DICON – ACCIONA ING. CONSORTIUM

REPORT ON ENVIRONMENTAL IMPACT ASSESSMENT

for Investment Proposal

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

CHAPTER 3: DESCRIPTION AND ANALYSIS OF COMPONENTS AND FACTORS OF THE ENVIRONMENT AND CULTURAL HERITAGE THAT SHALL BE LARGELY AFFECTED BY THE INVESTMENT PROPOSAL AND THE INTERACTION BETWEEN THEM

3.3. LANDS AND SOILS

3.4. EARTH INTERIOR AND NATURAL RESOURCES

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CONTENTS

LIST OF FIGURES

LIST OF TABLES

3 DESCRIPTION AND ANALYSIS OF COMPONENTS AND FACTORS OF THE ENVIRONMENT AND CULTURAL HERITAGE THAT SHALL BE LARGELY AFFECTED BY THE INVESTMENT PROPOSAL AND THE INTERACTION BETWEEN THEM

3.3 LANDS AND SOILS

3.3.1 LANDS

The investment proposal refers to 4 sites, of which the first three are located in the vicinity of the existing nuclear power plant and have been considered as far back as 1991 and the fourth is located within the boundaries of the Kozloduy nuclear power plant between units 5 and 6.

The Kozloduy nuclear power plant and two of the four sites proposed for building the New Nuclear Unit are situated on the first non-floodable (loess) terrace, whereon stand the existing units 1 – 6 of the nuclear power plant. The site between unit 4 and 5 is approximately marked by the building coordinates of the existing nuclear power plant. This part of the loess terrace has elevation of 35-37 m.

The main characteristics of the sites are presented in **Table 3.3-1.**

TABLE 3.3-1: MAIN CHARACTERISTICS OF THE ALTERNATIVE SITING OF THE NEW NUCLEAR UNIT

Site	Total area decare	Land of	Municipality	Property of	Area, decare
1	550	Harlets	Kozloduy	The Nuclear Power Plant Social organisation and state and private property	24.7 525.3
2	550	Harlets	Kozloduy	The Nuclear Power Plant GBS-ESM AD[1] Private lands	202.7 68.6 278.7
3	530	Harlets	Kozloduy	The Nuclear Power Plant Private agricultural lands	66.5 463.5
4	210	Harlets. Town of Kozloduy	Kozloduy	The Nuclear Power Plant Enemona AD	161 49.0

In **Table 3.3-1** and on **Figure 3.3-1** the four sites are presented according to type of property.

On **Figure 3.3-2** the four sites are presented according to the manner of traditional use of the land. Neither of them is part of the forest stock.

[1] GBS-ESM AD – Glavbolgarstroy–Energostroymontazh AD

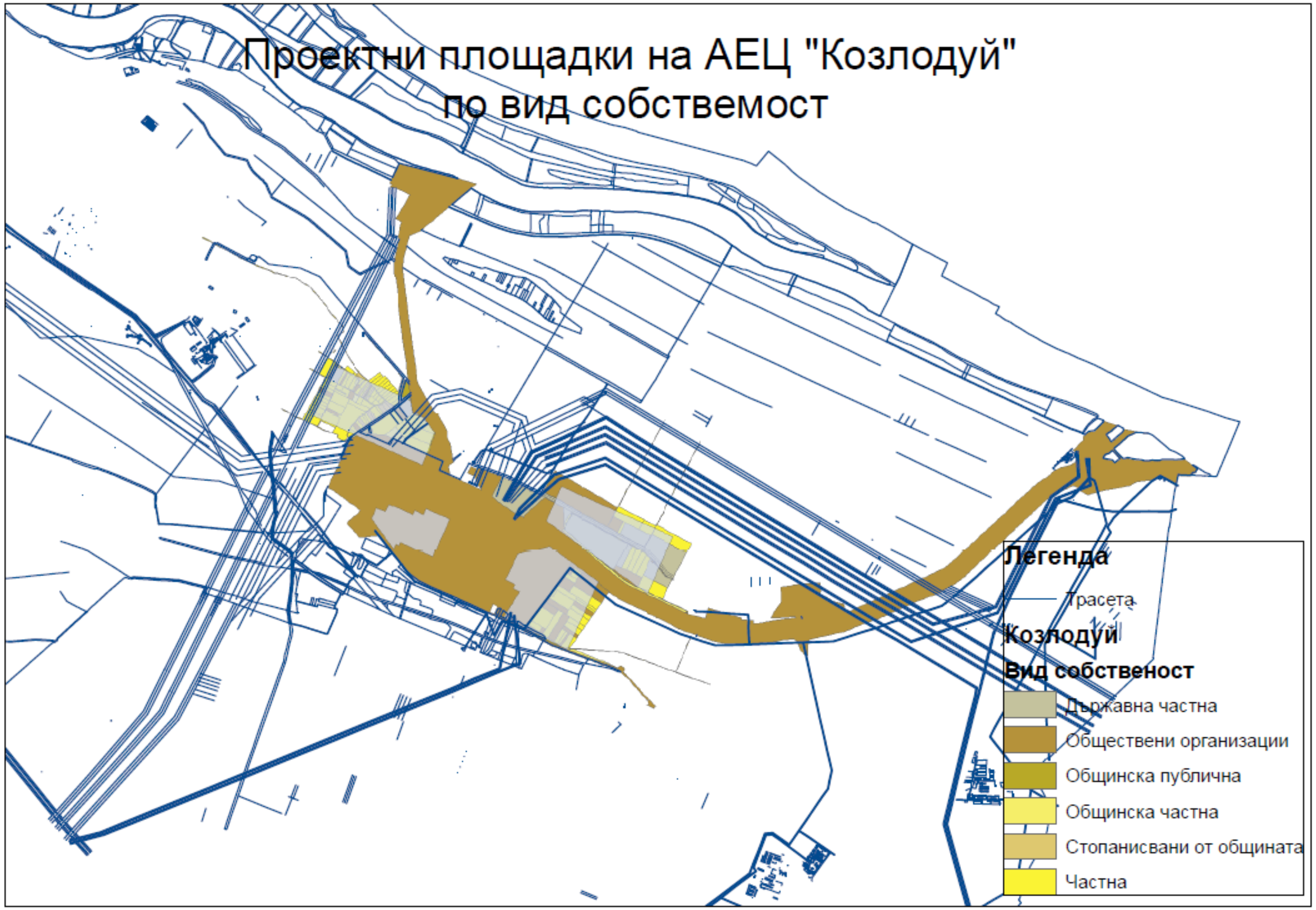

FIGURE 3.3-1: DESIGN SITES OF THE KOZLODUY NUCLEAR POWER PLANT ACCORDING TO TYPE OF PROPERTY

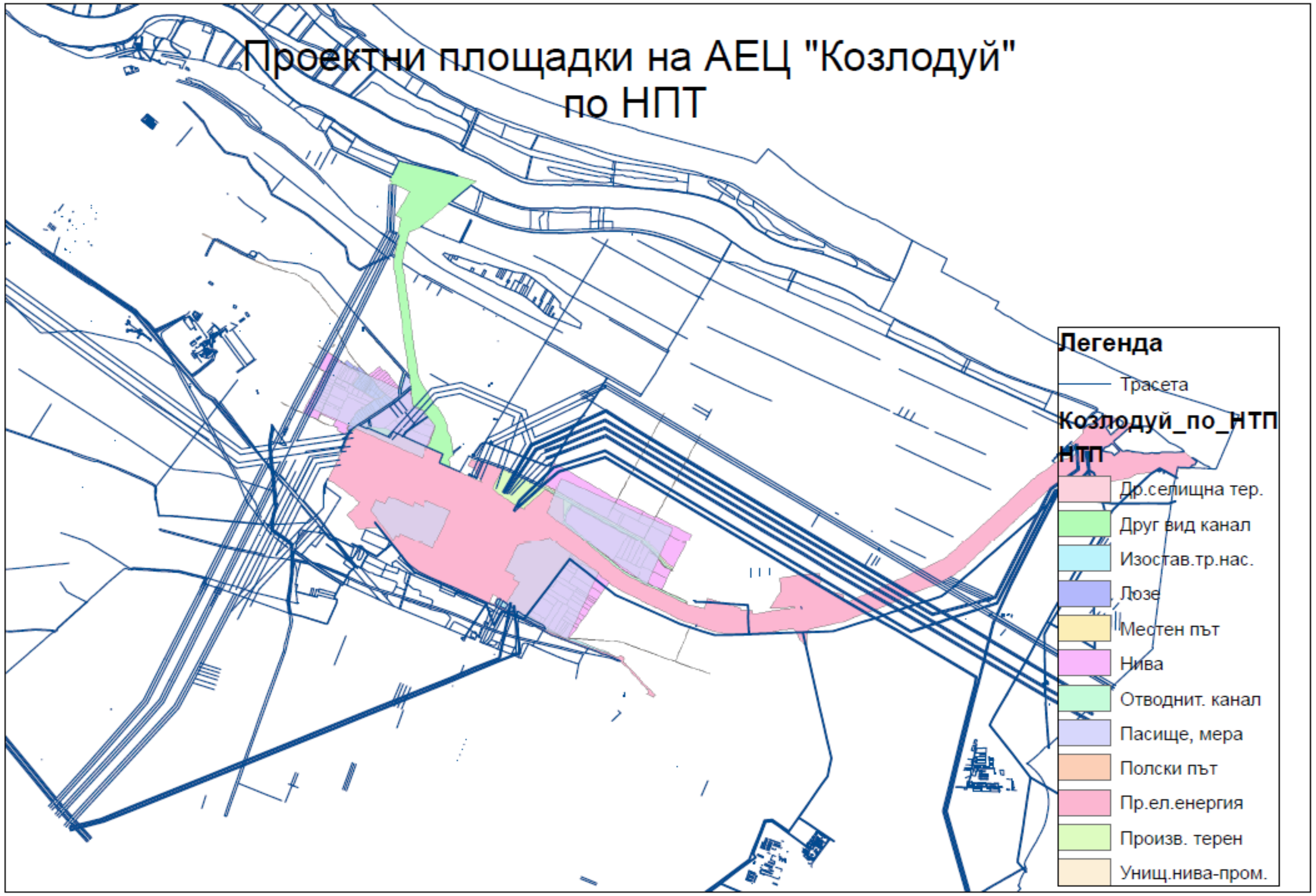

FIGURE 3.3-2: DESIGN SITES OF THE KOZLODUY NUCLEAR POWER PLANT ACCORDING TO MANNER OF TRADITIONAL USE OF THE LAND

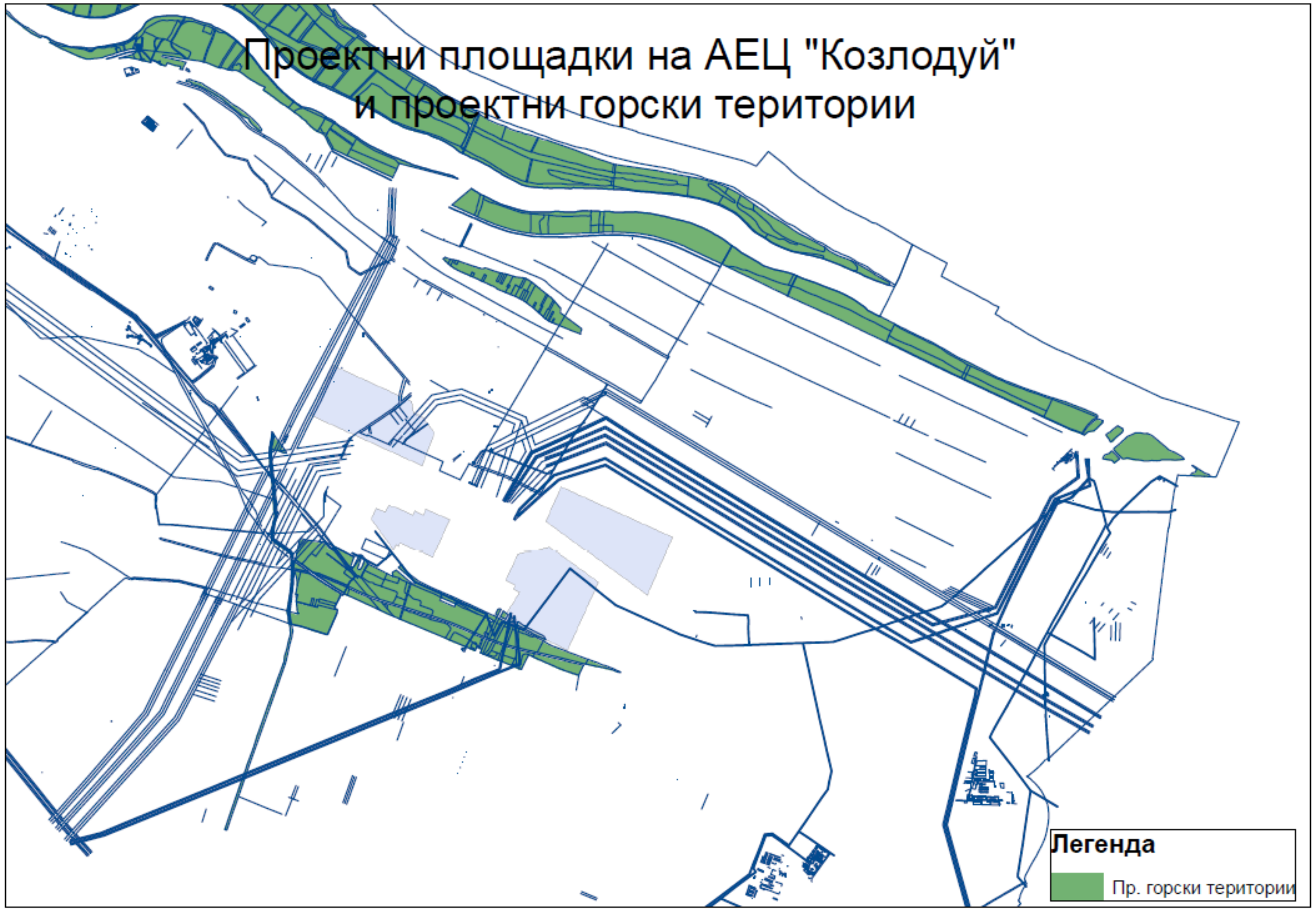

FIGURE 3.3-3: DESIGN-BASED SITES OF THE KOZLODUY NUCLEAR POWER PLANT AND FOREST TERRITORIES

FIGURE 3.3-4: DESIGN SITES OF THE KOZLODUY NUCLEAR POWER PLANT ACCORDING TO TYPE AND CATEGORY OF LAND

On **Figure 3.3-3** the four sites are presented including the design-based forest territories in their vicinity. They are abandoned lands, which are either self-afforested, or have been bushes turned into forests.

On **Figure 3.3-4** the design-based sites of the New Nuclear Unit and the site of the Kozloduy nuclear power plant according to type and category of land. The available data on the distribution of the arable land according to groups of crops in the 30 km monitored land area show that the arable land is used mainly for cereal crops (52.10%), technical crops – 8.83%, vegetables – 3.012% vine plantations.

The state of agriculture in the area of the Kozloduy nuclear power plant is determined on the basis of information on the structure of the soil cover and the productivity of the lands, as well as on the manner of traditional use of the agricultural lands.

The distribution of the areas (in decares (daa/[2]) in the zones around the Kozloduy nuclear power plant is shown in **Table 3.3-2**.

TABLE 3.3-2: DISTRIBUTION OF THE AREAS OF THE MONITORED ZONE OF THE KOZLODUY NUCLEAR POWER PLANT

Zones around the Kozloduy nuclear power plant	10 km	20 km	30 km	110 km
Total area, including:	174 000	710 000	1 587 000	21 368 000
Arable land area	100 000	406 000	908 000	12 280 000
- area under crops	84 000	346 000	774 000	10 468 000
- perennial fruit trees	4 000	15 000	33 000	446 000
- natural meadows	7 000	30 000	67 000	906 000
- pastures	5 000	15 000	34 000	460 000
Forests, bushes, rocky areas, rivers and water basins	14 000	304 000	679 000	9 088 000

According to the Ecological Assessment of Specialised Detailed Site Development Plan, the zone of preventive protection measures with radius of 2 km around the Kozloduy nuclear power plant totals 12,566 daa, of which 3,012 are occupied by the electricity generation site of the Kozloduy nuclear power plant and the site for storage and processing of the radioactive waste, belonging to the Radioactive Waste – Kozloduy Specialised Enterprise, the remaining lands being arable lands, planted each year with various agricultural crops. The summarising conclusion, which can be made, is that plant growing in the area is oriented towards production of grain; however the technical crops and the orchards and vineyards are also of significance. Cattle breeding are poorly developed; the animals bred are for personal use. The territory of the Kozloduy nuclear power plant affects mainly agricultural lands with diverse usage – planting agricultural crops, building sites, part of

[2] International abbreviation of **decare** – *deka* (**da**) + *ar* (**a**) = **daa** – equals to 10 are or 1000 m^2.

the lands are swampy etc. In addition to the existing facilities and the operating units of the Kozloduy nuclear power plant, there are some privatised buildings. The New Nuclear Unit is to be built on this territory. To this end four sites have been proposed. The register of the border points of the sites for the New Nuclear Unit, indicating the owner of the land and the area may be found in Letter No. 45 of 29.01.2013 of the Legal Office of the Kozloduy nuclear power plant EAD, Annex No. 3 to the letter.

The information provided on the acquired property shows the state of the terrain around the proposed sites for the building of the New Nuclear Unit. They are situated on the territory of the lands of the Town of Kozloduy and the Village of Harlets. The distribution of the sites is presented as a structure, manner of permanent usage and type of property (**Table 3.3-3).**

Concerning the area of the Town of Kozloduy the terrain contains water flows and water areas as draining channels, of which 16.107 daa are state private property, 1.829 daa are municipal private property and another type of canal, which occupies the greatest area of 530.265 daa on the lands of various public organisations. The total area of the channels comprises 548.194 daa.

The field roads, traced For agricultural needs, lie on public municipal property and comprise 42.125 daa of the territory. The pastures and the municipality-owned pasture lands comprise 3 plots with an area of only 12.614daa.

The share of the fields amount to 426.848 daa, of which 355.512 daa are private property, 26.901 daa belong to public organisations, 25.187 daa are state private property and 19.250 daa are fields on municipal private property.

The vineyards have a total area of 82.001 daa, the share of the private property being 46.440 daa, some 27.065 daa of vineyards are managed by the Municipality. Four plots of vineyards with a total area of 8.496 daa are owned by public organisations.

The total area of the lands of the Town of Kozloduy in the vicinity of the sites, considered as alternatives for the selection of the most suitable one for the building of the New Nuclear Unit, comprise 1111.781 daa.

TABLE 3.3-3: DATA ON THE ACQUIRED PROPERTY AND THE TYPE OF LAND UASGE

Land of	Cadastre identifier	VT_STR	Land usage	Type of property	Area, daa
Kozloduy	37798.0.2	Water streams and water areas	Other type of channel	Public organisations	530.265
Kozloduy	37798.0.196	Water streams and water areas	Draining channel	State private	15.160
Kozloduy	37798.0.618	Water streams and water areas	Draining channel	State private	0.940
Kozloduy	37798.0.197	Water streams and water areas	Draining channel	Municipal private	1.829
Kozloduy					**548.194**
Kozloduy	37798.0.418	For agricultural needs	Field road	Municipal public	11.026

Land of	Cadastre identifier	VT_STR	Land usage	Type of property	Area, daa
Kozloduy	37798.0.428	For agricultural needs	Field road	Municipal public	8.727
Kozloduy	37798.0.434	For agricultural needs	Field road	Municipal public	1.989
Kozloduy	37798.0.446	For agricultural needs	Field road	Municipal public	1.945
Kozloduy	37798.0.614	For agricultural needs	Field road	Municipal public	2.783
Kozloduy	37798.0.615	For agricultural needs	Field road	Municipal public	1.416
Kozloduy	37798.0.616	For agricultural needs	Field road	Municipal public	1.732
Kozloduy	37798.0.617	For agricultural needs	Field road	Municipal public	8.466
Kozloduy	37798.0.554	For agricultural needs	Field road	Municipal public	4.041
Kozloduy					**42.125**
Kozloduy	37798.0.447	For agricultural needs	Pasture, Common pasture land	Municipal public	2.421
Kozloduy	37798.0.499	For agricultural needs	Pasture, Common pasture land	Municipal public	0.940
Kozloduy	37798.0.761	For agricultural needs	Pasture, Common pasture land	Municipal public	9.253
Kozloduy					**12.614**
Kozloduy	37798.209.1	For agricultural needs	Нива	Частна	1.001
Kozloduy	37798.209.2	For agricultural needs	Нива	Частна	2.476
Kozloduy	37798.209.4	For agricultural needs	Нива	Частна	4.055
Kozloduy	37798.209.7	For agricultural needs	Нива	Частна	2.702
Kozloduy	37798.209.8	For agricultural needs	Нива	Частна	5.495
Kozloduy	37798.209.9	For agricultural needs	Field	Private	8.111
Kozloduy	37798.209.10	For agricultural needs	Field	Private	14.346
Kozloduy	37798.209.11	For agricultural needs	Field	Private	11.260
Kozloduy	37798.209.13	For agricultural needs	Field	Private	15.586
Kozloduy	37798.209.17	For agricultural needs	Field	Private	46.736
Kozloduy	37798.209.18	For agricultural needs	Field	Private	2.701
Kozloduy	37798.210.4	For agricultural needs	Field	Private	1.804
Kozloduy	37798.210.5	For agricultural needs	Field	Private	2.795
Kozloduy	37798.210.6	For agricultural needs	Field	Private	4.507
Kozloduy	37798.210.9	For agricultural needs	Field	Private	3.750
Kozloduy	37798.210.13	For agricultural needs	Field	Private	4.508
Kozloduy	37798.210.14	For agricultural needs	Field	Private	4.325
Kozloduy	37798.210.17	For agricultural needs	Field	Private	4.508
Kozloduy	37798.210.18	For agricultural needs	Field	Private	4.507
Kozloduy	37798.210.21	For agricultural needs	Field	Private	8.112
Kozloduy	37798.210.28	For agricultural needs	Field	Private	15.311
Kozloduy	37798.244.45	For agricultural needs	Field	Private	3.602
Kozloduy	37798.244.46	For agricultural needs	Field	Private	3.594
Kozloduy	37798.244.49	For agricultural needs	Field	Private	4.502
Kozloduy	37798.244.50	For agricultural needs	Field	Private	4.047
Kozloduy	37798.244.51	For agricultural needs	Field	Private	4.684
Kozloduy	37798.244.56	For agricultural needs	Field	Private	4.232

