemented in SZ, No. 15 of 21 February 2012).

Advantages:

- ✓ Relatively quick realization of the connection to the nearby "double channel", suitable area for the site construction, possibility to organize construction works, less excavation and filling works during the vertical planning.

Disadvantages:

- ✓ Proximity to the "double channel" may cause in case of failure unwanted filtration, site flooding and direct impact upon groundwater.
- ✓ Construction of dewatering system, requiring both significant costs for its regulation and construction and significant costs for the water abstraction, discharge and provision fees, as well as monitoring surveillance control.

Site 3

The site is located in the flooding terrace of the Danube River, to the northwest of the existing Units 5 and 6 of Kozloduy NPP. Open drainage channels, which should be reconstructed, fall within the area of the site. Groundwater level fluctuates as a result of the Danube River stands but it is high and it is necessary to design and construct a dewatering system and measures should be taken for the discharge of used water into the Danube River water body. In order to realize the implementation of the dewatering system and used water discharge it is necessary to regulate the procedures pursuant to Ordinance № 1 of 10 October 2007 – for research, usage and preservation of groundwater in force since 30.10.2007 (Promulgated in SG, No. 87 of 30 October 2007, amended in SG, No. 2 of 8 January 2010, amended and supplemented in SZ, No. 15 of 21 February 2012).

During the construction of the IP for NNU groundwater contamination is possible through direct filtration of domestic-faecal wastewater, rain water with high content of suspended solids and grease (from the construction equipment), construction wastewater, water from cleaning the construction site, etc.

In order to prevent these local and time-restricted negative impacts, the main sewerage collectors and sewerage network will be constructed at the so called "controlled zone" and "clean zone", as well as WWTP for the domestic-faecal wastewater, which will serve the NNU during exploitation.

Prior to the construction of sewerage and WWTP portable facilities /chemical toilets/ will be used.

Dewatering system. The presence of high groundwater will necessitate the construction of dewatering system at the site, which should be permanently working both during construction and in the period of operation.

The monitoring on the quantity and quality of used groundwater both during construction and operation should be summarized to the reports of the internal monitoring system at Kozloduy NPP.

Advantages:

- ✓ The terrain is not built.

Disadvantages:

- ✓ Reconstruction of the existing drainage channels, danger of unwanted filtration and direct impact upon groundwater, massive filling and excavation works to reach the elevation of the main operational site, direct impact upon groundwater as a result of construction works and their organization.
- ✓ Construction of dewatering system, requiring both significant costs for its regulation and construction and significant costs for the water abstraction, discharge and provision fees, as well as monitoring surveillance control.

Site 4

The site is located in the first non-flooding terrace of the Danube River, to the west of Units 3 and 4 of Kozloduy NPP and WSFSF, to the south of the cold and hot channels, entirely urbanized. It is situated at elevation of about 36 m within the existing built service facilities – the Equipment storage facility, the Vehicle Repair Workshop and the Assembly Facility. For the use of the site it is foreseen reconstruction and displacement of the main underground communications of the NPP, and demolition and removing of these facilities. Groundwater level is from 8.0 to 10 m from the surface.

During the construction of the IP for NNU groundwater contamination is possible through direct filtration of domestic-faecal wastewater, rain water with high content of suspended solids and grease (from the construction equipment), construction wastewater, water from cleaning the construction site, etc.

In order to prevent these local and time-restricted negative impacts, the main sewerage collectors and sewerage network will be constructed at the so called "controlled zone" and "clean zone", as well as WWTP for the domestic-faecal wastewater, which will serve the NNU during exploitation.

Dewatering system. Groundwater in the region of this site is located lower, at a greater depth, however, for the protection of NNU and provision of the requirements for safety operation of all buildings and facilities it is necessary to construct and have an operational dewatering system.

The monitoring on the quantity and quality of used groundwater both during construction and operation should be summarized to the reports of the internal monitoring system at Kozloduy NPP. The design of the dewatering system should envisage measures for the used water discharge into the Danube River water body. In order to realize the implementation of the dewatering system and used water discharge it is necessary to regulate the procedures pursuant to Ordinance № 1 of 10 October 2007 – for research, usage and preservation of groundwater in force since 30.10.2007 (Promulgated in SG, No. 87 of 30 October 2007, amended in SG, No. 2 of 8 January 2010, amended and supplemented in SZ, No. 15 of 21 February 2012).