Land of	Cadastre identifier	VT_STR	Land usage	Type of property	Area, daa
Kozloduy	37798.244.57	For agricultural needs	Field	Private	4.352
Kozloduy	37798.244.58	For agricultural needs	Field	Private	3.577
Kozloduy	37798.244.59	For agricultural needs	Field	Private	3.279
Kozloduy	37798.244.60	For agricultural needs	Field	Private	4.324
Kozloduy	37798.244.61	For agricultural needs	Field	Private	2.699
Kozloduy	37798.245.2	For agricultural needs	Field	Private	18.888
Kozloduy	37798.245.3	For agricultural needs	Field	Private	16.384
Kozloduy	37798.245.5	For agricultural needs	Field	Private	6.413
Kozloduy	37798.245.6	For agricultural needs	Field	Private	29.327
Kozloduy	37798.246.1	For agricultural needs	Field	Private	4.053
Kozloduy	37798.246.2	For agricultural needs	Field	Private	16.872
Kozloduy	37798.246.3	For agricultural needs	Field	Private	18.847
Kozloduy	37798.302.5	For agricultural needs	Field	Private	15.585
Kozloduy	37798.302.8	For agricultural needs	Field	Private	3.244
Kozloduy	37798.302.10	For agricultural needs	Field	Private	3.602
Kozloduy	37798.302.11	For agricultural needs	Field	Private	5.405
Kozloduy	37798.302.12	For agricultural needs	Field	Private	5.404
Kozloduy					**355.512**
Kozloduy	37798.302.14	For agricultural needs	Field	Public organisations	5.045
Kozloduy	37798.302.9	For agricultural needs	Field	Public organisations	2.692
Kozloduy	37798.245.4	For agricultural needs	Field	Public organisations	6.756
Kozloduy	37798.210.10	For agricultural needs	Field	Public organisations	5.589
Kozloduy	37798.209.12	For agricultural needs	Field	Public organisations	3.216
Kozloduy	37798.209.5	For agricultural needs	Field	Public organisations	3.603
Kozloduy		For agricultural needs	Field		26,901
Kozloduy	37798.209.6	For agricultural needs	Field	Municipal private	3.603
Kozloduy	37798.245.7	For agricultural needs	Field	Municipal private	13.380
Kozloduy	37798.302.13	For agricultural needs	Field	Municipal private	2.268
Kozloduy	37798.245.1	For agricultural needs	Field	State private	14.467
Kozloduy	37798.302.16	For agricultural needs	Field	State private	10.720
Kozloduy					**44.438**
Kozloduy	37798.630.63	For agricultural needs	Vineyard	Private	1.557
Kozloduy	37798.630.65	For agricultural needs	Vineyard	Private	2.649
Kozloduy	37798.630.67	For agricultural needs	Vineyard	Private	1.350
Kozloduy	37798.630.71	For agricultural needs	Vineyard	Private	1.254
Kozloduy	37798.630.73	For agricultural needs	Vineyard	Private	2.026
Kozloduy	37798.630.74	For agricultural needs	Vineyard	Private	1.861
Kozloduy	37798.630.75	For agricultural needs	Vineyard	Private	1.732
Kozloduy	37798.630.76	For agricultural needs	Vineyard	Private	1.607
Kozloduy	37798.630.77	For agricultural needs	Vineyard	Private	1.977
Kozloduy	37798.630.78	For agricultural needs	Vineyard	Private	2.503
Kozloduy	37798.630.79	For agricultural needs	Vineyard	Private	0.283
Kozloduy	37798.630.81	For agricultural needs	Vineyard	Private	0.954
Kozloduy	37798.630.82	For agricultural needs	Vineyard	Private	1.870
Kozloduy	37798.630.85	For agricultural needs	Vineyard	Private	1.045

Land of	Cadastre identifier	VT_STR	Land usage	Type of property	Area, daa
Kozloduy	37798.630.86	For agricultural needs	Vineyard	Private	3.306
Kozloduy	37798.633.4	For agricultural needs	Vineyard	Private	1.872
Kozloduy	37798.633.5	For agricultural needs	Vineyard	Private	5.318
Kozloduy	37798.633.8	For agricultural needs	Vineyard	Private	2.068
Kozloduy	37798.633.9	For agricultural needs	Vineyard	Private	1.966
Kozloduy	37798.633.10	For agricultural needs	Vineyard	Private	2.275
Kozloduy	37798.633.12	For agricultural needs	Vineyard	Private	2.592
Kozloduy	37798.633.14	For agricultural needs	Vineyard	Private	1.759
Kozloduy	37798.633.15	For agricultural needs	Vineyard	Private	2.616
Kozloduy					**46.440**
Kozloduy	37798.630.62	For agricultural needs	Vineyard	Managed by the Municipality	2.358
Kozloduy	37798.630.64	For agricultural needs	Vineyard	Managed by the municipality	0.782
Kozloduy	37798.630.66	For agricultural needs	Vineyard	Managed by the municipality	2.766
Kozloduy	37798.630.68	For agricultural needs	Vineyard	Managed by the municipality	2.123
Kozloduy	37798.630.72	For agricultural needs	Vineyard	Managed by the municipality	1.336
Kozloduy	37798.630.80	For agricultural needs	Vineyard	Managed by the municipality	1.246
Kozloduy	37798.630.84	For agricultural needs	Vineyard	Managed by the municipality	0.780
Kozloduy	37798.633.1	For agricultural needs	Vineyard	Managed by the municipality	2.039
Kozloduy	37798.633.2	For agricultural needs	Vineyard	Managed by the municipality	3.172
Kozloduy	37798.633.3	For agricultural needs	Vineyard	Managed by the municipality	3.408
Kozloduy	37798.633.6	For agricultural needs	Vineyard	Managed by the municipality	2.032
Kozloduy	37798.633.7	For agricultural needs	Vineyard	Managed by the municipality	2.464
Kozloduy	37798.633.11	For agricultural needs	Vineyard	Managed by the municipality	2.559
Kozloduy					**27.065**
Kozloduy	37798.630.69	For agricultural needs	Vineyard	Public organisations	1.302
Kozloduy	37798.630.70	For agricultural needs	Vineyard	Public organisations	1.395
Kozloduy	37798.630.83	For agricultural needs	Vineyard	Public organisations	2.411
Kozloduy	37798.633.13	For agricultural needs	Vineyard	Public organisations	3.386
					8.494
Harlets	77548.0.384	Water streams and water areas	Draining channel	State private	1.170
Harlets	77548.0.64	Water streams and water areas	Draining channel	State private	26.109
Harlets					**27.279**
Harlets	77548.0.71	Water streams and water areas	Draining channel	Municipal private	26.479
Harlets	77548.0.111	For agricultural needs	Field road	Municipal public	5.128
Harlets	77548.0.113	For agricultural needs	Field road	Municipal public	4.552

Land of	Cadastre identifier	VT_STR	Land usage	Type of property	Area, daa
Harlets	77548.0.155	For agricultural needs	Field road	Municipal public	1.860
Harlets	77548.0.158	For agricultural needs	Field road	Municipal public	5.859
Harlets	77548.0.201	For agricultural needs	Field road	Municipal public	12.390
Harlets	77548.0.645	For agricultural needs	Field road	Municipal public	5.242
Harlets	77548.0.344	For agricultural needs	Field road	Municipal public	2.714
Harlets	77548.0.538	For agricultural needs	Local road	Municipal public	0.128
Harlets					**64.352**
Harlets	77548.53.9	For agricultural needs	Field	Private	37.931
Harlets	77548.54.12	For agricultural needs	Field	Private	12.510
Harlets	77548.54.13	For agricultural needs	Field	Private	27.720
Harlets	77548.56.5	For agricultural needs	Field	Private	32.076
Harlets	77548.54.15	For agricultural needs	Field	Private	2.603
Harlets	77548.56.9	For agricultural needs	Field	Private	11.009
Harlets	77548.56.10	For agricultural needs	Field	Private	11.009
Harlets	77548.56.11	For agricultural needs	Field	Private	11.009
Harlets	77548.56.12	For agricultural needs	Field	Private	12.310
Harlets	77548.86.2	For agricultural needs	Field	Private	5.625
Harlets	77548.86.6	For agricultural needs	Field	Private	5.004
Harlets	77548.86.9	For agricultural needs	Field	Private	10.004
Harlets	77548.86.10	For agricultural needs	Field	Private	19.940
Harlets	77548.86.12	For agricultural needs	Field	Private	2.052
Harlets	77548.86.15	For agricultural needs	Field	Private	23.770
Harlets	77548.86.16	For agricultural needs	Field	Private	7.006
Harlets	77548.86.19	For agricultural needs	Field	Private	7.507
Harlets	77548.86.20	For agricultural needs	Field	Private	9.062
Harlets	77548.86.23	For agricultural needs	Field	Private	16.013
Harlets	77548.86.26	For agricultural needs	Field	Private	23.020
Harlets	77548.86.27	For agricultural needs	Field	Private	6.005
Harlets	77548.86.28	For agricultural needs	Field	Private	3.002
Harlets	77548.86.30	For agricultural needs	Field	Private	10.018
Harlets	77548.86.31	For agricultural needs	Field	Private	15.313
Harlets	77548.86.32	For agricultural needs	Field	Private	8.307
Harlets	77548.86.34	For agricultural needs	Field	Private	4.153
Harlets	77548.86.35	For agricultural needs	Field	Private	4.153
Harlets					**338.131**
Harlets	77548.0.208	For agricultural needs	Abandoned orchards	Public organisations	4.925
Harlets	77548.0.210	For agricultural needs	Abandoned orchards	Public organisations	12.822
Harlets					**17.747**
Harlets	77548.86.17	For agricultural needs	Field	Public organisations	2.002
Harlets	77548.86.21	For agricultural needs	Field	Public organisations	5.425
Harlets	77548.86.24	For agricultural needs	Field	Public organisations	17.795
Harlets	77548.86.29	For agricultural needs	Field	Public organisations	3.003
Harlets	77548.86.33	For agricultural needs	Field	Public organisations	8.307
Harlets	77548.86.36	For agricultural needs	Field	Public organisations	43.147

Land of	Cadastre identifier	VT_STR	Land usage	Type of property	Area, daa
Harlets	77548.86.11	For agricultural needs	Field	Public organisations	10.288
Harlets	77548.54.14	For agricultural needs	Field	Public organisations	12.151
Harlets	77548.55.35	For agricultural needs	Field	Public organisations	142.711
Harlets	77548.56.3	For agricultural needs	Field	Public organisations	22.718
Harlets	77548.86.7	For agricultural needs	Field	Public organisations	12.990
Harlets	77548.86.1	For agricultural needs	Field	Public organisations	4.007
Harlets	77548.86.14	For agricultural needs	Field	Public organisations	8.667
Harlets					**293.211**
Harlets	77548.56.4	For agricultural needs	Field	State private	30.551
Harlets	77548.56.8	For agricultural needs	Field	State private	11.009
Harlets	77548.56.1	For agricultural needs	Field	State private	132.085
Harlets	77548.54.16	For agricultural needs	Field	State private	31.535
Harlets	77548.53.10	For agricultural needs	Field	State private	73.685
Harlets					**278.865**
Harlets	77548.0.980	For agricultural needs	Destroyed field	State private	22.106
Harlets	77548.0.981	For agricultural needs	Destroyed field	State private	6.868
Harlets					**28.974**
Harlets	77548.0.211	For agricultural needs	Pasture, Common pasture land	Municipal public	**6.199**
Harlets	77548.0.212	For agricultural needs	Abandoned orchards	Municipal private	**6.443**
Harlets	77548.0.218	For agricultural needs	Electric lines	Public organisations	**3714.745**
Harlets	77548.0.358	For agricultural needs	Industrial terrain	State private	**101.712**
Harlets	77548.0.537	For agricultural needs	Other community terrain	Public organisations	**0.255**
Total area around the site:					**5989.697**
				Of which:	
				Area of Kozloduy	**1111.781**
				Area of Harlets	**4877.916**

The area of the land of the Village of Harlets, belonging to the sites, is considerably greater (over 4 times that of Kozloduy). Three draining channels are built on it on an area of 53.728 daa. Two of the draining channels are built on state private property and comprise an area of 27.279 daa and one is built on municipal private land of 26.479 daa.

The field roads take up 37.872 daa only municipal public property. The fields with a total area of 910.208 daa are property of various operators. The private fields occupy 338.131 daa. Public organisations own 293.211 daa, while the share of the state private property is 278.866 daa. In the information provided, some 28.974 daa have been specified as destroyed fields on state private property. Other 17.747 daa have been categorised as abandoned orchards and vineyards, property of public organisations and 6.443 daa on municipal private property. The area of a pasture, municipal pasturing land of 6.199 daa, is municipal property.

There is more variety of the type of land usage on the territory of the Village of Harlets. Part of the territory is taken up of facilities for transmission of electric energy, that part comprises the biggest share and totals 3714.745 daa and is property of public organisations. There is a terrain of 101.712 daa stated to be production area for the needs of agriculture on state private property and a public organisation own some 0.255 daa again for agricultural needs in another village territory. The total area of the lands of the Village of Harlets in the area of the sites is 4877.916 and the total area of the two inhabited localities comes to 5989.697 daa.

3.3.1.1 SITE 1 – 55 HECTARES

This site is situated to the northeast of units 1 and 2 within the site of the Kozloduy nuclear power plant between the open switchgear and the Valyata area, in the vicinity of the cold and hot channels – to the north of them. The area of the alienated terrains is about 55 ha (the nuclear power plant – 24.7 daa, public organisations and state private property – 525.3 daa) irrigated area situated on the first floodable terrace of the Danube River. The soils are alluvial-meadow. The terrain is flat with a slight sloping from southwest to northeast. The customization of the site will require a fill of about 3.5 million m^3 to raise the altitude. Half of the area is bushy. The area of the site includes open draining channels, which will be reconstructed.

An advantage is the link with Cold channel-1 and Hot channel-1, however the terrain is divided by the draining channel into two.

A disadvantage is the fact that the site is situated on the floodable terrace of the Danube River and at high level of the river, there is a real risk of floods and damages. Part of it is swampy and is referred to 9^{th} – 10^{th} category.

It would be necessary to remove the humus layer of the arable land. The alienated terrain on the floodable territory is used now for planting of agricultural crops.

3.3.1.2 SITE 2 – 55 HECTARES

The site is situated to the east of units 1 and 2 within the site of the Kozloduy nuclear power plant in the direction to the Village of Harlets, south of the existing cold and hot channels. The area of the alienated terrain is about the half of the 55 ha, 1^{st} category irrigated land and 3^{rd} category at non-irrigation (the nuclear power plant – 202.7 daa; Glavbolgarstroy – Energostroymontazh AD – 68.6 daa; private lands – 278.7 daa). The site is at a distance of 3 km from the Village of Harlets and 4 km from the Town of Kozloduy. Reference information – buildings for plots and cadastre units belonging to part of the territory of Site 2 – is given in Letter No. 45 of 29.01.2013 of the Legal Department of the Kozloduy nuclear power plant EAD, Annex 1 to the letter.

The terrain is at an elevation of 37-38 m, hilly, with a considerable sloping from the south to the north, more evident at the south-eastern part of the site. The soils are alluvial-meadow. The customization of the site will require earthwork.

The area of the site includes a former farm management facility, which at the moment is used as auxiliary production facility of the companies servicing the nuclear power plant. The rest of the terrain is used for planting agricultural crops.

At the end of the site, it is crossed by two electric lines, however this does not make necessary new building works. The channels are nearby, the link being very good as infrastructure and because of that this site is a good alternative to have the New Nuclear Unit built there from the viewpoint of the earthwork and change of the designation of the arable land for non-agricultural purpose.

3.3.1.3 SITE 3 – 53 HA

The site is situated to the north-northwest of units 5 and 6 of the Kozloduy nuclear power plant in the vicinity of the road surrounding the existing power plant. The relief of the site is flat with an average elevation of 26-28 m. The lowland and the site are protected by a dike reaching an absolute elevation of 30.40 m. From the north the site is delimited by the floodable part of the river valley and is at a distance of 3.7 km from the midstream of the river and from the south – by the base of the steep slope of the catchment plateau. The nearest inhabited places are the Town of Kozloduy – 2.6 km to the northwest, the Village of Harlets – to 3.5 km to the southeast, the village of Glozhene – 4.0 km to the southeast, the Village of Saraevo – 6 km to the southeast, the Town of Mizia – 6.0 km to the southeast, the Village of Butan – 8.4 km to the south and the Town of Oryahovo is at a distance of 8.4 km to the east of the site.

The site is situated on a flat terrain on a floodable terrace with a slight sloping to the north, which is around 53 ha property land with the following ownership: the Kozloduy nuclear power plant – 66.5 daa, private owners of agricultural lands – 278.7 daa. The customization will need a fill of at least 10 m to raise the altitude. Its present state is more of a swamp than arable land. This is proved by the open draining channels, which will be necessary to reconstruct. The soils are alluvial-meadow, very swampy.

In case of building on this site it would be necessary first to remove the humus horizon of the arable land. According to earlier information provided by Energoproekt AD the terrain, subject to alienation, is being used for vineyards, orchards and other crops. The current examination of the terrain did not confirm this information.

A disadvantage of this site is the swamps in part of the terrain and the great area of private arable land, which will need to be alienated and paid for additionally in order to have their purpose changed.

3.3.1.4 SITE 4 – 21 HA

This site is situated to the west of units 3 and 4 of the Kozloduy nuclear power plant and the Depot for the spent fuel of the nuclear power plant, south of the cold and hot channels.

The disposable land is around 21 ha within the boundaries of the alienated terrains of the nuclear power plant. Reference information – buildings for plots and cadastre units belonging to part of the territory of Site 4 – is given in Letter No. 45 of 29.01.2013 of the Legal Department of the Kozloduy nuclear power plant EAD, Annex 2 to the letter.

The terrain comprises the existing servicing facilities – Equipment Bureau, Vehicles Repair Unit, Mounting works unit and Enemona. In order to customise the site, it is foreseen to reconstruct and displace basic underground communications of the Kozloduy nuclear power plant and to clear and move these service units.

The soil is carbonated chernozem, sealed in most part, very antropogenised and degraded. The site is sealed with asphalt and built up.

It is an advantage that no change of the purpose of land would be necessary.

A disadvantage is the small area of the site and the fact that there would be many building to demolish.

The analysis of the advantages and the disadvantages of the sites under consideration makes it clear that site 2 has least disadvantages and at the same time it has a number of positive economic advantages.

Table 3.3-4: Analyses of the sites

	Site 1	Site 2	Site 3 3	Site 4
Layout of the lines between the site and the distribution utility.	The link with the open switchgear is difficult because the site has a back location and there will appear need to build route for the incoming ground lines and the region of the open switchgear, opposite the access spots, or make changes in the open switchgear, like for instance installation of new spots in order to ensure better access to the 400 kV bus	There is a much easier and shorter electrical access to the open switchgear than the one from sites 1 and 3 with less conflicts with the infrastructure. The electrical link with the open switchgear is easy since the distance is short and it is a front location, which would not involve changes of the spots of the open switchgear.	It has the most complicated electrical access by overhead lines to the open switchgear since it will have interaction with the overhead lines of units 5 and 6. The electrical link with the open switchgear is difficult because the site is back located, which will prompt building of route for the incoming air lines and the area of the open switchgear opposite the access spots or it may become necessary to make changes in the open switchgear q like for instance installation of new spots in order to ensure better access to the 400 kV bus.	There is a much easier and shorter electrical access to the open switchgear than the one from sites 1 and 3. The electrical link with the open switchgear is easy because the distance is small and it is a front location, which would not require change of the spots of the open distribution utility.
Air lines on the site.	This site is the one, which lacks interconnections; there are no overhead lines on the site.	There are two overhead lines of 110 kV and 1 of 20 kV.	On this site there is a crossing of 5 electric lines of 400 kV and one electric line of 220 kV.	There are no overhead communications over this site.
Link with the old hot channel..	The link with the hot channel is complex because the pipes under pressure have to pass through the cold channel. The distance to the hot channel is about 120 m	The discharge to the hot channel is not complicated because the hot channel is the north boundary of Site 2	A new pipeline/channel from Site 3 to the open part of the old hot channel as it is recommended to avoid any connections through the underground part of the hot channel.	Despite the fact that the underground part of the hot channel is at the north corner of the site, in order to avoid any connection with the underground part of the hot channel as it is recommended, the discharge need to be made to the open hot channel.
Link with the new hot channel.	Because of the fact that the new hot channel is being used by units 5 and 6 only, it has not been considered to use it for the new unit	Because of the fact that the new t channel is being used by units 5 and 6 only, it has not been considered to use it for the new unit	Because of the fact that the new t channel is being used by units 5 and 6 only, it has not been considered to use it for the new unit	Because of the fact that the new t channel is being used by units 5 and 6 only, it has not been considered to use it for the new unit
Link with the existing cold channel.	The site is near the cold channel and this allows easy access to it. A new intake chamber for circulating water ought to be designed.	The inflow of circulating water may be achieved by one more use of the existing construction of the central pump station for units 1 and 2 while the layout of the new piping from the cold channel will have to cross over the underground part of the hot channel.	A new circulation pump station needs to be built at the end of the cold channel, thereby adding new water to the existing circulation. This will not contradict the normal operation of the existing units.	The intake of the circulation water may be from the one for units 3 and 4 and the layout of the pipes from the cold channel ought to pass over the underground part of the hot channel, which the northern corner of the site.

Distance to the existing cold channel.	60 m	75 m	235 m	75 m
Topography	The site is even. The average elevation is about 26 m in the northern half of the site and the remaining part is inclined to the maximum level of about 30 m in the southern corner. An enormous fill of earth may be needed in order to reach a level above the maximum water level	The site is quite flat with an average elevation of about 36 m. The southern part of the site is slightly elevated than the rest its maximum level reaching about 46 m. Small earthwork (excavating and filling) may be necessary.	The topography is quite uneven in comparison with the other sites and the average level is about 30 m, however the site is cut across by a river bed with an altitude of 27 m. Enormous fill with earth may be needed in order to reach level above the maximum water level.	The site is even with an average elevation of about 37 m in the northern corner and of about 39 m in the southern corner. Some earthwork may be necessary (excavating and filling).
Layout of the sites in relation to the zone of flooding of the Danube River.	This is the first floodable terrace of the Danube River.	This is the first non-floodable terrace of the Danube River.	This is the first floodable terrace of the Danube River.	This is the first non-floodable terrace of the Danube River.
Demolition of the existing buildings and other structures.	There are no buildings and on this site only the fire protection piping may be laid out	There are a few buildings in the western part of the site.	There are no buildings and any other interferences except the overhead communications	The site is overfilled with existing buildings and bridge cranes. There may be some underground pipelines on this site. The high 150 m ventilation pipe for units 3 and 4 need to be classified seismically, this must be verified or otherwise the effect on the site in case of collapse will be rejected.
Property on the land and zones with special status	Part 1 – area of 52.53 ha for agricultural use and the property is state public or state private. Part 2 – area of 2.47 ha is classified as urbanised territory and is property of the Kozloduy Nuclear Power Plant EAD	Part 1 – area of 16.29 ha is classified as urbanised territory and is property of the Kozloduy Nuclear Power Plant EAD. Part 2 – area of 3.98 ha is classified as urbanised territory and is property of the Kozloduy Nuclear Power Plant EAD. Part 3 – area of 6.86 ha is classified as urbanised territory and is property of Glavbolgarstroy-Energostroymontazh Part 4 – area of 27.87 ha for agricultural use – property of private owners.	Part 1 – area of 6.65 ha is classified as urbanised territory and is property of the Kozloduy Nuclear Power Plant EAD Part 2 – area of 46.35 ha for agricultural use – property of private owners.	Part 1 – is classified as urbanised territory and is property of the Kozloduy Nuclear Power Plant EAD. Part 2 – area of 4.9 ha is classified as urbanised territory and is property of Enemona.
Transportation of heavy equipment	There is road to access the site, which can be used for transportation of heavy equipment from the river port and from the road surrounding the Kozloduy Nuclear Power Plant. The existing road runs parallel to the cold	There is a road to access the site, which may be used to transport heavy equipment from the river port and from the road surrounding Kozloduy Nuclear Power Plant. The existing road runs parallel to the cold channel and	There is a road to access the site, which may be used to transport heavy equipment from the river port and from the road surrounding the Kozloduy Nuclear Power Plant. The existing road runs parallel to the cold	There is a road to access the site, which may be used to transport heavy equipment from the river port and from the road surrounding Kozloduy Nuclear Power Plant. The existing road runs parallel to the cold channel and

	channel and therefore is crossed by overhead electric lines 400, 200 and 100 kV to the north of the Open switchgear. Alternative access is also possible or easy to provide through the main road to the Nuclear Power Plant.	therefore is crossed by the electric lines 400, 200 and 100 kV to the north of the open switchgear. It is possible and easy to provide alternative access through the main road of the Nuclear Power Plant. It is possible to build a new road from the river port to the site in order to avoid rounding the whole site of the Kozloduy Nuclear Power Plant.	channel and therefore is crossed by three electric lines 400, 200 and 100 kV to the north of the open switchgear. It is possible and easy to provide alternative access through the main road of the Nuclear Power Plant..	therefore is crossed by the electric lines 400, 200 and 100 kV to the north of the open switchgear. It is possible and easy to provide alternative access through the main road of the Nuclear Power Plant.
Distance to the access From Kozloduy From Harlets	 3.65 km 3.60 km	 3.95 km 3.00 km	 2.00 km 5.00 km	 2.65 km 4.25 km

Additional data from the Investor – Letter No. 43/29.04.2013 presents concentrated analysis of the lands quality indicators of the four sites in **Table 3.3-4.**

It is clear from the Table that the second site is the most suitable one for the purposes of the design of the nuclear power plant. In the next **Table 3.3-5** from the same source, a comparative analysis is made of each site and this proposal is specified in detail.

TABLE 3.3-5: PROPOSED SITED – MAIN ADVANTAGES AND DISADVANTAGES

Site No.	Location	Advantages	Disadvantages
1	To the northeast of units 1 and 2 of the Kozloduy Nuclear Power Plant, between the open switchgear and the Valyata area in vicinity to the old cold and hot channel Area 55 ha.	Short and easy link with the existing cold channel 1 (distance of 75 m). Short link to hot channel 1. Even terrain No overhead lines. No necessity of buildings demolition.	Low average elevation (the site is located on the first floodable terrace of the Danube River). The link with hot channel 1 has to run over or under the cold channel. It is necessary that the greater part of the land change its classification and its owner. There is no easy link to the open switchgear. The greater part of the land has to be purchased from the Kozloduy Nuclear Power Plant and its usage category changed.
2	East of units 1 and 2 of the Kozloduy Nuclear Power Plant, to the south of the old cold and hot channels. Area 55 ha.	The site is located on the non-floodable terrace of the Danube River (its average elevation is equal to that of the Kozloduy Nuclear Power Plant). Short link with cold channel 1 (the distance is 75 m) Short and easy link with existing hot channel 1. Easy link with the open switchgear. Even terrain. It will require little earthwork. Building and mounting structures available next to the site. Half of the territory of the site is property of the Kozloduy Nuclear Power Plant and is urbanised.	The link with the cold channel 1 has to run under or above the hot channel. Three electric lines cross the site. (2x110 kV and 1x20kV).
3	North of units 5 and 6 and near the road surrounding the existing Nuclear Power Plant Area 53 ha.	No necessity of buildings demolition.	Low average elevation (the location of the site is on the floodable terrace of the Danube River) Hilly terrain. Long link to hot channel 1. Long link to cold channel 1. The link with the open switchgear is not easy. Three overhead high voltage lines 400 kV. The greater part of the land has to be purchased from the Kozloduy Nuclear Power Plant and its usage category changed.
4	West of units 3 and 4 of the Kozloduy Nuclear Power Plant and south of the old cold and hot channels and from blocks 5 and 6 of the Kozloduy Nuclear Power Plant.	The site is located on the non-floodable terrace of the Danube River (the elevation is the same as that of the Kozloduy Nuclear Power Plant). Short link with cold channel 1(a distance of 75 m). Easy kink with the open switchgear. Little earthwork required. Easy link with the existing hot channel 1. No overhead high voltage lines. The territory is property of the Kozloduy	The greater part of the site is occupied by industrial facilities, which will have to be dismantles or demolished.

	Area 21 ha.	Nuclear Power Plant and is urbanised.	

3.3.2 Soils

According to the soil geographic regionalisation of Bulgaria[3, 4] the Kozloduy municipality is located in the soil-geographic region of the Danube sub-zone of the chernozems. It is an average Danube province whose agro-ecological region is also the region of the chernozems. Regarding erosion, it belongs to the plain and hilly regions not affected by erosion. The Kozloduy municipality soils appear to be deep soils in the lowland areas – mainly carbonated chernozems and alluvial (delluvial)-meadow soils[5].)

In climatic aspect the region belongs to the Moderate-continental climatic sub-region of the European continental climatic region, characterised by cold winter and hot summer – the absolute measured temperature values are maximum of +43.5°C and minimum −35.5°C. During the year some 60 – 70 days have temperature lower than 0°C; the amount of the summer rains is more than 30% of the amount of winter rains; the snow cover is stable and with greater thickness; there are frequent and strong winds.

The soils of the proposed sites are in the agro-ecological region of the chernozems[6]. The main soil types are calcareous, typical and meadow chernozems and alluvial (delluvial) – meadow soils. In relation to the mechanical composition and density, the chernozems are characterised as slight sandy-clay to heavy sandy – clay with texture co-efficient of 2 to 1.3. The alluvial soils are sandy and sandy-clay depending on the character of the deposited material.

What concerns the land evaluation grouping, the soils are referred to the first (soils evaluated at 80 and more points) and second evaluation group (good soils with evaluation 60 – 80 points)[7].

The main soil-forming rocks, on which largely clay-sandy and sandy-clay soils are to be found, are of calcareous material, conglomerates and sandstones, and on the low areas and the river terraces – alluvial and delluvial deposits. The plant cover consists mainly of sparse offshoot forests of Oriental hornbeam, manna-ash, oak and acacia, at places mixed with coniferous plants. The bushes found frequently are hawthorn, raspberry, blackthorn, Christ's thorn, briar, blackberry etc.

These are the main soil forming factors, which contributed to the formation of the genetic soil types found in the region: calcareous chernozems – in a wide strip along the Danube

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[3] Koynov, V. et al., 1974. Soil-geographical regioning. Sofia.

[4] Ninov N., 1982. Soil-geographical regions. page 399-400. Georgraphy of Bulgaria. Bulgarian Academy of Sciences edition.

[5] Koynov, V., Iv. Kabakchiev and K. Boneva. 1998. Atlas of the soils in Bulgaria, Zemizdat, Sofia.

[6] Yolevski. M., A. Hadzhiyanakiev, Ya. Georgieva, Iv. Kabakchiev, 1980. Map of the agroecological regions of Bulgaria.

[7] Petrov, E., Iv. Kabakchiev, Ya. Georgieva, P. Bozhinova, 1988. Methodology of work with the cadaster of the agricultural soils in Bulgaria.

River, typical chernozems – to the south of the calcareous in the vicinity of the medium flows of the rivers Ogosta and Skat, leached chernozems – in the upper parts of the territory to the south of the typical and calcareous , grey forest (usually above 500 – 800 m) alluvial (delluvial) meadow soils – around the rivers of Tsibritsa, Ogosta and Skat and their tributaries, a small part of the terrain having been occupied by meadow-swamp soils. The variety of grey forest soils, a result of the influence of the main rock and the elementary soil processes is increased by the variety of soils depending on degree of erosion and mechanical composition[8].

A more-detailed description of the soils[9] may be seen on

Figure 3.3-5*. **The chernozems*** have the widest distribution within the 30 km zone around Kozloduy Nuclear Power Plant. Of them one finds mostly calcareous, sandy-clay, typical sandy-clay, eroded calcareous and typical, as well as typical heavily leached sandy-clay chernozems.

The calcareous chernozems have very good general physical properties and structure, not great plasticity and are cultivated well. The water regime of these soils is not very good because of continuous dry periods during the summer and the considerable unproductive moisture evaporation. In relation to their resistance to pollution, they belong to a high class because of their high amount of carbonates and the comparatively high contents of humus.

The typical chernozems are relatively less in the region, they are situated to the south of the calcareous chernozems and due to the hilly relief, part of them has eroded.

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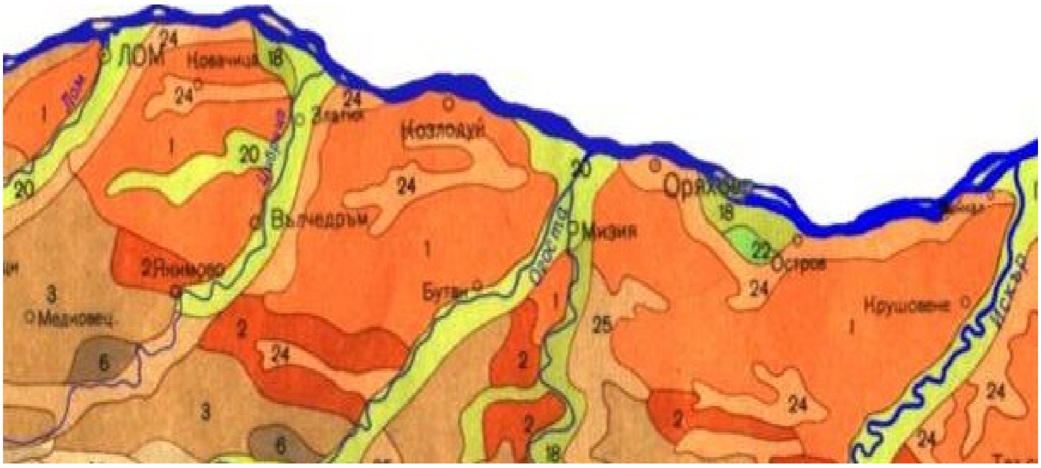
[8] Yolevski. M., A. Hadzhiyanakiev, Iv. Kabakchiev, 1982. Agroproduction groupingof the soils, Georgraphy of Bulgaria. The Bulgarian Academy of Sciences edition.

[9] Koynov, V et al., 1968. Soil map of Bulgaria.



15 KM

FIGURE 3.3-5: TYPICAL SOILS IN THE REGION OF KOZLODUY MUNICIPALITY[10]

Legend:

1 – Calcareous chernozems
2 – Typical chernozems
3 – Leached chernozems
6 – Dark grey forest
7 – Grey forested
18 – Meadow chernozems
20 – Alluvial and Delluvial meadow
22 – Meadow and peat -swampy
24 – Eroded calcareous and typical chernozems
25 – Eroded leached chernozems
26 – eroded grey forest
32 – Grey forest

The leached chernozems have formed predominantly over loess, clayed loess and loess-type sandy clays. Unlike the preceding group, they have bigger humus horizon and distinct soil profile.

The active soil acidity fluctuates little in the alkaline spectre of 7.4 pH – 8.4 pH. Lower values are met rarely – in the area of Krushovitsa (pH=6.0), Manastirishte (pH=5.5) and some other places.

The buffer ability of the chernozems is high. Their physical and chemical characteristics show that the buffer capacity is due mainly to the solution of calcium carbonate, and the buffer capacity of such soils is high. A region with vigorous wind erosion – of the first class – is the plateau-like area of Zlatiyata. In relation to the structural class and contents of humus indicators, which determine the susceptibility of the soil to erosion the calcareous chernozems are evaluated by a general rate of 6, i.e. they are very susceptible to wind erosion.

The alluvial and delluvial soils are located in the floodable and over-floodable terraces of the Danube River, of the rivers of Tsibritsa, Ogosta and Skat, which flow into it and their tributaries. They have formed over alluvial deposits under the influence of meadow vegetation and near-by underwater during the winter-spring period.

[10] Koynov Iv. et al, 1968. Soil map of Bulgaria.

The **alluvial** soils in the 30 km zone in question around the Kozloduy Nuclear Power Plant, take up the floodable terrace of the Danube River and the islands therein.

Alluvial-delluvial soils can be found in the land areas of the villages of Rogozen and Selanovtsi. They are 115 – 160 cm deep and exhibit weak alkaline reaction and medium dusty-clay mechanical composition.

The meadow-swamp soils, situated near the site described, are hydromorphic soils developed under the influence of the meadow process and in the presence of abundant groundwater. Usually the water is at a depth of 50 cm – 100 cm, moving deeper or rising higher depending on the humidity of the year. To the north of the nuclear power plant, in the Blatoto area are also ***over-humid and swampy soils.*** The cause of these degrading processes is natural and anthropogenic. The depth of the groundwater, which is directly influenced by the level of the Danube River, creates condition for swampland.

Anthropogenic soils. They are found on the territory of the Kozloduy Nuclear Power Plant and in the 30 km zone. On the site of the nuclear power plant, building works related to the building of the power plant, caused their formation.

The soils of the selected sites in one way or other are anthropogenised, irrespective of the fact that their genetic origin is clear.

On the first, second and third site the soils are alluvial meadow, while on the fourth they are calcareous chernozem – highly anthropogenised, reduced and covered to a great extent by buildings and impermeable asphalt. The alluvial-meadow soils on the *third* site are very swampy, therefore if selected for the building of the New Nuclear Unit, this site will need to be drained and filled up with a thick layer of earth, which is not only an expensive exercise, but it reduces the stability of the built structure. The degradation and the pollution of the soils may be presented in the following way:

3.3.2.1 DEGRADED LANDS AND SOILS AND SUCH WITH CERTAIN DEGREE OF DEGRADATION

3.3.2.1.1 Erosed soils

In relation to erosion the lands and soils of the radiation-protected zone and the 30 km monitored zone around the Kozloduy Nuclear Power Plant refer to the groups of not eroded, slightly eroded and medium eroded soils. Because of the openness of the terrain and the characteristic north-eastern and north-western winds, the soils in the region, mainly agricultural soils used for annual crops, are subjected to deflation particularly in winter, when they have no plant cover. These are however soils of the agricultural lands outside the sites. The water erosion is significant for them in the spring and autumn season, when there are more intensive precipitations. Quite often in some parts of the region there are hailstorms[11]. If the vegetation cover is restored on the open areas of the

[11] Report on the environemtal impact assessment related to the building of a National Depot for burial of short-lived low and intermediate level radioactive waste. ASSIGNER – RADVE WASTE STATE ENTERPRISE.

sites after the construction of the New Nuclear Unit, the erosion processes will not have any negative effect both on the site and on the adjacent areas.

The risk of water erosion refers mainly to the third site. The soils on the first, second and third site are not affected by water erosion.

3.3.2.1.2 Acidized, over humidified and swamped soils

In the regions of the presumed impact on the sites there are no acidized soils because the genetic soil types are with natural alkaline, poor alkaline or neutral reaction.

No over humidification or swamping of the genetic soil types is observed on the first, second and fourth site because of their good filtration ability. No noticeable densification is exercised on them, which could cause worsening of their density or filtration qualities. Exception of this is the soils of the first and third site, where over humidified and swampy soils can be found, polluted by building waste. Here the swampiness is caused by processes of natural influence of the Danube River and its tributaries, since the area is located in the lowest part of the lands around the Kozloduy Nuclear Power Plant, in the floodable part of the river. Because of the swampiness, the soil fertility is lower, while the buildings works on this particular terrain would need a great amount of funds and time.

3.3.2.2 POLLUTED LANDS AND SOILS

The lands in the area of the 3 km radiation protected zone of the Kozloduy Nuclear Power Plant (2 km zone for the data after 2011), including the sites, proposed for construction of the New Nuclear Unit, may be polluted by radioactive elements, heavy metals, oil products, pesticides, concentration of large quantities of organic waste on small areas, mineral fertilisers etc.

The summary of the research data in connection with the preparation of the Report on the environmental impact assessment of the Kozloduy Nuclear Power Plant in 1999 related to the building of a National Depot for Radiation Waste and data from other administrative and scientific institutions[12, 13, 14], showed the following:

3.3.2.2.1 Lands polluted by heavy metals

The samples analysed in connection with the study “Ecological model of Kozloduy Municipality” show a relatively good picture of the state of municipality pollution by various industrial activities, including by the Kozloduy Nuclear Power Plant. The following sources of pollution were identified, other than the Nuclear Power Plant: the concrete plant, the construction company, the asphalt centre and the ceramics factory, the gas

[12] Report on the environemtal impact assessment of a depot for dry storage of spent nuclear fuel in the Kozloduy Nuclear Power Plant; September 2005.

[13] Report of the Regional Environment and Waters Inspection – Vratsa. Ministry of Environment and Waters on the state of the environment in 2006, 2007 and 2008.

[14] Report of the Kozloduy Nuclear Power Plant EAD, March 2009.

deposit and the industrial companies in the Town of Mizia, which, because of the direction of the winds, have direct influence on the territory under consideration. In the Report on the environmental impact assessment, related to the building of a National Depot for burial of short-live low and intermediate level radioactive waste, it is noted that the region, examined in connection with the activities of the Nuclear Power Plant, has been polluted according to the following indicators:

- ✓ There is increased pollution of the atmospheric air with dust around the companies;
- ✓ Soils polluted by lead are found around the villages Glozhene, Harlets, Butan (farmer's yard, the deposit), the territory of the Town of Kozloduy, the Ogosta River valley and the southern boundary of Kozloduy municipality;
- ✓ The soils of the machine and Tractor Station – Glozhene contain lead, copper and zinc with values high above the norm. This is due to the motor vehicles – tractors, trucks and agricultural equipment. The case is isolated and not typical (representative) for the region;
- ✓ The contents of manganese in the examined soils is within the limits of Clark's concentration of 850 mg/kg, however, deviations 4 times above the background contents have been registered near Glozhene and Sofronievo, in the Ogosta River valley and at the vehicle centre of the Kozloduy Nuclear Power Plant.

The registered amounts of some heavy metals like copper, lead etc. are not considered connected with the operation of the Kozloduy Nuclear Power Plant. The registered higher amounts of copper in some agricultural regions of the Vratsa District is connected most probably with the use of copper-containing preparations for spraying the vineyards and other agricultural crops (of the total of 31 agricultural lands with orchards and vineyards, 23 have been found to contain higher concentrations of copper and zinc).

The data of **Table 3.3-6** show the concrete pollution by heavy metals in the area of the Kozloduy Nuclear Power Plant, analysed in the Report on the environmental impact assessment related to the building of a National Depot for burial of short-live low and intermediate level radioactive waste[15, 16].

3.3.2.2.2 Lands polluted by oil products

The data from the research of the team, which studied the soils in the area of the Kozloduy Nuclear Power Plant in relation to the Report on the environmental impact assessment of the Nuclear Power Plant show that the oil products pollution does not differ from the one seen one way or another around any industrial company at any industrial site, which is controlled by its own monitoring and by the state control authorities.

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[15] Program for environment protection in the Kozloduy municipality for th period 2004 – 2010.

[16] Progam for the Development of Tourism of the Kozloduy municipality for the Period 2008 – 2011

The authors of the Report on the environmental impact assessment of the Nuclear Power Plant in 1999 have studied also the salt contents of the soils. They found by chemical analysis that their electric conductivity is not more than 4.0 mS/cm, which shows that the soils fall into the zero class of salinity (from 0 to 4 dS/m). In general the pollution of the soils by oil products in the area of the Kozloduy Nuclear Power Plant is minimal and does not differ from the pollution of any industrial site, which is being controlled by monitoring of its own or by the state control authorities.

TABLE 3.3-6: CONTENTS OF HEAVY METALS AND NON-METALS IN SOIL SAMPLES (MG/KG) IN THE 30 KM ZONE OF THE Kozloduy Nuclear Power Plant[17]

Sample No.	pH	Cu		Pb		Zn		Ni		Hg	
		Concentration	Maximum permissible concentration	Concentration	Maximum permissible concentration	Concentration	Maximum permissible concentration	Concentration	Maximum permissible concentration	Concentration	Maximum permissible concentration
1	6.9	28.950	<260	20.408	<80	60513	<340	27.765	70	-	-
2"	7.2	21.244	<270	18.070	<80	32.695	<360	28.814	70	-	-
4*	7.0	18.929	<260	23.481	<80	44.566	<340	32Л07	70	-	-
5*	7.0	20.747	<260	21.850	<80	37.080	<340	26.927	70	0.232	1
6	7.0	17.705	<260	18.548	<80	30.773	<340	24.871	70	-	-
7-	7.0	18.031	<260	21.930	<80	41.910	<340	26.072	70	-	-
8	7.0	18.689	<260	20.678	<80	32.607	<340	25.052	70	-	-
9	6.8	35.413	<260	47.217	<80	57.515	<340	26.874	70	-	-
10	7.3	20.583	<270	19.142	<8()	36.226	<360	31.286	70	0.412	1
11	7.5	22.533	<270	21.347	<80	39.611	<360	30.123	70	-	-
12	7.3	17.735	<270	32.711	<80	53.992	<360	23.252	70	-	-
13	7.0	22.001	<260	22.719	<80	38.741	<340	28.219	70	-	-
H	7.0	16.858	<260	21.639	<80	36.987	<340	22.142	70	-	-
15	8.0	17.200	<280	10.500	<80	43.700	360	21.000	70	1.350	1
14'	-	--	-	-	-	-	-	-	-	1.040	1
15'	-	-	-	-	-	-	-	-	-	0.810	1
16	-	-	-	-	-	-	-	-	-	0.602	1
17	-	-	-	-	-	-	-	-	-	<0.050	1

TABLE 3.3-6 – CONTINUATION

Sample No.	pH	As		Cd		Cr		Mn	Co	Fe	B
		Concentration	Maximum permissible	Concentration	Maximum permissible	Concentration	Maximum permissible	Concentration	Concentration	Concentration	Concentration
1	6.9	-		Traces	3.0	-	-	320.123	7.831	745.610	-
2"	7.2	-	-	Traces	-3.0	-	-	293.270	6.837	760.402	-
4*	7.0	-	-	Traces	3.0	-	-	298.304	7.188	751.390	-
5*	7.0	8.6	29-55	Traces	3.0	-	-	278.317	7.504	689.503	-

[17] According to the Report on the environemtal impact assessment of the Kozloduy Nuclear Power Plant, 1999.