Advantages:

- ✓ The site is located in the non-flooding terrace of the Danube River and is owned by Kozloduy NPP.

Disadvantages:

- ✓ The site is urbanized, with many industrial buildings and facilities, which should be deplanted and moved to new terrains, moving of the underground communication related to the operation of the existing site.

Expected impact:

The expected impact on groundwater will be identical for all sites assessed as suitable to accommodate the NNU.

GROUNDWATER - (non-radioactive aspect)

Potential prospects of impact during construction are expected as a result of excavation works, equipment used and accompanying activities on the territory of the chosen site. Impact can be direct, negative, with high level of impact, restricted if regulatory requirements and relevant planned measures are observed.

Impact characteristics – continuous, due to the eventual building up and maintenance of a dewatering system with expected cumulative effect on the level of groundwater.

GROUNDWATER - (radioactive aspect)

No substantial negative impact from the implementation of the investment proposal is expected due to the planned engineering barriers preventing the transmission of radionuclides into the environment and groundwater. Impact is not likely to occur during construction. There can be positive impact if using improved projects and technologies developed based on the good practices, modern requirements of the normative basis and the envisaged safety measures.

No transboundary impact is expected.

4.2.2.1.7 During operation

Sites 1, 2, 3 and 4

GROUNDWATER - (non-radioactive aspect)

Potential prospects of impact during construction is expected only as a result of unforeseen failures of collection, transportation and any spill from damaged pipeline or damaged collection or storage facilities. Impact scope on the territory of the selected site: direct, negative, middle level of impact, restricted if regulatory requirements and relevant planned measures are observed. Impact features: temporary, short-term, however with cumulative effect by regional sensitivity. Reversible after the end of this phase.

GROUNDWATER - (radioactive aspect)

Potential prospects of impact during construction is expected only as a result of unforeseen failures of collection, transportation, storage and conditioning of radioactive waste and any spill from damaged pipeline or damaged collection or storage facilities. Impact scope on the territory of the selected site: direct, negative, middle level of impact, restricted if regulatory requirements and relevant planned measures are observed. Impact features: temporary, short-term, however with cumulative effect by regional sensitivity. Reversible after the end of this phase.

No transboundary impact is expected.

4.2.2.1.8 During decommissioning

Sites 1, 2, 3 and 4

GROUNDWATER - (non-radioactive aspect)

Provided regulatory requirements are strictly observed, the selected option for decommissioning the nuclear unit will be optimal and safe and no negative impact on groundwater is expected. Potential prospects of impact after decommissioning are expected only as a result of unforeseen failures or natural disasters. Impact scope on the territory of the selected site: direct, negative, middle level of impact, restricted if regulatory requirements and relevant planned measures are observed. Impact features: temporary, short-term, however with cumulative effect by regional sensitivity. Reversible.

GROUNDWATER - (radioactive aspect)

Вероятност от поява на въздействие след закриване се очаква само вследствие непредвидени аварии или природни бедствия. Impact scope on the territory of the selected site: direct, negative, middle level of impact, restricted if regulatory requirements and relevant planned measures are observed. Impact features: temporary, short-term, however with cumulative effect by regional sensitivity. Reversible.

No transboundary impact is expected.

4.2.2.2 CONCLUSION UNDER SECTION 4.2.2 – GROUNDWATER

The impact on groundwater will be identical for all sites and throughout all implementation phases of the Investment Proposal. During the construction of the NNU for all sites it is necessary to design and construct a dewatering system, however at Sites 4 and 2 groundwater lays lower and the drainage activities can be relatively optimized without significant negative impact on the water levels in the region.

The analysis and interpretation of the information available about the component "Groundwater" shows that Site 2 appears to be the most suitable one.

Site 2 is situated on the first non-intertidal terrace of the Danube River. The implementation of the considered Investment Proposal will require minor earth work (excavating and filling), which suggests less direct impact on the water aquifer due to direct infiltration resulting from spillages and accidents during construction. The proximity of Site 2 to the Hot Canal, however, will require reliable measures focused on preventing any risks of overflows and/or undesirable filtration from the Canal to Site 2.