Sample No.	pH	As		Cd		Cr		Mn	Co	Fe	B
		Concentration	Maximum permissible	Concentration	Maximum permissible	Concentration	Maximum permissible	Concentration	Concentration	Concentration	Concentration
6	7.0	5.98	25	Traces	3.0	23.3	200	265.366	6.323	660.990	36.7
7-	7.0	-	-	Traces	3.0	-	-	280.458	7.066	1561.89	35.6
8	7.0	0.2	25	Traces	3.0	-	-	259.066	7.158	624.304	-
9	6.8	-	-	Traces	3.0	-	-	322.986	8.037	787.121	39.5
10	7.3	10.3	25	Traces	3.0	-	-	279.722	8.645	645.892	-
11	7.5	-	-	Traces	3.0	34.0	200	312.381	8.776	744.307	52.0
12	7.3	-	-	0.197	3.0	-	-	262.868	5.518	609.285	-
13	7.0	-	-	Traces	3.0	-	-	306.103	8.370	749.474	-
H	7.0	-	-	Traces	3.0	-	-	256.894	5.787	772.192	-
15	8.0	4.4	25	.0.440	3.0	23.6	200	335.000	2.800	-	37.1
14'	-	-	-	-	-	-	-	-	-	-	-
15'	-	-	-	-	-	-	-	-	-	-	-
16	-	-	-	-	-	-	-	-	-	-	-
17	-	-	-	-	-	-	•	-	-	-	-

Note: Samples marked by asterisk (*) No. *2. 4. 5 and 7 are taken from the site of the Kozloduy Nuclear Power Plant and are assessed as representative for non-agricultural lands, i.e. as lands with old pollutions in industrial companies (as per the standards of the "Dutch list")*

3.3.2.2.3 Lands and soils polluted by radionuclides

As recipient – accumulator and filter, the soil cover builds up together with the useful chemical compounds, also many harmful ones, in most cases toxic substances for the plants, animals and human beings, which get into the soil layer as a result of the industrial and agricultural activity of man – through the atmospheric air, the precipitations and the irrigation waters, the mineral fertilizers and the chemical preparations for plant protection from weeds, diseases and pests. Most heavy metals in the form of microelements are closely connected with the fertility of the soils. Both the shortage and the excess of these elements affect the amount and the quality of the yield.

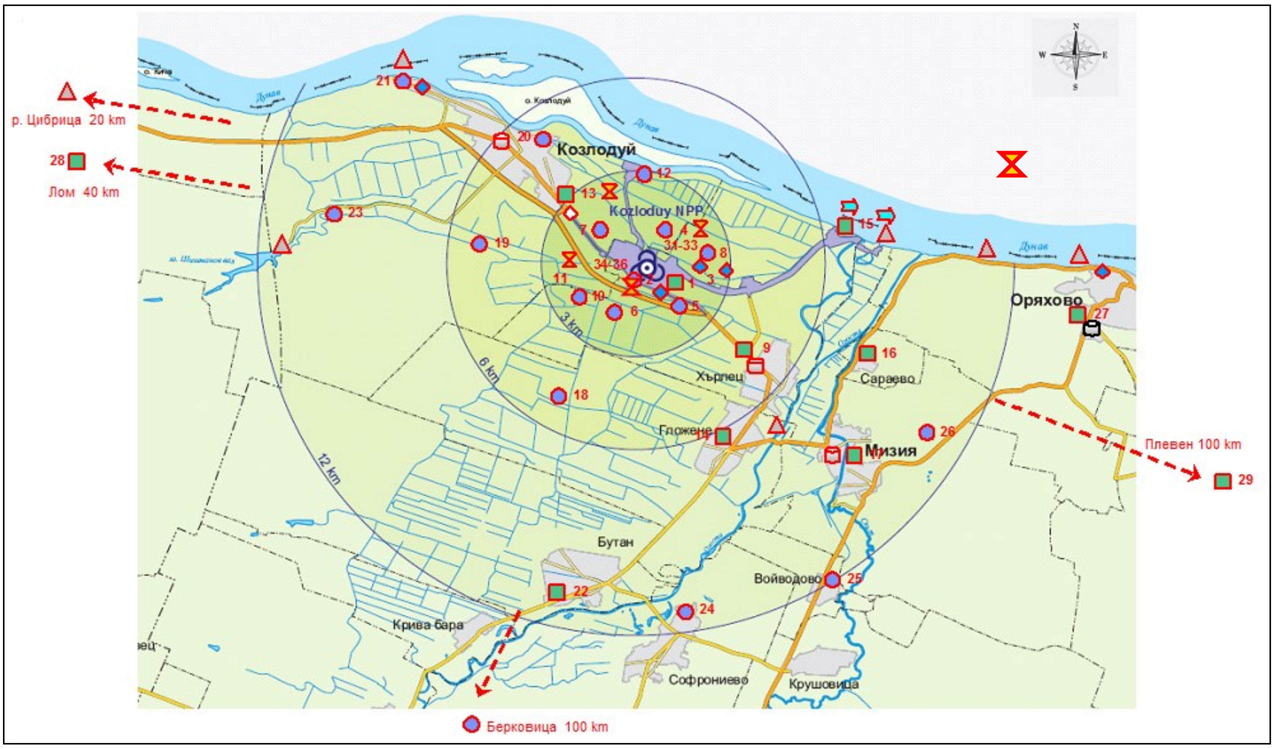
It is expedient to accept as starting base the natural and technogenic radioactivity in order to characterise the environmental components of a wide geographic area, of which it is assumed that it could be potentially influenced by the operation of a future nuclear unit.

In accordance with the requirements of legislation for monitoring and control of pollution around and in the industrial companies in the country, within a radius of 100 km and in greater detail – within 30 km around the Kozloduy Nuclear Power Plant, monitoring is being provided to the soils by the power plant management and by the state control authorities. Greater attention has been paid to the radiation monitoring. A wide program of surveillance has been implemented on radioactive pollution of the soils by four independent institutions: the plant's authorities (Radiation control of the environment) of the Kozloduy Nuclear Power Plant, The National Centre of Radiology and Radiation Protection, the departments of the Ministry of Environment and Waters (the Environment and Waters Regional Inspection – Vratsa) and the Nikola Pushkarov Institute of Soil Science, Agro technologies and Plant Protection.

In accordance with the international requirements for radiation monitoring reference and control points have been established for surveillance. Their choice has been coordinated with the concrete meteorological and geographic conditions of the area and is representative for obtaining reliable and all-round information.

During the whole period of operation of the Kozloduy Nuclear Power Plant the contents of the two most dangerous biologically radionuclides – ^{90}Sr and ^{137}Cs is being determined. Some institutions have been monitoring the levels of other radiotoxic elements like ^{60}Co, ^{241}Am, ^{110m}Ag, the isotopes of U, ^{226}Ra and in recent years also $^{238,\ 239\ +240}Pu$. The data are summarised in annual reports for radiological monitoring since the building of the power plant in 1974 up to now.

The points for radiation monitoring are presented on **Figure 3.3-6**.



Legend:

*– control point of the type "**A**": aerosols, atmospheric deposits, soil, plants, gamma-background (TLD) – 11 posts*

*– control point of the type "**B**": atmospheric deposits, soil, plants, gamma-background (TLD) – 15 posts*

*– control point of the type "**C**": water, bottom deposits, water weeds, gamma-background – 7 points;*

Products of the food chain: – drinking water; milk; - fish; cereals

FIGURE 3.3-6: SCHEME OF DISPOSITION OF THE POSTS FOR RADIATION MONITORING AROUND THE KOZLODUY NUCLEAR POWER PLANT

In 2002 when all 6 units of the Kozloduy Nuclear Power Plant were in operation and the environmental impact was greater, the data of the monitoring of soils[18] show that the indicators for ^{90}Sr were within the limits of 0.23 parts – 1.86 Bq/kg a.d.w., while the mean annual contents for all 36 control points was 1.01 Bq/kg a.d.w. These are results within normal limits for this geographic area, characterised by depositions from the nuclear tests in the atmosphere and the accident at the Chernobyl Nuclear Power Plant on the surface of the earth. The values are close to the ones measured in previous years with a slight tendency of self-cleaning of the upper soil layer. Before the commissioning of the Kozloduy Nuclear Power Plant in 1972-74 the average contents of ^{90}Sr was 5.0 ± 0.4 Bq/kg a.d.w.

The contents of ^{137}Cs in the examined soils vary from <0.4 to 70.3 Bq/kg a.d.w., the mean value for 2002 being 18.7 Bq/kg a.d.w. In former years the activity fluctuated within close limits reaching 114 Bq/kg a.d.w in 1996. At some of the points the contents of ^{137}Cs is considerably lower than the average. This refers to the industrial site of the Kozloduy Nuclear Power Plant, where as a result of the intensive building activity; the uppermost soil layer has been removed or replaced by soil from the deeper layers. Non-homogeneity in the contents of ^{137}Cs is evident at other points of the Radiation Protected Zone and the Monitored Zone point 11, 15, 21 и 24)[19].

As a whole the contents of ^{90}Sr and ^{137}Cs in the soils of the area of Kozloduy is lower than the one measured in other regions of the country. The reason for this is the insignificant precipitations in Northwest Bulgaria in May 1986 and respectively the lower amount of the deposited technogenic radionuclides.

In 2002 (and in the following years) 60Co has been registered in the soils of some monitoring points of the industrial site (No. 3, 31-34) or in the immediate vicinity to it.

The contents of the natural radionuclides ^{238}U, ^{226}Ra, ^{232}Th is within the limits of the natural contents for the soils in the area, while the contents of the ^{90}Sr and ^{137}Cs in the surface soil layer does not differ from the contents in the entire Northern Bulgaria and is due to the residual pollutions from Chernobyl. Its constant contents is proof of the lack of additional local deposits by the operation of the Kozloduy Nuclear Power Plant. According to data for the results of the radiological monitoring by the Kozloduy Nuclear Power Plant the contents of ^{137}Cs varies in the interval 1.53÷48.5 Bq/kg a.d.w., ^{90}Sr – varies in the interval 0.37÷3.51 a.d.w., determined in 36 control points in the 100 km zone around the Nuclear Power Plant.

According to the Kozloduy Municipality Program for Protection of the Environment for the period 2004 – 2010, there is no pollution with heavy metals or non-metals established in the area of the site. There is local spillage of oil products at the oil station in the site of the Kozloduy Nuclear Power Plant and slight pollutions with oils, oil products are found at the

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[18] Results of the radiation monitoring of the Kozloduy Nuclear Power Plant in 2002, Annual report, May 2003, Town of Kozloduy.

[19] Results of the radiation monitoring of the Kozloduy Nuclear Power Plant in 2002, Annual report, May 2003, Town of Kozloduy.

gas deposit in the Village of Butan, the landfills of the villages of Harlets and Kriva Bara in former agricultural sites.

The monitoring of the soils carried out by the Kozloduy Nuclear Power Plant in 2011 revealed that the measured activity of ^{137}Cs in the surface soil layer was in the range from 1.55 to 45.4, average 13.2 Bq/kg (dry weight), and of ^{90}Sr – from 0.22 to 3.97 Bq/kg. These are values characteristic for the soils in this geographic region, the measured values of ^{137}Cs are lower than in other regions of the country, the examined vegetation showed technogenic activity in normal limits – ^{137}Cs, to 2.55 Bq/kg, and ^{90}Sr – to 1.15 Bq/kg (dry weight)[20].

In parallel to the monitoring, carried out by the laboratories of the Kozloduy Nuclear Power Plant, other organisations, external for the Kozloduy Nuclear Power Plant, carry out their own monitoring. They are departments of the Ministry of Environment and Waters, the Ministry of Agriculture and Foods and the Ministry of Health.

According to data for 2010 from the Environment Executive Agency[21] the specific activity of the technogenic ^{137}Cs, in the soils, deposited as a result of the accident at the Chernobyl Nuclear Power Plant, is characterised by non-homogeneity and the pollution of the soils has spotty character – **Table 3.3-10**.

The study of the radioactive pollution of the soils in the 30 km zone of the Kozloduy Nuclear Power Plant by the Laboratory of Radioecology and Radio-isotope Research at the Nikola Pushkarov Institute of Soil Science, Agro technologies and Plant Protection started in 1978 by determination the specific activity of technogenic radioactive isotopes in soils, taken from the area of the Kozloduy Nuclear Power Plant and collected along the wind flow around the Nuclear Power Plant. The gathering of the samples is made annually and at one and the same time in the year. At the same time control samples are collected from reference sites along the valley of the Danube River – respectively the City of Vidin and the Town of Silistra.

On order to characterise fully the surface pollution at the reference sites along the wind flow in the 30 km zone around the Kozloduy Nuclear Power Plant, samples are collected from the surface soil layer (0 – 5 cm). After drying, homogenising and grinding through a 2 mm sift, all collected samples are subjected to a full gamma-spectrometric analysis and radio-chemical determination of the ^{90}Sr[22,23].

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[20] Annual report – 2011 Kozloduy Nuclear Power Plant EAD.

[21] Report of Environment Executive Agency for 2010 – Radioactivity of the Environment

[22] Naydenov M., Misheva L., Yordanova I., Staneva D., Dureva L. Collection of methods for determination of alpha, beta and gamma emitting radioactive isotopes in sites of the environment, 2001, National Centre for Agrarian Scienes, Sofia

[23] Tarpanova, Hr., M. Naidenov, 1992, Adapted method for determination of ^{90}Sr in soils, XIV Colloquium The Physics in the Protection of Man and the Environment, Gyoletchitsa, 19-21.06.1992, page 10-21.

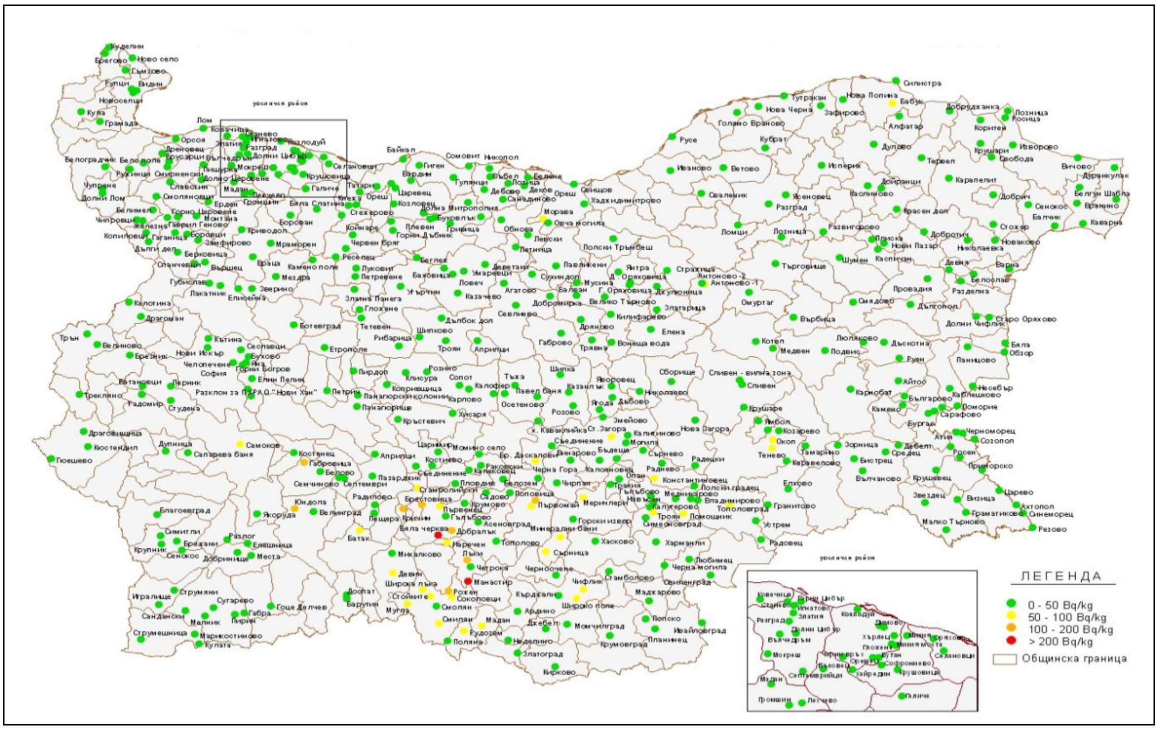

FIGURE 3.3-7: SPECIFIC ACTIVITY OF ^{137}CS IN NON-ARABLE SOILS BQ/KG [4]

In order to evaluate correctly the radiation status of the soil, it is mandatory to take into account the impact of the accident at the Chernobyl Nuclear Power Plant in April 1986, which changed fundamentally the radiation situation. In order to evaluate this change we have made a comparison with results from our studies before the accident.

On **Table 3.3-7** one can see the averaged results for the years 1980 – 1985 of the levels of radioactive pollution with technogenic radionuclides of soils of some permanent reference sites in the 30 km zone around the Kozloduy Nuclear Power Plant[24] [5].

TABLE 3.3-7: CONTENTS OF TECHNOGENIC RADIOISOTOPES IN THE AREA OF THE KOZLODUY NUCLEAR POWER PLANT (1980-1985)

No.	Site	Depth (cm)	^{90}Sr Bq/kg	^{137}Cs Bq/kg
1	leskovets	0 – 5	2.2	21 ± 4
2	Botev alley	0 – 5	5.0	23 ± 5
3	Bazovets	0 – 5	2.7	14 ± 4
4	Kozloduy – the Vet clinic	0 – 5	1.7	3 ± 0.5
5	Glozhene	0 – 5	3.7	5 ± 2
6	Butan	0 – 5	3.7	9 ± 0.5
7	Sofronievo	0 – 5	2.8	12 ± 0.5
		Average	**3.1±1.0 (32%)**	**12±7 (58%)**

[24] Naydenov, M., 1986 Contents of technogenic radionuclides in soils in the area arounf the Kozloduy Nuclear Power Plant, Collection of scientific reports and announcements of SA, Sofia, page 50-68.

The averaged values for Northern Bulgaria are: ^{90}Sr – 4 Bq/kg, и ^{137}Cs – 10 Bq/kg, which is not different statistically from the values displayed in the Table.

In the "hottest" period – the first months after the accident at the Chernobyl Nuclear Power Plant, the total technogenic activity of the soils increased between 10 and 300 times. Only for ^{137}Cs this increase was from 3 to 10 times, thought with some samples it reached 50 times above the characteristic background values.

In the first several months after the accident, the radiation status of the soils was determined by the contents of long-live isotope of ^{137}Cs и ^{90}Sr.

In **Table 3.3-8** data is provided for the contents of technogenic gamma emitters in soils of the reference sites in the area of the Kozloduy Nuclear Power Plant, coordinated with the wind flow, researched at the Nikola Pushkarov Institute of Soil Science, Agro technologies and Plant Protection. The data is from 1968[25,26].

TABLE 3.3-8:. CONTENTS OF TECHNOGENIC GAMMA-EMITTERS AND ^{90}SR IN SOIL SAMPLES FROM THE AREA OF THE KOZLODUY NUCLEAR POWER PLANT [BQ/KG]

No.	Site	Depth (cm)	^{90}Sr	^{137}Cs	^{134}Cs
1	Leskovets	0 – 5	8.1	120±3	20±2
2	Botev alley	0 – 5	12.8	48±2	12±1
3	Bazovets	0 – 5	4.9	46±2	2±0.5
4	Kozloduy, vet clinic	0 – 5	1.4	7±1	<1
5	Glozhene	0 – 5	3.5	60±2	7±1
6	Butan	0 – 5	8.1	78±2	9±1
7	Sofronievo	0 – 5	3.2	38±1	6±1
		Average	**6±3.6 (60%)**	**56±33 (60%)**	-

By comparing with data for contents of radio caesium and radio strontium in soils in other regions of the country (**Table 3.3-9** and **Table 3.3-10**), it is clearly seen that the mean values for content of ^{137}Cs and ^{90}Sr, characterising the pollution in the area around the Nuclear Power Plant are not considerably different from the ones for Northern Bulgaria.

[25] Tsvetkov Ts., S. Buchvarova, M. Joreva, A. Zlatev, M. Poynarova, Ts. Bineva, D. Staneva, I. Yordamova et al. (2006) Twenty years after Chernobil. Impact on agricutureal production. The experience of the agrarian science in overcoming consequences – Ministry of Agriculture and Forests, National Centre for Agrarian Scences, Sofia, page 238.

[26] Naydenov, M., I. Yordanova, Hr. Turpanova, (1989). Dynamics of surfsce soil pollution ^{90}Sr and ^{137}Cs in the period 1986 – 1988. Collection of scientific reports and announcements, Part 1, Sodia, Agricultural Academy, page 18.

TABLE 3.3-9: AVERAGED VALUES FOR CONTENTS OF ^{137}Cs IN SOILS FROM VARIOUS REGIONS OF THE COUNTRY [BQ/KG]

Year	1988 г.	1994 г.	2001 г.	2009 г.	2011 г.
30 km zone of the NPP	56±33 (60%)	51±27 (54%)	25±15 (27%)	19±8 (42%)	19±13(69%) Min –7; Max -48
North Bulgaria	51±32 (64%)	46±28 (61%)	27±20 (75%)	14±9 (64%)	14±10(53%) Min -4; Max-32

TABLE 3.3-10: AVERAGED VALUES FOR CONTENTS OF ^{90}Sr IN SOILS FROM VARIOUS REGIONS OF THE COUNTRY [BQ/KG]

Година	1988 г.	1994 г.	2001 г.	2009г.	2011
30 km zone of the NPP	6±3.6 (60%)	5.7±2.6 (46%)	2.3±0.54 (20%)	3.4±1.1 (32%)	2.6±0.5 (20%) Min-1.9; Max-3.0
North Bulgaria	5.5±3.7 (68%)	5.0±3.0 (60%)	2.8±1.4 (48%)	2.7 ±1.1 (45%)	2.2±0.9 (41%) Min–0.8; Max 3.6

A characteristic peculiarity of the surface pollution all these years has been its strong non-homogeneity. This makes difficult the subtle changes registration of the radioactive status of the soils and categorical assessment of apparent increase of the contents of these radionuclides in the surface soil layer around the Nuclear Power Plant. Only certain tendencies may be discerned.

In order to evaluate the influence of the Kozloduy Nuclear Power Plant on the radio-ecological state of the soils in Northern Bulgaria, reference points have been set for sample collection along the valley of the Danube River, to the east and west of the Nuclear Power Plant – from the Village of Novo Selo, Vidin District to the Town of Silistra. In order to obtain reliable and precise information, the selection of the reference points has been made in accordance with the international requirements for radiation monitoring around the Nuclear Power Plant and adjusted to the concrete meteorological and geographical conditions.

The averages values according to regions for the specific activities of ^{137}Cs and ^{90}Sr in the soils have been shown on **Figure 3.3-8** and **Figure 3.3-9.**

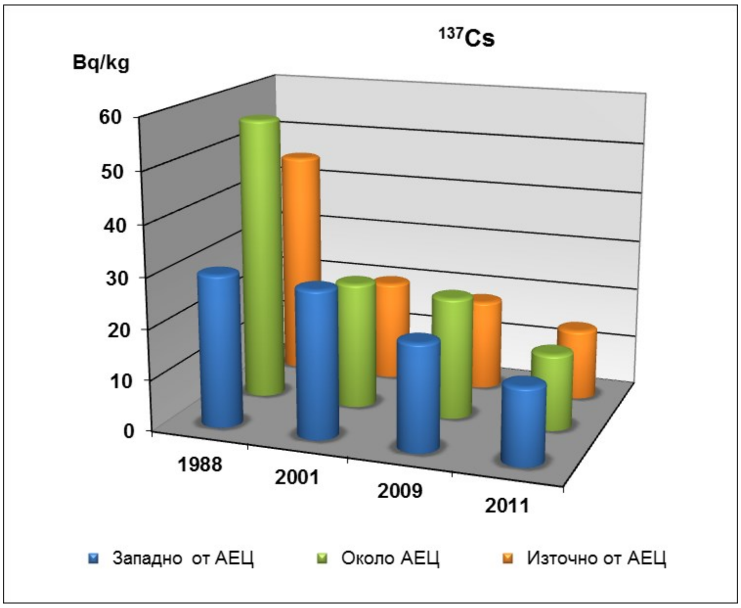

FIGURE 3.3-8: AVERAGED SPECIFIC ACTIVITIES FOR ^{137}Cs

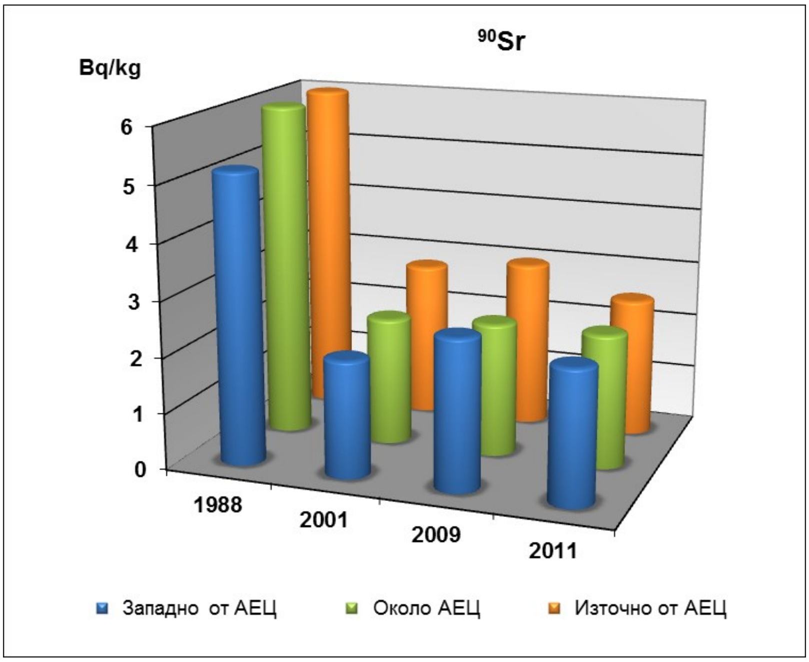

FIGURE 3.3-9: AVERAGED SPECIFIC ACTIVITIES FOR ^{90}Sr

The results represented on the figures indicate lack of radioactive pollution as a result of the operation of the Nuclear Power Plant in respect of the studied radionuclides. The differences registered in the average values for the specific activity of ^{137}Cs and ^{90}Sr in soils of regions to the east and west of the Nuclear Power Plant, compared with the values from the 30 km zone around the power plant are not statistically significant. The differences are within the variations of the averaging in the different regions.

The samples from the reference points in the 30 km zone around the nuclear power plant were analysed for contents of $^{238, 239+240}$Pu[27]. The averaged results are: for ^{238}Pu – (1.32 ± 0.35) x10^{-2} Bq/kg with a maximum value of 0.02 Bq/kg, and for $^{239+240}$ Pu – (0.18 ± 0.06) Bq/kg with a maximum value of 0.3 Bq/kg, and are within the range of fallout background values.

On the basis of the presented date and their comment the following conclusions can be made:

- ✓ As a result of the studies carried out throughout the period of operation of the Kozloduy Nuclear Power Plant, informative and presentable data base has been compiled on the state of the region in respect of contents of the two radionuclides, which are biologically most dangerous – ^{137}Cs and ^{90}S.
- ✓ The values estimated for the contents of ^{137}Cs and ^{90}S do not prove any contribution by the functioning of the Nuclear Power Plant. Up to 1986 the amount of the nuclides mentioned above was due to the experiments with nuclear arms in the atmosphere for a number of years.
- ✓ After 1986 the contribution of the disaster at the Chernobyl Power Plant was significant as it increased the level of the radioactive pollution of the soils in the whole of Bulgaria and more specifically – in the region under consideration.

3.4 SUBSURFACE AND NATURAL RESOURCES

3.4.1 SUBSURFACE

In that part of North-western Bulgaria, where the potential sites for the New Nuclear Unit are located, geological (including more than 50 deep boreholes) and geophysical studies in search of oil and gas have been made. The reports on these studies are stored in the Geo-fund of the Ministry of Environment and Waters. They have been analysed and summarised in connection with the designing of the nuclear facilities of the Kozloduy Nuclear Power Plant [28, 29, 30].

[27] Tsvetkov Ts., S. Buchvarova, M. Dzhoreva, A. Zlatev, M. Poynarova, Ts. Bineva, D. Staneva, I. Yordanova et al. (2006). Twenty years after Chernobil. Impact on agricutureal production. The experience of the agrarian science in overcoming consequences – Ministry of Agriculture and Forests, National Centre for Agrarian Scences, Sofia, page 238.

[28] Research nd activities to enhance the security of the site of the Kozloduy Nuclear Power Plant – series of reports related to the implementation of the recommendations of IAEA, Geophysical Institute, 1994

[29] Assessment of the geological conditions for long-time storing of radioactive waste on the site of the Kozloduy Nuclear Power Plant and cmplex analysis and techno-economical assessment of the possibilities for long-time storage of conditioned radioactive waste on and in the vicinity of the Kozloduy Nuclear Power Plant site, Geophysical Institute, 2003

[30] Study of the possibilities to build a deep geological depot. Analysis and regioning on the territory of the Republic of Bulgaria, determination of potential intaking geological blocks for deep burial of radioactive waste. Geological Institute of the Bulgarian Academy of Sciences, contracted by Risk Engineering AD under agreement with Radioactive waste State Enterprise, 2010.

The region of the sites has been object of morphological studies, which have been summarised by Evlogiev (2006)[31] and by the Geotechnics Research base (2012)[32].

In this Report on the Environmental Impact Assessment the engineering-geological and hydrogeological conditions of the potential sites will be analysed and evaluated on the basis of the results of studies specially carried out for this purpose[33].

The evaluation of these conditions referring to site 2 and 4, which are located on the first non-floodable terrace of the Danube River takes into consideration also the studies of Energoproekt AD in the period 1967-1999 in relation to the designing energy units 1 – 6 and other nuclear facilities of the Kozloduy Nuclear Power Plant. Also used are the results of the studies used to design the Radiana National Depot for low and intermediate level active wastes.

What concerns sites 1 and 3, in addition to the data from Energoproekt AD, data from Vodproekt, related to studies for draining the Kozloduy lowland, have been used.

There is reliable information both for the in-depth and the sub-surface aqueous horizons, which, according to the Danube Region Basin Directorate, are in the water catch of the following groundwater bodies:

- → Porous waters in the Quaternary – the Kozloduy lowland, code BG1G0000QAL005;
- → Porous waters in the Quaternary – between the rivers Lom and Iskar code BG1G0000QPL023;
- → Porous waters in the Neogene – the Lom-Pleven depression, BG1G00000N2034.

3.4.1.1 METHODOLOGY FOR EVALUATION OF THE IMPACT OF THE INVESTMENT PROPOSAL ON THE GEOLOGY IN THE AREA

The evaluation will be done with the application of the following principles and approaches:

- → The impact on the environment will be considered from two aspects:
  - ✓ Impact of the New Nuclear Unit on the components of the geological environment at the various sites;
- → The opposite view, what influence may the geological environment and mostly the processes of geological risk exert on the safe and long-term functioning of

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[31] Y. Evlogiev. The Pleistocene and the Holocene in the Danube plain, Doctor's Theses 2006

[32] Geotechnics research unit in the Geological Institute of the Bulgarian Academy of Sciences, 2012, Development of geological and hydrogeological profiles from the plateau through the Radiana site to the Danube River. Contract with the Radioactive Waste State Enterprise.

[33] Research and determination of the location of preferred site for the construction of New Nuclear Capacity on the site of the Kozloduy Nuclear Power Plant and Adjacent territories. Review of completed studies, Ref. No. REL-1000-ST-001-2, January, 2013.

the New Nuclear Unit wherefrom harmful consequences for the environment may occur;

→ Analysis and evaluation of the geological data of the geological and geophysical studies in search of oil and gas, carried out after 1969 in the area. Thanks to very deep drillings, the information of the in-depth geological structure, necessary for the Report on the Environmental Impact Assessment, could be provided. The other principal source of data are the reports of Energoproekt AD on the engineering geological studies in connection with the building of the Kozloduy Nuclear Power Plant in the period 1967 – 1999;

→ Analysis and evaluation of the newest results in the surveys in the zone of the potential sites for the New Nuclear Unit;

→ Taking account of the experience of the nuclear states in the European Union:

  ✓ Utilisation only of results obtained by the methods of contemporary geology and with the technical possibilities thereof, in accordance with the Bulgarian standards and the IAEA standards, including the newest scientific achievements;

  ✓ Preference of the facts to the interpretations – prevalence have the data, obtained by direct measurements and tests to results and conclusions obtained in an indirect way – by analogy with excessive model simplifications, logical conclusions or such, assumed by intuition.

3.4.1.2 GEOMORPHOLOGICAL CONDITIONS

From the point of view of the selection of site for the nuclear power plant and of the possible mutual influence between the power plant and the geological environment, the geomorphological conditions are studied both on a wider territory (i.e. on a smaller scale) and on the adjacent zone to the power plant (i.e. on a larger scale)

On the smaller scale the layout of the sites in the 30 km area around them is presented including the peculiarities of the relief and the type of the large topographic forms. The small scale analysis assists the study of the neotectonic processes – faults, swinging movements and the like.

The large-scale studies have as their subject the peculiarities of the adjacent zone to the site and are focused on the preconditions for development of eventual geologically hazardous processes, at the peculiarities of the relief from the viewpoint of the building of the power plant and its communications.

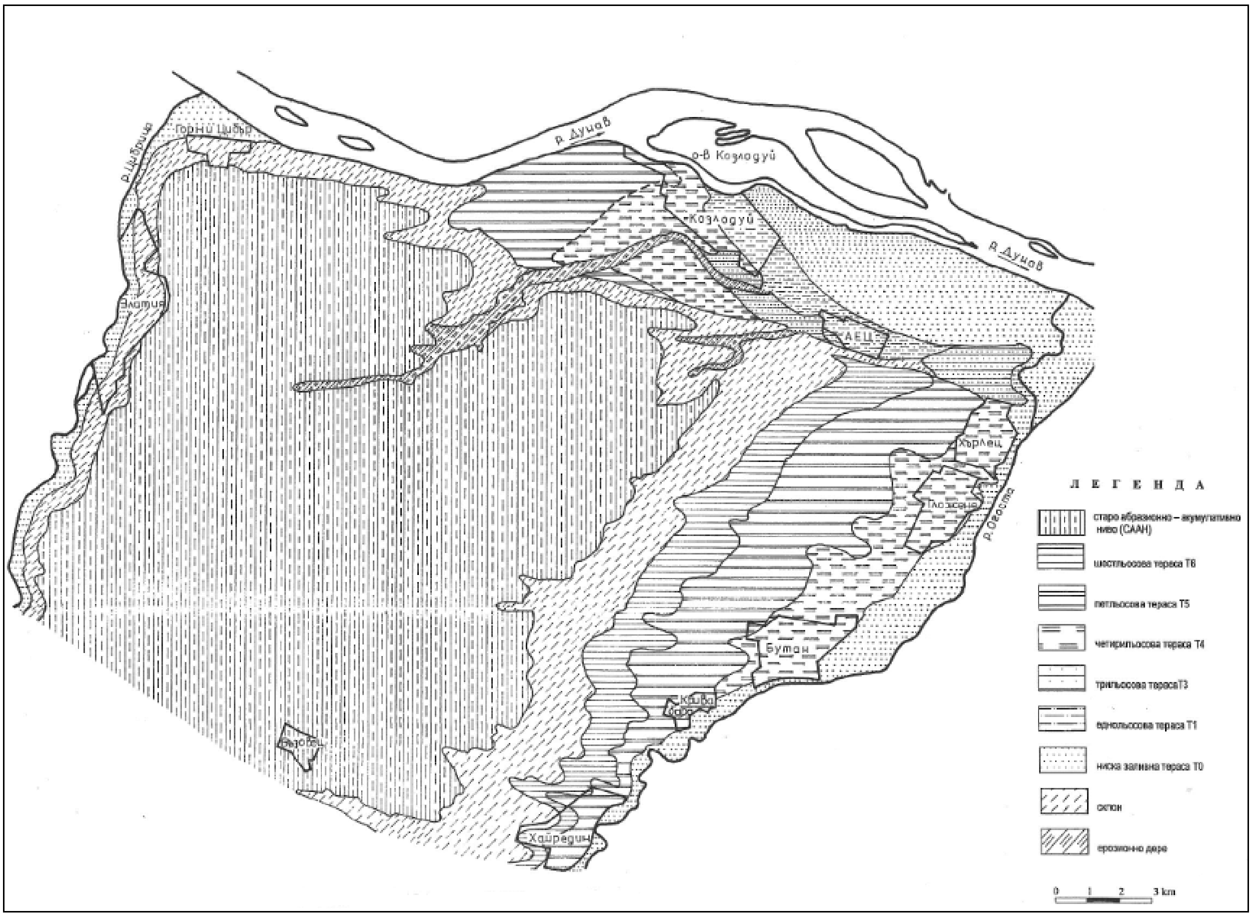

FIGURE 3.4-1: GEOMORPHOLOGICAL MAP OF THE AREA

In this section the geomorphological features of the area of the New Nuclear Unit are presented on a map in M 1:100 000 (**Figure 3.4-1)**, and the zone of the potential sites in M 1: 10 000.

The analysis and the assessment the geomorphological conditions is based mainly on the newest research, which has been carried out in connection with the selection and characteristics of a site for building of a depot for radioactive waste[2,7], and on some other sources[4,5].

In the assessment of the impact on the environment by the building of the New Nuclear Unit, taken into account are the requirements of the International Atomic Energy Agency[34,35], the most important of which are the following:

- → - the geomorphological conditions of the area ought to exclude the risk of flooding and exogeodynamic hazardous processes, which may endanger the operational safety of the facilities;

[34] SSG-18 Meteorological and Hydrological Hazards in Site Evaluation for NPP, IAEA, 2011.

[35] IAEA Safety guide, 2004. Safety standarts series. NS – G – 3.6. Geotechnical aspects of site evaluation and foundations for nuclear powerplants.

- -preferable are flat terrains with small elevation, which make building easy and the migration of pollution in the groundwater happening rapidly and uncontrollable less probable;
- The relief conditions allow access to a large water resource, necessary for the functioning of the facility.

3.4.1.2.1 Geomorphological conditions in the area of the sites

The Bulgarian part of the studied area (that is the 30 km zone, **Figure 3.4-1**) from geomorphological aspect is situated in the western part of the Danube hilly plain. The area is part of the valley between the rivers of Tsibritsa and Ogosta and contains the following geomorphological forms: **loess plateau** (old flattened area), cut by the tributary lowlands of the rivers Danube, Tsibritsa and Ogosta and river terraces.

The Loess plateau has a plane relief and is genetically connected with the so-called **old accumulative-abrasion level (Figure 3.4-1**). This level cuts into Pliocene (lower-Roman) clays. The cutting is exhibited on the high right bank of the Tsibritsa River near the Village of Zlatia, Valchedram and the Village of Madan. On the eroded lower-Roman clays are deposited lake-river sediments, represented by basic gravel-sandy and covering gravel-clay complex with an age of 2.59-0.94 Ma BP. The upper part of the alluvium has an absolute elevation of 125 – 130 m and a slope towards the Danube River. Over them is the loess complex represented by six loess horizons, divided by buried soils.

To the south, outside the boundaries of the area under consideration, the old Accumulative-abrasion level is bounded by a Pliocene denuded surface.

The loess plateau is cut by relatively few tributary valleys – two of the rivers are tributaries of the Danube River and the rest – of the Ogosta River south of the Village of Glozhene, at the Village of Butan, the Village of Kriva Bara, the Village of Bazovets, the Village of Gorna Gnoynitsa etc. The tributary valleys have formed during Pliocene. Re-deposited loess has accumulated in them, which has smaller thickness than the plateau.

From the plateau towards the current river bed of the Tsibritsa River, Ogosta River and the Danube River there follows a spectre of river terraces, formed during the glacial Pleistocene and the Holocene (**Figure 3.4-1**). The enumeration of these terraces is from T_6 to T_0, according to the number of the loess horizons.

In the loess plateau and the high river terraces around the Kozloduy Nuclear Power Plant is a number of steppe areas and dry valleys. All they are imprints on the contemporary relief of older lower areas, which were flooded during the eolithic loess drifts and that is why the deposits are of more or less modified and clay loess.

Information on the Romanian part of the researched area is contained in the work of the Geological Institute of the Bulgarian Academy of Sciences[2]. It has been derived out of cartographic material processing. It looks like that the Romanian territory possesses the same level and terraces as on the Bulgarian right Danube bank. These are the old abrasion-accumulative level, the six-loess terrace T_6, the five-loess terrace T_5, the four-loess terrace T_4 etc to the low floodable terrace T_0.

The terraces on the Romanian territory are better shaped spatially. While on the right bank of the river some of them appear like small spots, on the left bank they occupy large areas.

The analysis of the geomorphological conditions of the area of the potential sites allows to make the following conclusions:

- The surface of the terrain is plain-like and has low elevation – from 30 to 130 m on the Romanian territory and from 30 to 160 on the Bulgarian territory;
- The right banks of the rivers Ogosta and Tsibritsa have steeper slopes susceptible to landslides and erosion processes, i.e. far from the potential sites;
- The presence of wide flat surfaces (plateaus) on the two banks of the Danube River is one of the geomorphological proofs that no notable cuttings during the Quaternary happened.

3.4.1.2.2 Geomorphological conditions on the sites

The geomorphological map of the sites and of the adjacent zone embraces area of the high slope (altitude 95 m) to the Danube River and two km to the east and 2 km to the west of the area of the Kozloduy Nuclear Power Plant. Within these boundaries the following geomorphological forms can be found (Annex 9):

Slanted slope (C)

It has been shaped between the old abrasion-accumulative level and Terrace T_6 – from an elevation of 110 to 98 m, and between Terraces T_6 and T_2 – elevation of 58 to 46 m. In the south-western part, where Terrace T_6 is not present, the slope encloses the terrain from elevation 110 to 46 m. The slope is cut into low-Roman clays and sands of the Brusartsi formation. The loess cover has maximum depth not more than 47 m in the high part of the slope (*Annex 9)* and with the increase of the inclination between T6 and T_2 – it decreases to 7 – 8 m.

Terrace T_6

The terrace has a width around 300 m in the boundaries of the Kozloduy Nuclear Power Plant. To the east it widens because of its merge with Terrace T_6 at the Ogosta River and to the west it gradually becomes wedge-like. The terrain has absolute elevation of 98 to 58 m. The main geomorphological elements, characterising the terrace, have the following parameters:

- The footing of the terrace in the central and western part at the Kozloduy Nuclear Power Plant cuts into the low-Roman clay (Brusartsi Formation) at elevation 51-54 m. At the eastern side the footing has an elevation of 50 m and is of sand of the Brusartsi Formation;
- The upper part of the alluvium has elevations in the interval 52 – 57 m;

- The Loess cover over the alluvium is made of five buried plates divided by loess horizons.

The terraces T_5, T_4 and T_3 at the Kozloduy Nuclear Power Plant do not exist because they have been washed away by the erosion of the Danube River, which occurred after their formation. Since this issue is of substantial importance from the viewpoint of the safety analysis of the New Nuclear Unit, it will be considered more extensively in Chapter 4 – **Description, analysis and assessment of the assumed considerable impacts**.

Terrace T_2

It embraces the low part of the slope with elevations 39 – 45 m. Its width within the boundaries of the Nuclear Power Plant is from 60 to 90-100 m. To the east it has almost the same width, while to the west the width expands to 600 – 800 m *(Annex 9)*. The geomorphological elements of the terrace are:

- The footing cuts into low-Roman clays and sands at absolute elevation of 23 – 24 to 25 m, while the back side of the terrace has elevation to 27 m;
- The upper part of the alluvium at the back side of the terrace is at an elevation of 26-27 to 30 m;
- The loess cover is by two loess horizons divided by buried soil.

The building of the National depot for low and intermediate level (short-live) wastes of the Nuclear Power Plant was designed on terrace T_2.

Terrace T_1

Potential sites 2 and 4 of the New Nuclear Unit are situated on Terrace T_1. It is a plain with absolute elevation of 38-28 m. Its width to the north of the nuclear power plant is from 900 to 1000 m., to the northwest within the boundaries of the Town of Kozloduy it widens to 1300 m. To the east it gets narrower to 300 m *(Annex 9)*. It has been examined by more than 100 boreholes by MEG Energoproekt, 1967[36], Research Institute Energoproekt, 1978[37], IPP Vodoproekt, 1961[38], Geotehnika АБС, Geological Institute, 2009[7], etc.

The footing of the terrace cuts into the clays of the Brusartsi Formation. In the vicinity of Terrace T_2 the footing has elevation 15-16 m, thereafter it rises to elevation 17-18 m and at the front of the terrace it lowers to 13-14 m.

The upper layer of the alluvium has an average elevation of 22 – 24 m, though there are topographic inequalities with elevations of 21 and 25 m. The loess cover over the alluvium is of loess horizon, which at the reach of the water level is more clay.

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[36] NIPPIES „Energoproekt" 1967, Kozloduy Nuclear Power Plant – Engineering geological and hydrogeological conditions of the site.

[37] NIPPIES „Energoproekt" 1968, Report on the results of the drilling and laboratory studies carried out in connection with the microseismic regioning of the site of the Kozloduy Nuclear Power Plant (1st stage) – Engineering geological and hydrogeological Studies Directorate.

[38] IPP "Vodproekt", 1961 „Report on the geological and hydrogeological conditions of the Kozloduy lowland".

Terrace T_0

The potential sites 1 and 3 are situated on this terrace. It spreads in the Kozloduy lowland with elevation from 28 to 26 m. Its relief includes low areas with marshlands and swamps. At places of the terrace high inequalities may be seen reaching elevation to 30 m, and they form a broken chain of hills, prolonged in the direction northwest – southeast. They have been formed by drifting of loess sand and for this reason they are called aeolian ridges.

The footing of the terrace has formed in the clays of the Brusartsi Formation at elevation 13 to 15 m. Towards the Danube River the elevation of the footing lowers to 12-13 m. At some places there are falls in the bed of the terrace to elevation of 10 m *(Annex 9).* In the western riverside the footing has a lower elevation – from 7 to 10 m, while in the eastern part it reaches 12-13 m. In the easternmost part of the adjacent zone of the New Nuclear Unit *(Annex 9)* the footing is made of sands of the Brusartsi Formation and Archar Formation.

The alluvium has a two-layer composition – gravel-sandy and clay-sandy.

From the viewpoint of the environmental impact assessment the following conclusions can be made on the geomorphological conditions of the sites and the adjacent zone:

- The zone adjacent to the sites is characterised by consistent relief in which no changes, which could endanger the operational safety of the New Nuclear Unit are expected;
- The sites happen to be in a plain terrain with good conditions for inlet and discharge of the water cooling the reactor;
- Taking into consideration potential unfavourable influence of the Danube River, the geomorphological conditions of sites 2 and 4 are better than those of sites 1 and 3.

3.4.1.3 DEVELOPMENT OF THE RELIEF DURING THE QUATERNARY AND PROGNOSIS FOR ITS FUTURE CHANGES

During the Pliocene the site was part of the Lom bay of the Daki lake basin. Some 2.50 Ma ago the climate became cold and there occurred elevation of the land accompanied by intensive riverside erosion processes. On the low-roman clays lay the sediments of the basic gravel-sandy complex. This is the foundation of the old abrasion-accumulative level. At the beginning of the glacial Pleistocene (0.94 Ma) a second abrasion cutting took place, which left behind the sediments of the so-called “covering gravel-clay complex” of SAAN.

The second stadial of Gunz (G2), which started 0.80 Ma BP ago, caused regression of the lake-river basin, which retreated in Romania towards the deepest part of the Fore-Carpathian lowering. At that time the Danube pierced the Pannonia lake basin and started flowing in our lands and through its morph sculptural activity in the middle and late Pleistocene created the contemporary shape of the relief.

On the stratigraphic scheme (**Figure 3.4-2**) dating is marked of the old abrasion-accumulative level and the river terraces. It has been made on the basis of paleo-magnetic, stratigraphic and radioisotope analyses. The time shown is when the footing of the terraces and the structure of their loess cover was formed. This figure in fact represents the geohistorical development of the area's relief. It is seen that the footing of the first non-floodable terrace T_1, on which the sites 2 and 4 are situated, has taken shape 186,000 years ago and the alluvium surface of the paleo-Danube on this footing is 127,000 years of age. The formation of the alluvium on Terrace T_0, on which sites 1 and 3 are situated, came to an end 6,000 years ago and since then the Danube River flows in its contemporary riverbed.

These data allow making the following conclusions:

- → no changes are expected of the relief of the first non-floodable terrace T_1, where sites 2 and 4 are, in the next tens of thousands years;
- → no substantial changes in the relief of floodable terrace T_0 (sites 1 and 3) will occur in the next 1000 – 2000 years; in this period the flooding of the river and the aeolian transfer may cause small changes in the elevation of the surface of parts of the terrace.

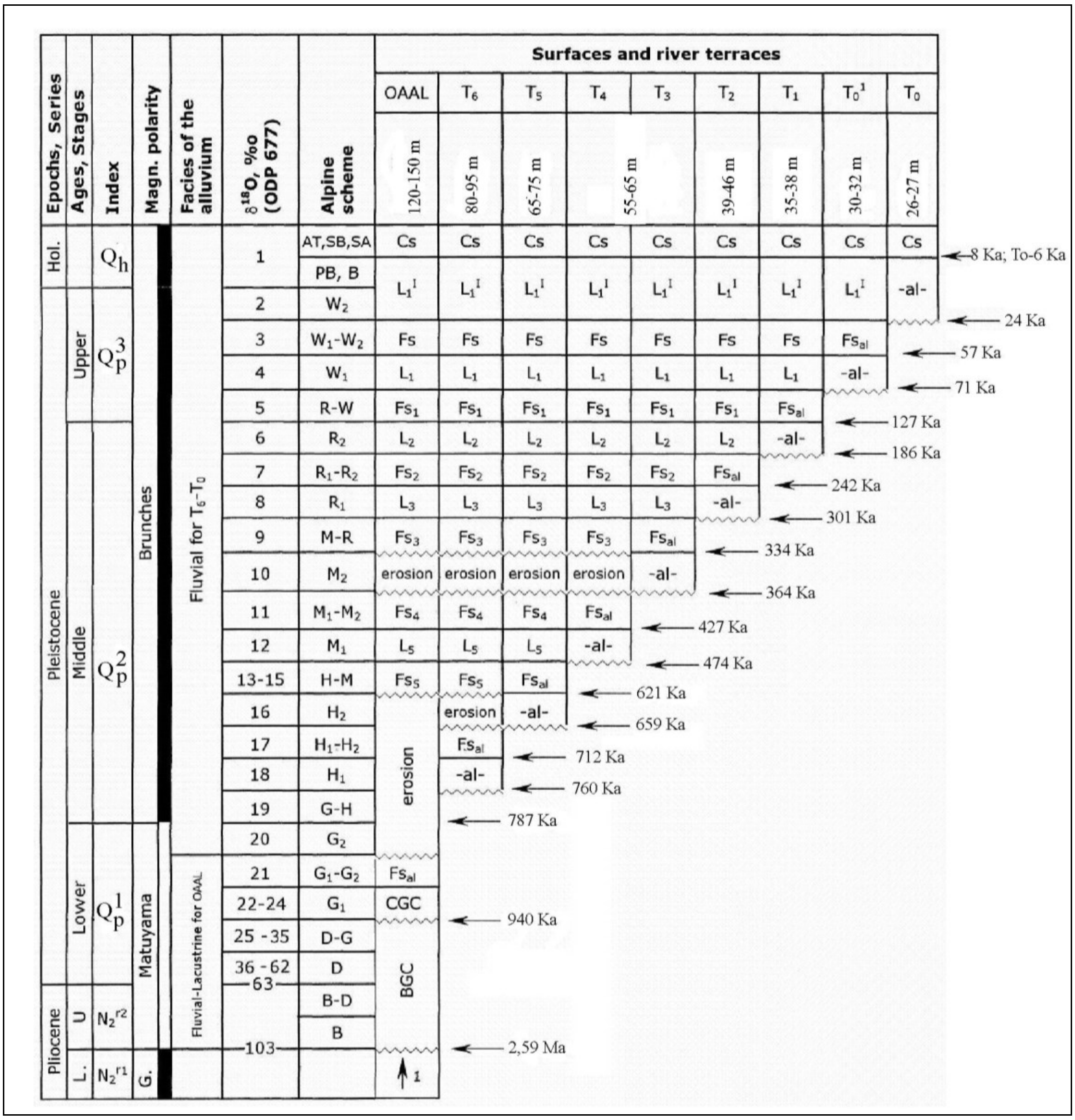

FIGURE 3.4-2: STRATIGRAPHIC SCHEME OF QUATERNARY AND THE RIVER TERRACES IN THE AREA OF THE KOZLODUY NUCLEAR POWER PLANT AND THE TOWN OF KOZLODUI (ACCORDING TO EVLOGIEV, 2006)

B – biber; B-D – biber-Dunavium; D – Dunavium; D-G – Dunavium-Günz; G_1 – Günz $_1$; G_1-G_2 – Günz $_1$- Günz $_2$; G_2 – Günz $_2$; G-H – Günz -Haslah; H_1 – Haslah $_1$; H_1-H_2 – Haslah $_1$- Haslah $_2$; H_2 – Haslah $_2$; H-M – Haslah -Mindel; M_1 – Mindel $_1$; M_1-M_2 – Mindel$_1$- Mindel$_2$; M_2 – Mindel$_2$; M-R – Mindel -Riss; R_1 – Rissc$_1$; R_1-R_2 – Riss$_1$-Riss$_2$; R_2 – Riss$_2$; R-W – Riss- Würm; W_1 – Würm$_1$; W_1-W_2 – Würm$_1$- Würm$_2$; W_2 – Würm$_2$; PB – Preboreal; B – Boreal; AT – Atlantic; SB – Subboreal; SA – Subatlantic; L_1-L_5 – lakes horizons; Fs_1-Fs_5 – buried soils developed over loess; Fs_{al} – buried soils developed over alluvium; Cs – contemporary soils; T_0-T_6 – river terraces; OAAL – old erosion-accumulative level, BGC – basic gravels and sands, CGC – covering gravels and sands; $\delta^{18}O$ – stages according to isotopes to the oxygen, drilling 677 (Shackleton et al., 1990; Bassinot et al., 1994); 39-46 m – absolute elevation of contemporary surfaces of the geomorphological forms; 1 – erosion and abrasion surface; ; G – Gauss geomagnetic epoch.

3.4.1.4 GEOLOGICAL STRUCTURE OF THE AREA OF THE SITES. TECTONIC AND NEOTECTONICS

3.4.1.4.1 Deep geological structure

The Bulgarian territory of the 30 km zone around the Kozloduy Nuclear Power Plant, which is the place of the potential sites for building the New Nuclear Unit, is geologically explored to quite a high degree. The information about the Romanian territory has been taken mainly from Enciu (2009)[39]. It refers only to the Pliocene-Quaternary sediments and does not consider the deep geological structure on the Romanian territory because no deep drilling has been made.

The knowledge of the deep lithologic and stratigraphic structure for any given area brings important information on the material composition of the rocks, the circumstances and the time of their formation, which is in direct correspondence with their physical and chemical properties and their behaviour in tectonic events. The superposition of the lithologic and stratigraphic units and the tectonic structures to which they belong, mark well shaped tectonic events in various intervals of geological times and they are of substantial importance for the interpretation of the geodynamic and neotectonic development of the area. These data are very important for a prognosis assessment of the long-term impact of the engineering facility over the environment.

In the period 1960 – 1995 intensive geological and geophysical studies have been carried out in North-eastern Bulgaria in search of oil and gas and as a result more than 50 boreholes above the depth of 2500 m have been drilled, some of them reaching a depth of 4900 m. Valuable information on the deep geological structure of this part of the Moesian platform has been acquired and it is considered that in general the issue of the structure has been well researched.

Lithologic and stratigraphic characteristics

From the geological aspect the area of the Kozloduy Nuclear Power Plant falls in the north-western part of the Moesian platform, respectively in the eastern periphery of the Lom depression, which is a tectonic structural unit of the second degree. The geological map in M 1:50 000 **(Figure 3.4-3**) shows the distribution of the Quaternary and Neocene rocks, open on the surface in the 30 km zone around the Kozloduy Nuclear Power Plant, and the geological profile II – their superposition to a depth of ~ 600 m (**Figure 3.4-4**). To the north, on Romanian territory, in the Pliocene-Quaternary sediments the formations Berbeshti and Jiu-Motru, which are lateral analogue of our Archar and Brusartsi Formation. The latter are described hereunder.

The geological basis in a depth to some 5000 m is built by sediment rock of Paleozoic, Mesozoic and Neozoic age. Further in this document, the stratigraphic units of Paleozoic and Mesozoic age and Palaeogene sediments, which are at a relatively great depth (under 500 m) and will not have substantial influence, are considered briefly. Great attention has been paid to the Neogene and Quaternary sediments, which are the basic environment for the engineering facility foundation. Their geological characteristics have key role when evaluating its impact on nature's environment.

[39] Pliocene and Quaternary of the Western part of the Dacian Basin, Ed. Romanian Acad. Sci., Enciu, 2009.

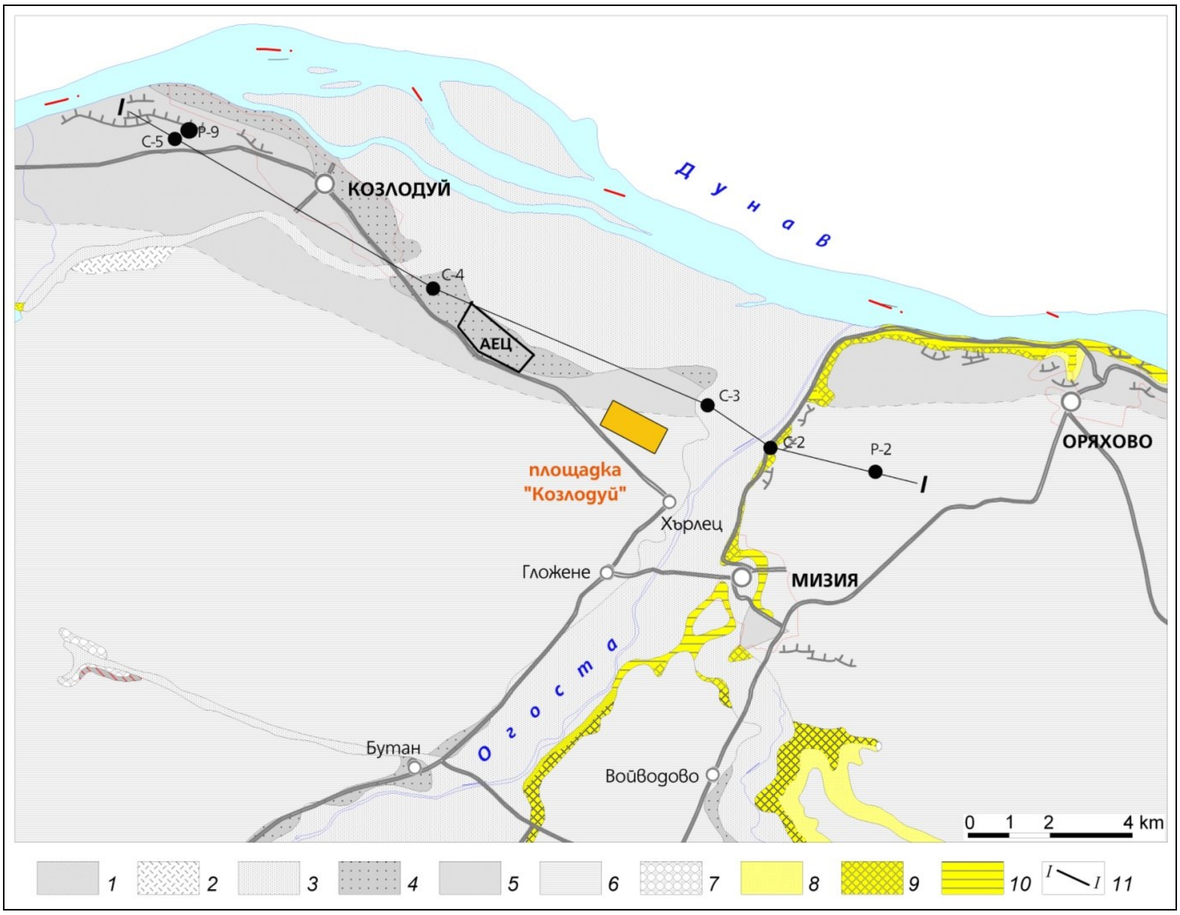

FIGURE 3.4-3: GEOLOGICAL MAP OF THE AREA AROUND THE TOWN OF KOZLODUY

Quaternary: 1 – proluvial formations – gravel, clay-sandy and loess materials; 2 – delluvial formations – clay-sandy and loess materials; 3 – alluvial formations – the riverbed and the floodable terraces – gravels, sands and clays; 4 – alluvial formations – I and II above floodable terrace; 5 – eolitic formations – sandy loess; 6 – loess; 7 – alluvial-proluvial formations – gravel sands and gravels; neogene: 8 – Byala Slatina formation – sands and with lenses of conglomerates and clay seams; 9 – Smirnenski formation – clays; 10 – Furen formation – limestone with frequent seams of sandstone, sands and clays; 11 – geological profile.

Pre-Neocene sediments

Palaeozoic and Mesozoic rocks are presented by diverse terrigenous and carbonate sediments: limestone, marls and clays, sandstones, alevrolites, sandy argilites and conglomerates. A number of official litho-stratigraphic units have been singled out among them – formations and they have been characterised in detail in earlier publications and fund reports (a summary is given in the report of the Geological Institute of the Bulgarian Academy of Sciences). The disposition of the profile is shown on **Figure 3.4-3** (according to data in a report of the Geological Institute, 2008-2010[3]).

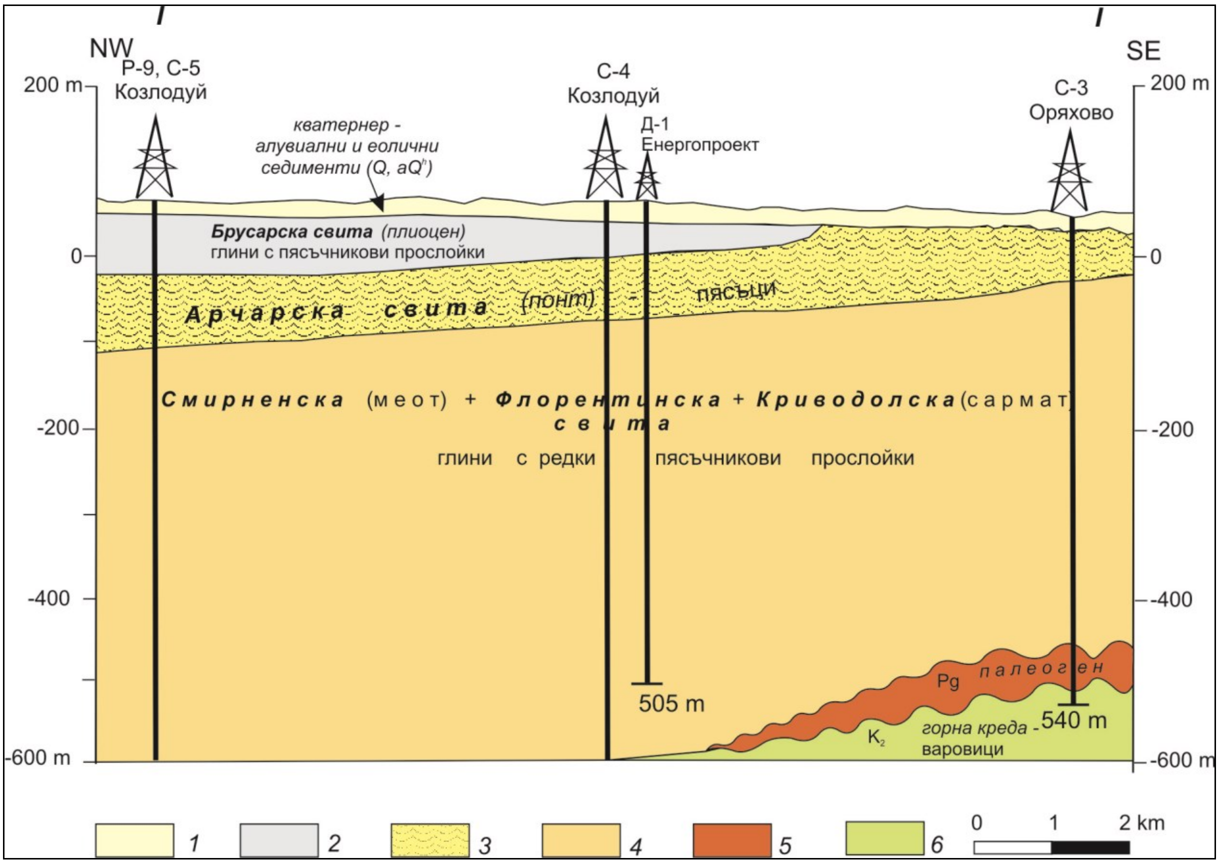

FIGURE 3.4-4: GEOLOGICAL PROFILE I – I IN A DEPTH OF 600 M THROUGH THE POTENCIAL KOZLODUY GEOLOGICAL UNIT.

Quaternary: 1 – alluvial and aeolian sediments – gravel, clay-sandy and loess materials, neogene: 2– Brusartsi Formation – clays with sandy seams (Oliocene); 3 – Archar Formation – watery sands with clay seams (pond); 4 – Smirna (meot) and Krivodol (sarmat) formation – clays; Palaeogene: marls and sandstones; Upper Creta: 5 – limestone.

Neocene

The pad of the Neocene in the area of Kozloduy consists of Palaeogene marls, alevrolites and clays of the clay-alevrolite amalgamation (upper Eocene – Oligocene). It is represented by marls, dense, with unclear layers, with varying contents of the clay-alevrite component. They are widely scattered in the area of the Lom depression. The depth varies from 150 to 700 m. It is specific for the cutting of the amalgamation in the Lom depression that they are monotonous, built mainly of marls and clays. The marls and the clays have the best insulating properties and have all the qualities of a geological barrier to the spreading of the radionuclides.

The Neocene sediments have all-round distribution in the 30 km zone around the Town of Kozloduy. The main Formations, building the Neocene section, are (upwards): the Deleyna, Krivodol, Furen, Florentine, Smirna, Archar and Brusartsi. The first five Formations are of Miocene age, the last – of Pliocene age.

Deleyna Formation. The formation is represented by grey-bluish clays with frequent seams of grey limestone, sands, sandstones and alevrolites. A characteristic feature is that in the middle a packet of gypsum and anhydrite with a thickness of 25 to 30 m is seen. The thickness of the formation varies from 200 to 400 m. It is of mid Miocene (Baden) age. The Deleyna Formation lies deepest in the Neocene cutting, most probably, having been washed away into the pad of Palaeogene marls. The latter however, because of the insufficient depth of the available drillings immediately next to the Kozloduy Nuclear Power Plant, cannot be established for sure.

Krivodol Formation. The formation has a similar lithology with the lower Deleyna and the upper Smirna Formations. It is represented predominantly by grey-bluish clays, limy clays and marls, with seams of clayey limestone and sand. The thickness of the formation in the area of Kozloduy is 120 – 140 m. Its age is Sarmatian. From the available drillings it is difficult to determine the boundary between the Smirna and the lying underneath Florentine and Krivodol Formations and for this reason these formations are represented together with the summarising stratigraphic column on **Figure 3.4-5.**

Florentine Formation. The formation has a small thickness (25 – 50 m), however it presents interest as it is built only of clays and situated between the clays of the Smirna and Krivodol Formations. It adds to the depth of the rocks with good insulating properties and potential as geological barrier preventing the migration of radionuclides. Its age is Sarmatian.

Smirna Formation. The formation is built of clays mainly. They are grey and grey-greenish, with unclear layers, slightly limy, alevrite. They lie on the Florentine (C-5 Gomotartsi, C-7 Mladenovo, C-1, Dalgodeltsi) or the Krivodol Formation (C-2 Cherni Vrah). They have been found in the Kozloduy area by more than 55 boreholes, 27 of them having been made entirely kernel-like, therefore sufficient data has been collected. In the clay material of the boreholes at Gorna Gnoynitsa and Kozloduy there are seams of clayey limestone and marls with a thickness of 5 to 10 m. In the area of Kozloduy and the nuclear power plant, in drillings C-4 and C-9 the power of the formations increases and within the clays layers of poorly united sands is frequent with a thickness below 10 m. They are mainly in the lower or the middle part of the fault. In the area of Kozloduy the thickness of the formation reaches 200 – 250 mq, in the paleovalleys (C-4 and C-9) – more than 450 – 550 m, and to the west of Tsibritsa it exceeds 900 m. The age of the formation is meot-early pont.

The domination of the clays in the Smirna Formation (and sand seams to a smaller extend) is a favourable circumstance from the point of view of the set purpose. The clayey rocks with their physical and chemical and mechanical properties are the best geological barriers preventing the distribution of fluids, gases, including technogenic pollutants.

Archar Formation. The main aquifer in the area is to be found in this formation. This is the only formation in the fault of the Neocene, which is separated from beneath and from the formations lying above by its lithologic composition. It is built almost entirely of water-abundant sands, which are used for drinking water supply. On the surface they are yellowish to rusty, small grained, with lenses of grainy material, with slanted and crossed layers. The sands are poorly welded oligomers, quartz, spotted, with local increase of ferrous hydroxides. Seams and lenses are found with grainier sand. They have been found at small depths (50 – 100 m) in many drillings and on the surface south of Kozloduy. The depth of the Archar Formation varies from 40-50 m in the area of Kozloduy to 100 m towards the Village of Gorna Gnoynitsa. In boreholes C-4, P-8, P-9, P-10 and P-13 in the Kozloduy area in the lower twenty meters of the sands there are seams of slightly limy thin-layered clays. The age of the formation is late pont.

Brusartsi Formation. It is built of clays with sand seams, the clays are grey, with greenish tint and rust-coloured spots, alevrite, slightly limy, with unclear layers. In the area of Kozloduy they alternate with thicker sand layers (to 5 – 10 m). The latter are grey and greyish, loose, with a dust component, small to medium grained, with single quartz grains. The sediments of the Brisartsi Formation lie above the sands of the Archar Formation. In the lowest part of the fault of the Brisartsi Formation, immediately over the Archar, lie layers of lignite coals at various depths. The depth of the Brisartsi Formations in the area changes from 50 m to 200 m. Its age is Pliocene (Daci-Roman).

The formation has been studied in detail in the area of Kozloduy in connection with the construction of depot for low and intermediate radioactive wastes. (Geological Institute, 2003, Geological Institute, 2010). It has a very important significance for the surface utilities.

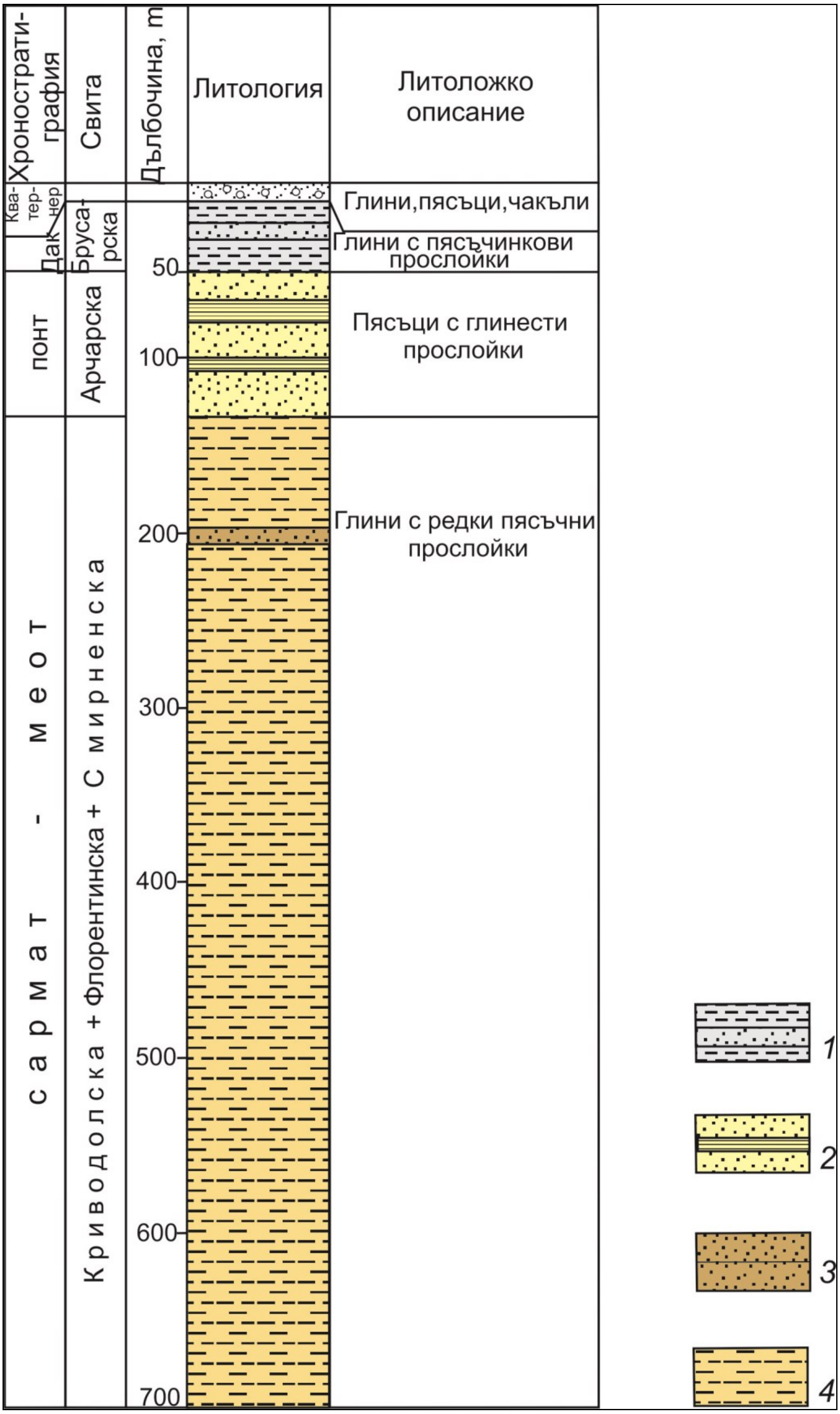

FIGURE 3.4-5: COMBINED LITHOLOGICAL-STRATIGRAPHIC COLUMN FOR THE AREA OF THE SITE ACCORDING TO DATA OF DRILLING D-1 (ENERGOPROEKT) AND C-4 AT THE AREA OF KOZLODUY (COMMITTEE OF GEOLOGY)

1 – clays with sandy seams; 2 – sands with clay seams; 3 – sandstones and sands; 4 – clays.

Quaternary

Quaternary sediments are represented by lake-river, eluvial, river, Aeolian and eluvial deposits. They are genetically connected with certain geomorphological forms. The basis of the Quaternary deposits are embedded on various levels of Pliocene's clays, which are of mid and late Roman age. The contemporary data on the structure of the Quaternary in the area around the Kozloduy Nuclear Power Plant are obtained as a result of many years of studies and detailed profiling according to drilling data. They have been summarised in a special report of the Research Geotechnical base of the Geotechnical Institute of the Bulgarian Academy of Sciences, 2012[5]. They will be presented hereunder. More data in detail on the structure of the Quaternary sediments and its significance as a geological foundation for the construction of the New Nuclear Unit are quoted in Chapters **3.4.1.1.2 – Geomorphology of the sites area** and **3.4.1.5 – Engineering geological conditions of the potential sites.**

Lake-river sediments. They have been deposited in lake-river conditions. They are represented by gravel, coarse sand, sand and clays. The sediments of the basic grave-sandy and covering gravel-clayey complexes refer to them (**Figure 3.4-6**). Their thickness varies within the range of 10-13 m.

Eluvial sediments. They form as a result of the wearing of basic rocks under the influence of temperature changes, groundwater etc. They have been uncovered in the southern parts of the region, where they rest over the so-called Pliocene denudation surface. Under the denudation surface pieces of basic rocks and red "Terra rosa" clays with a thickness from 1 to 5 m occur. They have formed during the late Roman, early Pleistocene and at the beginning of Mid Pleistocene.

Alluvial (river) deposits. These deposits have come from the rivers, which flew through the territory of the area. The alluvium of the river terraces is built of gravels, sands and clays with buried soil on them. Six terraces above the floodable level and two floodable have been found. The profile of the Quaternary in the valley of the Ogosta River is shown on **Figure 3.4-6**. The index at the designation of the terraces indicates the number of the loess horizons, which are above them (**Figure 3.4-6**). The age of the alluvial sediments is from mid Pleistocene to the Holocene.

Aeolian and eluvial sediments. They include the sediments formed as a result of the drifting and depositing rock particles borne by the wind. This refers to all loess horizons (L) and the soils (P) buried between them. In the valley between the rivers of Lom and Ogosta the Eolithic loess accumulation is not complete. A full loess profile should exist on the old accumulative-abrasion level. The drilling research carried out, however, failed to find presence in the lower part of the loess complex of L_6, P_6, L_7, P_7 and L_8. The sixth loess horizon has been modified by the soil process of P_5. Probably no Eolithic dust has reached this area during the deposition of the horizons L_7 and L_8. Full data on the loess complex and the buried soils in the river terraces between Ogosta River and Lom River have been summarised by Evlogiev (2006[4]).

The interruption in the sediment formation during the Quaternary, i.e. the time of the intensive erosion process is in the time interval from 0.80 to 0.62 Ma. The contemporary soil started taking shape before the beginning of the Atlantic – 7900 BP.

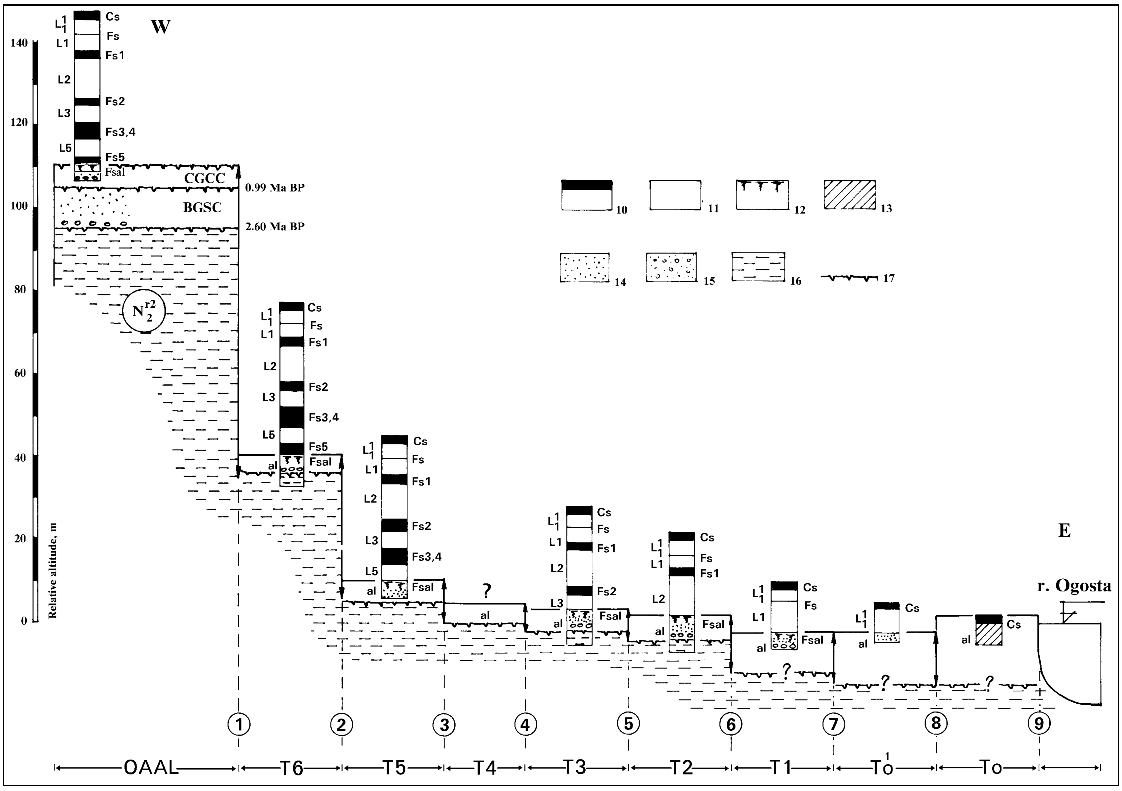

FIGURE 3.4-6: SUMMARISED LITOLOGIC AND STRATOGRAPHIC PROFILE FOR THE QUATERNARY IN THE VALLEY OF THE OGOSTA RIVER (ACCORDING TO EVLOGIEV, 2006)

OAAL – old accumulative-abrasion level; To-T6 – terraces; 1-9 – erosion cuts; 10 – contemporary Cs or buried soils Fs (P); 11 – loess horizons L; 12 – buried soils developed over alluvium Fsal; 13, 14, 15 – alluvium from clays, sands and gravels; 16 – mid Roman clays; 17 – eroded or abrasion surfaces; BGSC – basic gravel sand complex; CGCC – covering gravel clay complex.

3.4.1.4.2 Tectonics and neotectonics of the sites area

At the beginning of this part it was noted that the area of the Kozloduy Nuclear Power Plant is situated in the North-western part of the Moesian platform, respectively in the eastern periphery of the Lom depression. The Moesian platform is a first degree tectonic unit, located on Bulgarian and Romania territory. Its foundation in Bulgaria is built of slightly undulating Palaeozoic rocks, which on Romanian territory are lain by more intensively deformed metamorphous complexes of assumed Neoproterozoic- Cambrian age. The cover of the Moesian platform embraces sub-horizontal Mesozoic and Neozoic complexes with a total thickness to 7 – 8 km. The Lom depression is the lowest sitting part of the Moesian plarform (**Figure 3.4-7**). It is filled with sediments with thickness of more than 5 um, the oldest drilled rocks here being the Triassic (Dabovsli, Zagorchev, 2009[40,41]).

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[40] Dabovski, H., I. Zagorchev 2009. Introduction: Mesozoic evolution and Alpine structure

[41] I. Zagorchev, Dabovski, H., T. Nikolov (ed.), 2009. Geology of Bulgaria. Volume II. Mesozoic geology. Sofia, Bulgarian Academy of Sciences publication, page 13-37

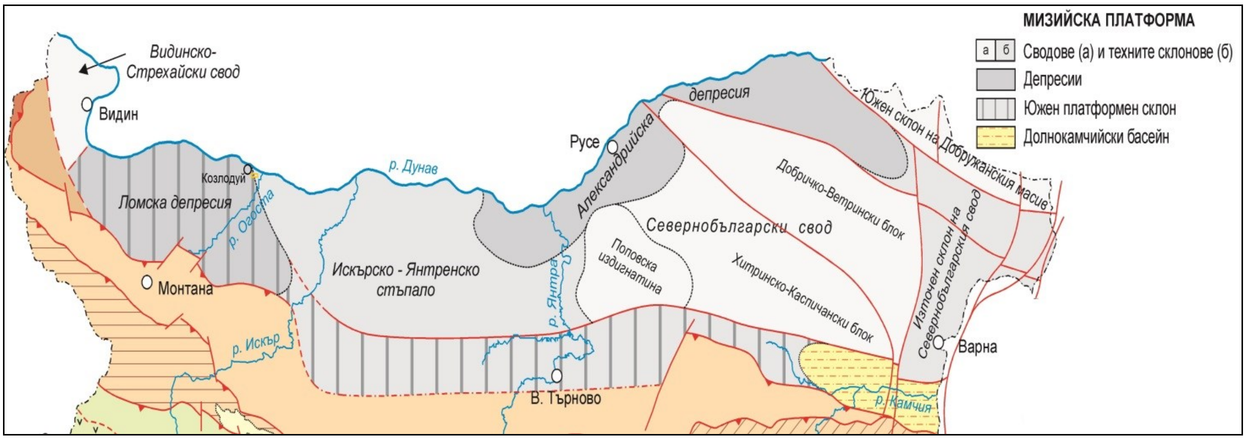

FIGURE 3.4-7: TECTONIC SCHEME OF THE BULGARIAN PART OF THE MOESIAN PLATFORM (ACCORDING TO DABOVSKI, H., I. ZAGORCHEV , 2009)

In the cross section of the sediment cover of the platform regional disagreements are established in the base of the Trias, Jura, Upper Creta and Eocene, which correspond to the fundamental tectonic events in the Alpine orogeny. From tectonic point of view the most significant fact is the angular disagreement between the Trias and the Jura (some 200 million years ago), which marks the end of the intensive tectonic activity. The Jurassic, Cretaceous, Palaeogene and Neocene-Quaternary rocks, resting above the disagreement, are practically horizontal, with an inclination of 10 to 3-40. These geological facts, documented by a number of boreholes and natural exposures, have an enormous significance for the long-term forecasts and expectations for tectonic stability of the geologic foundation in the area of the sites..

The southern slope of the platform embraces its folded and deeply sunk southern ridge before the dragged front of the Alpine orogeny. In previous studies it has been named “South-Moesian fault”, rather as a regional tectonic structural boundary. The recent studies revealed that in practice the only active fault, really established by geological explorations in the 35 km zone around the nuclear power plant, is the Deven uplift (**Figure 3.4-8**[42]). Concerning this fault, there are documented geological facts only in the section between the villages of Vladimirovo and Gromshin that it was active and events have occurred in the last 71 thousand years. These events happened in a 250 m wide zone, but no breaches have been established reaching the earth surface.

[42] Filipov, L., E. Koyumdzhieva, N. Popov. 1993. Geological map of the Republic of Bulgaria in M 1:100 000, Map pages Byala Slatina, Troyan, VTS.

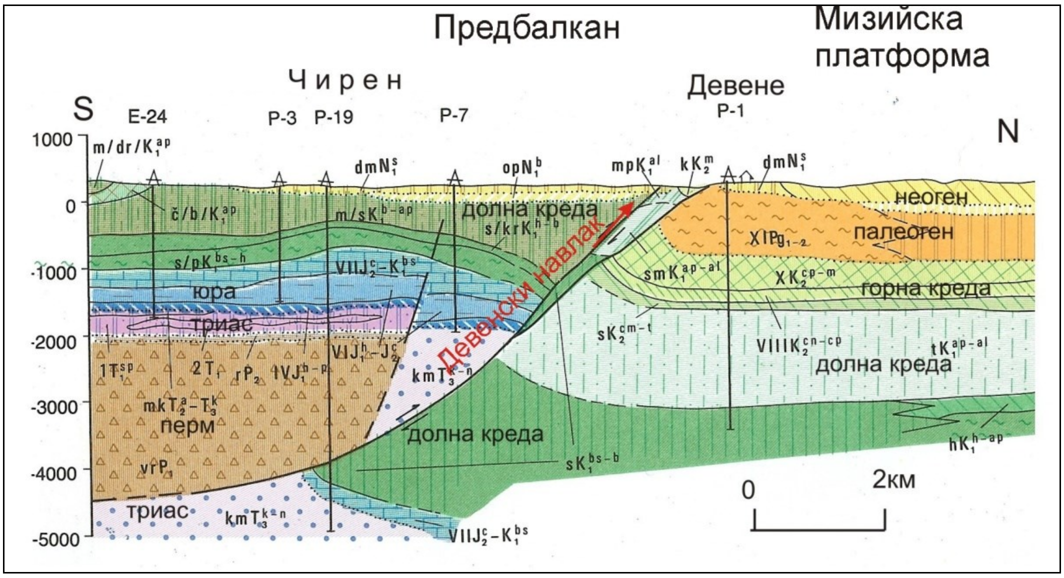

FIGURE 3.4-8: DEPTH GEOLOGICAL CROSS SECTION S-N IN THE AREA OF THE DERVEN UPLIFT

The tectonic development of the area passed through a number of stages, which can be combined into three groups: *Pre-Palaeogene, Palaeogene-Neogene and Quaternary.*

The Pre-Palaeogene tectonic development includes the Paleozoic-Mesozoic geodynamics of the area. The most important event here is the formation of the poorly undulating foundation of the Moesian platform to the middle of the Palaeozoic and the termination of the intensive tectonic activity at the end of the Trias.

Palaeogene-Neogene structural stage. According to the existing data from a number of boreholes in the area, no movement ("survival") of old faults has been proven. Some authors assume that such exist along the rivers of Tsibritsa, Ogosta and Skat (the so-called Tsibritsa and Ogosta lineaments), however this assumption is not based on factual evidence. The recent geological studies found no facts of presence of faults with impacts on the contemporary relief along the rivers of Tsibritsa and Ogosta (Review of the studies carried out, ref. No. REL-1000-ST-001-2, January 2013 г.). There are no documented folded structures both in the Miocene and in the Pliocene sediments.

Quaternary structural stage. The lack of considerable tectonic events and faulting during the Quaternary is evidenced by the comparison between the underlay and the upper part of the alluvium of the old accumulative-abrasion level of the Lom bay and the Ruse-Silistra bay. It shows that the elevation in both areas is almost the same – around 125-133 m, hence they have experienced equal positive movements (Evlogiev, 2006, **Table 3.4-1**).

TABLE 3.4-1: ABSOLUTE ELEVATION OF THE TOP OF THE ALLUVIUM OF OAAL AND OEAL IN THE 10 KM ZONE ALONG THE DANUBE RIVER (ACCORDING TO EVLOGIEV, 2006)

OLD ABRASIVE (EROSIONAL) ACCUMULATIVE LEVEL				
The Gulf of Lom OAAL		Central North Bulgaria River Level - OAL		The Gulf of Rousse-Silistra OAAL
between Lom-Tzibritza rivers	B1, Mladenovo - 130,70 m B2, Zamfirovo - 133,10 m B3, Komoschtica - 133,00 m middle 132,27 m	between Vit-Osam rivers	B16, Meshka - 130,00 m B17, Slavianovo - 133,00 m B18, Milkovitza - 127,00 m middle 130,00 m	B27, TV tower Rousse - 121,00 m
between Tzibritza-Ogosta rivers	B5, G. Tzibar - 124,60 m B6, Zlatia - 125,60 m B7, Valshedram - 127,60 m middle 125,93 m	between Osam-Iantra rivers	B7, Petokladentzi - 131,00 m B10, Karamanovo - 129,40 m middle 129,40 m	
between Ogosta-Iskar rivers	B10, Mizia - 129,90 m B11, Stavertzi - 128,30 m B12, B. Geran - 133,10 m middle 130,43 m			
between Iskar-Vit rivers	B13, Slavovitza - 129, 50 m B14, Oriahovitza - 129,90 m B15, Trastenik - 131,60 m middle 130,33 m			
	middle 129,74 m		middle 130,10 m	middle 121,00 m

Neotectonic development. In the 30 km zone around the New Nuclear Unit there are no proven active tectonic structures. This conclusion is based on profound studies of scientific teams, carried out in the area of the Kozloduy Nuclear Power Plant (Geophysical Institute, 1994r.[1]) and in the selection process of a site for National Depot for Radioactive Waste (Geological Institute, 2003[2], 2009[7], Nakov et al, 2007[43]). Additional data for the neotectonoc and seismic tectonic situation in the area around the Kozloduy Nuclear Power Plant are quoted in Section **3.4.2.2**.

In conclusion, concerning the tectonic and neotectonic development of the area around the Nuclear Power Plant, it can be summarised that:

- → The active tectonic processes on the territory of the area were most intensive up to the Triassic period and with its end they gradually came to a stop. Thereafter, during the Creta, Palaeogene and Neogene, the tectonic activity subsided and did not go beyond slow oscillatory movement.
- → At the end of the Pliocene and during the Quaternary the movements had a positive sign and led to the formation of flat areas and river terraces. As the site of the New Nuclear Unit is situated in the most stable inner part of the Moesian platform, there

[43] Nakov, R. et al, 2007. Joint analysis of the results of very precise geodesic measurements, geomorphological and geotectonic observations. Contract with the Radioactive Waste State Enterprise.

is no ground to assume sharp changes in the velocity and orientation of the contemporary positive vertical movements.

- From the viewpoint of the tectonic movement, it can be surmised that in the next 2-3 million years (Ma) there is no probability that substantial changes would occur in today's geodynamics of the area, like for instance, emergence of new seismic focus, seismic conductive faults, volcano structures etc.

3.4.1.5 ENGINEERING GEOLOGICAL CONDITIONS OF THE POTENTIAL SITES

The potential sites will be considered in pairs according to their disposition and similarity of conditions (sites 2 and 4 and sites 1 and 3), first describing the common features of the respective pair, then their characteristic features separately.

Sites 2 and 4 are situated in the first non-floodable terrace T_1 on the Danube river, whose surface has an elevation of 35 – 38 m (*Annex* 9). In the geological profile of the terrace three sediment complexes are discerned: loess, alluvial and lake (the Brusartsi Formation). The loess complex has a depth of 12-14 m. under the loess underlies the alluvium of the terrace, built of sands in the upper part and by gravel in the lower part. The upper alluvium has an average elevation of 22-24 m and has irregularities with elevations 21 and 25 m. The footing of the terrace with an elevation from 15 to 18 m, is cut into Pliocene clays of the so-called Brusartsi Formation.

From an engineering geological point of view, the loess deposits present the greatest interest because in their depth range the foundation of the New Nuclear Unit will be laid down. They have been studied well by field and laboratory methods in connection with the construction of energy units 1 – 6 of the Kozloduy Nuclear Power Plant (Energoproekt 1967-1968[10]; 1999[44], Minkov et al., 1972[45], Study and determination of the location of preferred site for building of New Nuclear Unit on the site of the Kozloduy Nuclear Power Plant EAD and adjacent territories[46],). The most important feature of the loess is its susceptibility to collapse upon moistening.

According to the Bulgarian Rules for Designing flat foundations (1997), the collapsibility of the loess may be of the Ist or IInd type. The loess foundation of the Ist type, such as the foundation of sites 2 and 4, practically subsides only by the additional load of the facilities, the wet subsidence by the own weight being less than 5 cm. The elimination of its collapsibility is no problem for the foundation laying.

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[44] NIPPIES Energoproekt 1999 Technical economic study for building of New Nuclear Capacity with use of the equipment provided for the Belene Nuclear Power Plant.

[45] Minkov, Evstatiev, Anastasov, 1972. Engineering geological conditionя and possibilities for construction of foundation of the main building of the Kozloduy Nuclear Power Plant by means of combination of compaction with heavy-duty rammer and a pillow of cement-loess - Yearbook of NIPPIES "Energoproekt, 12, 1, 213-237

[46] Review of the completed studies, ref. No. REL-1000-ST-001-2, January 2013

The collapsibility of the loess has been overcome in respect of units 1 – 4 of the Kozloduy Nuclear Power Plant by deepening the excavations to the non-subsiding loess and building of cement and soil cushion (Minkov, Evstatiev, 1975[47]). Concerning energy units 5 and 6, where the load of the foundation is greater, all loess has been taken away, including the upper sandy-clay part of the alluvium to the gravels. After that a coarse aggregate and cement-soil cushions were built to the elevation of the foundation.

No foundation problems have ever emerged during the many years of operation of the Kozloduy Nuclear Power Plant. The permanent geodesic monitoring showed that the subsidence of units 1, 2, 3 and 4 coincided with the forecasts and on the average they range from 5.0 to 7.0 cm. Energy units 5 and 6 have a bigger load at the foundation and because of that the subsidence is bigger – to 12 cm. It has been proved that the cement-soil cushion, on which all units have their foundation, plays the role of protection barrier to the spreading of radionuclides to the groundwater. This is due to its low water permeability[48] – filtration coefficient kf <0.002 m/24h, the filtration starting at pressure gradients of 5 to 10. In the hydro-melioration construction about 20 water-equalising ponds have been built with bottom cement-soil screen with a thickness of 0.15 m. All they have been functioning without problem for decades. Under the energy units of the Kozloduy Nuclear Power Plant the cement-soil cushion has a thickness over 1.5 m usually and under an initial pressure gradient of 5 to 10; filtration through it, in the meaning of the Law of Darcy, practically does not occur. This makes it an efficient protection barrier against the spreading of radionuclides, originating from eventual leakages of the nuclear facilities. It is precisely with this aim in mind that a construction of cement-soil cushion 2.0 m thick is due to be built under the Workshop for cutting and deactivation, which will be put I place in connection with the decommissioning of the first four energy units and will be situated next to the first energy unit of the Kozloduy Nuclear Power Plant.

After the Vrancea earthquake in 1977 parallel examinations were carried out on buildings of the same construction type, including nuclear facilities of the Kozloduy Nuclear Power Plant, existing at that time. It was found that the buildings with foundation lying on cement-soil cushion (some 100 buildings at that time) had considerable less damages in comparison with buildings built on natural loess[49, 50]. The explanation of this fact is the following: The cement-soil cushion has a module of general deformation E_0=110 MPa, static elasticity E=200-300 MPa and dynamic elasticity module 2-3 times more. These indicators are several times larger than the ones of the natural loess, which has a module of general

[47] Minkov, M., D. Evstatiev. 1975. Foundations, revetments and screens by stabilized loess. Publ. house Technica, 189 p.

[48] Minkov, M., D. Evstatiev. 1975. Foundations, revetments and screens by stabilized loess. Publ. house Technica, 189 p.

[49] Minkov, M., Evstatiev, D. and Karachorov, P., 1978. On the influence of the stabilization bracing of the ground foundations on the destructive action of earthquakes, *Bulgarian geophysical Journal* 4, 76-85.

[50] Minkov, M., D. Evstatiev. 1979. On the seismic behavior of loess soil foundations. – In. 2 nd US National Conf. on Earthquake Engineering, Stanford, University, 988 – 996.

deformation E_o = 15-20 MPa. For this reason the cement-soil cushions reduce the risk of plastic deformations at the foundation by the action of the seismic forces.

Sites 1 and 3 are situated in the floodable terrace T_0 of the Danube River, which has an elevation of 26 – 28 m. The footing of the terrace, at an elevation of 13 to 15 m, near sites 3 and 1 was formed in Pliocene clays (Brusartsi Formation). At places, terrace bed lowering is found to elevation 10 m. The alluvium with an average thickness of about 13-14 m has a two-layer structure – gravel-sand as the lower layer and clay-sand as the upper layer. The alluvial deposits are characterised by great heterogeneity both vertically and horizontally.

The available geomorphological map of the sites embraces a zone from the plateau to the Danube River and two kilometres in each east and west direction (*Annex 9)*. Two of the profiles in this map pass through the sites or near them.

3.4.1.5.1 Physical and mechanical indicators of the layers building the land foundation of the sites and the zone adjoining them

The land foundation of the sites and the zone adjoining them is built of 8 engineering geological layers. The description given here of the layers and their physical and mechanical indicators is based on summarised data of the studies made to this moment. As in the preceding part of the report, the numeration of the layers of the geological-geomorphological profile has been preserved (Annex *9*).

- **Layer 1. Collapsible loess IInd type**

It builds the elevated part of Terrace T_6 terrain, where its depth is from 9-11 to 20 m. It is represented by dust loess, macro-porous, light yellow, with fragile structure. The basis of the layer is of loess clay, dark-brown, with macro-porous. The layer, as the next layer 2, both are located outside the outline of the site and it has been studied in connection with the building of the National Depot for Short-live low and intermediate level radioactive waste (the Radiana Depot).

- **Layer 2. Non-collapsible loess of the high Danube terrace**

Dust loess, without macro-porous, layered by solid loess-like clay (buried soils). It lays under layer 1 having a thickness to 28-30 m, which decreases towards the slope. The dust loess and the loess clay have the following parameters:

Dust non-collapsible loess:

- Bulk density ρ=1.60 g/cm^3;
- Bulk density of the of the skeleton ρ_d=1.45 g/cm^3;
- Water contents w=10.0 %;
- Porous coefficient e=0.91;
- Degree of water saturation S_r =0.33;
- Plasticity indicator I_p =7.4%;
- Filtration coefficient k=0.7 m/d.

Loess-type clay

- Bulk density ρ=1.76 g/cm^3;

- Bulk density of the of the skeleton ρ_d=1.54 g/cm^3;
- Water contents *w*=13.9 %;
- Porous coefficient *e*=0.79;
- Degree of water saturation S_r =0.51;
- Plasticity indicator I_p=12.2 %;
- Filtration coefficient *k*=0.15 m/d.

Layer 1a. Collapsible loess of the Ist type

It builds the surface part of the slope, of Terrace T_2 and of Terrace T_1 and has a depth of 7 to 11 m. It is represented by dust to dust-sandy loess, macro-porous, light yellow, with loose structure, at places stratified by clayey loess (initial soil-formation). Payer 1 has the following physical and mechanical mean features:

- Bulk density ρ=1.59 g/cm^3;
- Bulk density of the of the skeleton ρ_d=1.40 g/cm^3;
- Porosity *n*= 49.1 %;
- Plasticity indicator *Ip*=7.0 %;
- Relative collapse $\delta_{co.0.2}$=2.39 %;
- Compression module average $M_{0.2}$=6.3 MPa;
- General deformation module E_0=12.6 MPa;
- Filtration coefficient *k*=0.7 m/d.

Layer 2a. Non-collapsible (subsiding) loess

It is found within the boundaries of terraces T_2 and T1 where it has a depth of 2-4 to 8 m. It is built of clayey loess without macro-porous. Main characteristics: compact structure, very wet to water-saturated, non-collapsible at p=0.3 MPa, can be found under water level or in the zone of capillary rise. It is characterised by the following mean indicators:

- Bulk density ρ=1.89 g/cm^3;
- Bulk density of the of the skeleton ρ_d=1.56 g/cm^3;
- Porosity *n*=43.0 %;
- Plasticity indicator *Ip*=13.0 %;
- Compression module $M_{0.2}$=7.9 MPa;
- General deformation module E_0=16.0 MPa;
- Filtration coefficient *k*=0.2 m/d.

Layer 3. Sandy clay, alluvial

It can be traced in the upper part of the alluvium with thickness of 1.50-2.50 – T_6 and T_2, and 4-9 m – T_0. It is built of sandy clay, beige-brown, at places with gravel pieces. The layer has the following indicators:

- Bulk density ρ=2.03 g/cm^3;
- Bulk density of the of the skeleton ρ_d=1.65 g/cm^3;
- Porosity *n*=40.0 %;
- Plasticity indicator *Ip*=13.0 %;
- General deformation module E_0=20.0 MPa;

- Filtration coefficient k=0.5 m/d (T_0), which in the gravel clays of T_6 and T_2 is 0.24 m/d.

Layer 4. Gravel, alluvial

Within the boundaries of T_6 usually it has a thickness to 1.5 m, though in lowering of the footing it reaches 4 m. At terraces T_1 and T_0 the thickness varies from 2-5 to 9-13 m. It represents gravel or gravel sands with clay sandy (Terrace T_6) and sandy (terraces T_1 and T_0) filling. In the range of the lower terraces, layer 4 has the following averaged features:

- Bulk density in loose state ρ=1.60 g/cm^3;
- Bulk density in compacted state ρ=1.79 g/cm^3;
- Angle of the natural levee φ=34^o;
- Angle of the natural levee under water φ=23^o;
- General deformation module E_0=30.0-40.0 MPa;
- Filtration coefficient k=50-80 m/d.

For the gravels of Terrace T_6 the Filtration coefficient is K_f=5.0 m/d.

Layer 4a. Sand, alluvial

It is found in the lower terraces (T_1 and T_0) with thickness from 1 to 3 m in the type of lenses and strata in Layer 4. It consists of fine and medium sand, at places clayey, thixotropic. It is characterised by the following averaged indicators:

- Bulk density in loose state ρ=1.42 g/cm^3;
- Porosity in loose state n=47.0 %;
- Bulk density in compacted state $\rho_{упл.}$=1.60 g/cm^3;
- Porosity in compacted state n=39 %;
- Angle of the natural levee φ=32^o;
- Angle of the natural levee under water φ=18^o;
- General deformation module E_0=8.0-9.0 MPa for the clayey fine sand and E_0=15.0 MPa – for the medium grainy sand;
- Filtration coefficient k=10.0-11.0 m/d.

Layer 5. Dust clay, Pliocene (Brusartsi Formation)

It builds the footing of the terraces and the greater part of the cut of the Formation. It consists of dust clay, compact, yellow-rusty, varicoloured to grey in depths with carbonated and single gravel pieces. According to plasticity it is defined as clay and according to grain size – as dust clay. Under the water level it practically is in a state of water saturation (Sr=0.861), and its consistency becomes hard plastic. It is characterised by the following indicators:

- Bulk density ρ=2.03 g/cm^3;
- Bulk density of the of the skeleton ρ_d=1.70 g/cm^3;
- Porosity n=39.5 %;
- Water contents w=19.4 %;
- Degree of water saturation S_r=0.87;
- Plasticity indicator Ip=23.0 %;

- Under the level of groundwater the clay is water-saturated S_r=1.0, w=22 %, ρ=2.07 g/cm^3;
- General deformation module E_0=35.0 MPa;
- Elasticity module 135 MPa;
- Filtration coefficient k=0.1 m/d.

Layer 6. Sand Pliocene (Brusartsi Formation)

It forms bands among the clays of the Brisartsi Formation with thickness 7-11 to 24 m. It is represented by fine to medium sand, at places clayey. It is characterised by the following averaged parameters:

- Bulk density ρ=2.02 g/cm^3;
- Bulk density of the of the skeleton ρ_d=1.73 g/cm^3;
- Water contents w=16.5 %;
- Porous coefficient e=0.54;
- Degree of water saturation S_r=0.82;
- Plasticity indicator I_p=2.3%;
- Under the level of groundwater the clay is water-saturated S_r=1.0, w=20.2 %, ρ=2.08 g/cm^3;
- Filtration coefficient k=3.0 m/d.

Layer 7. Clay sand, Miocene (Archar Formation)

It is found under the absolute elevation of 1 m. It is built by fine clayey sand, grey-green, water-bearing, thixotropic. It is characterised by the following parameters:

- Bulk density ρ=2.05 g/cm^3;
- Bulk density of the of the skeleton ρ_d=1.68 g/cm^3;
- Water contents w=21.8 %;
- Degree of water saturation S_r=1.0;
- Porous coefficient e=0.58;
- Plasticity indicator I_p=1.6%;
- Filtration coefficient k=3.0 m/d.

Layer 8. Dust clay, Pliocene (Archar Formation)

It is found in the western part of the site at profile II-II (*Annex 9*). It consists of dust clay, compact, grey-blue, turning into clay marl. There is no data on the parameters of the layer.

3.4.1.5.2 Structure of the earth foundation of the sites

The description of the earth foundation of the sites is made on the basis of data from a special study – Study and determination of the location of preferred site for building of New Nuclear Unit on the site of the Kozloduy Nuclear Power Plant EAD and the adjoining territories[51], carried out by the Geotechnics Research Base (2012) and by Energoproekt

[51] Review of the studies carried out, Ref. No. REL-1000-ST-001-2, January 2013

(1967)[52], and (1999)[53], Minkov, Evstatiev (1975). The analyses and the conclusions have been coordinated by IAEA Safety Guide Series, NS – G – 3.6, 2004 и IAEA Safety Guide Series, SSG – 9, 2010.

Structure of the earth foundation of site 2

Site 2 is situated on the first non-floodable terrace T_1 of the Danube River to the east of units 1 and 2 of the Kozloduy Nuclear Power Plant in the direction towards the Village of Harlets, south of the cold and hot channels of the nuclear power plant *(Annex 9*). The site borders to the south with T_2 and to the north with T_0. The relief is low hills and the surface of the terrain has elevation between 34 and 37 m. Only one storey warehouses and other service buildings have been built on the site. If the New Nuclear Unit is built on this site, its facilities will have foundations in an excavation.

The engineering and geological conditions of Site 2 are similar to the ones of energy units 1 and 2 of the Kozloduy Nuclear Power Plant. However if this site is selected, the foundations of the New Nuclear Unit will have to be built like the energy units 5 and 6 because of the greater loads on the foundation.

The earth foundation is built by the following soil varieties: dust collapsible loess (layer 1a) with thickness of 7.0 to 11.0 m, forming collapsible foundation of the I^st^ type. Deeper follow clay non-collapsible loess (layer 2a) with thickness 3-4 m, under which lay alluvial sands thick 5.0 – 8.0 m and gravels (layers 4 and 4a). The latter have been deposited over Pliocene clays (Brusartsi Formation, layer 5) with thickness of 5.0-7.0 m. Under the clays there lay a sand layer 4-5 m (layer 6) related also to the Brusartsi Formation.

The level of the groundwater is from 8.0 to 10.0 from the surface.

Structure of the earth foundation of Site 4

The site is situated on the first non-floodable terrace T_1 of the Danube River to the west of units 3 and 4 of the Kozloduy Nuclear Power Plant and the Depot for storage of spent fuel under water, south of the cold and hot channels (*Annex 9)*. It has an elevation of about 36 m in a built-up terrain among existing service centres. If the New Nuclear Unit is built on this site, its structures will need to have foundations in an excavation.

The engineering geological conditions of Site 4 are similar to the ones of the first four energy units of the Kozloduy Nuclear Power Plant. However if this site is selected, the foundations of the New Nuclear Unit will have to be made as the foundations of units 5 and 6 because of the greater load on its foundations.

The earth foundation of site 4 is built of the following soil varieties: dust collapsible loess (layer 1a) with thickness from 6.0 to 9.0 m, forming collapsible foundation of the I^st^ type. At

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52 NIPPIES Energoproekt 1967 – Kozloduy Nuclear Power Plant – Engineering geological and Hydrogeological conditions of the site.

53 NIPPIES Energoproekt 1999 Technical economic study for building of New Nuclear Capacity with use of the equipment provided for the Belene Nuclear Power Plant.

a depth of 12.0-15.0 m the loess becomes more clayey, less collapsible to non-collapsible, but highly prone to sagging (layer 2a). Under the loess lay alluvial sands thick 4.0-7.0 m and gravels (layers 4 and 4a). They are deposited on Pliocene clays (Brusartsi Formation, layer 5) with thickness of 6.0-8.0 m.

The level of the groundwater is 8.0 to 10.0 m from the surface.

Structure of the earth foundation of site 1

The site is situated on the floodable Terrace T_0 of the Danube River to the northeast of unit 1 of the Kozloduy Nuclear Power Plant, between the open switchgear and the Valyata area, north of the cold and hot channels. In the area of the site there are open draining channels. The terrain is flat with a slight slope from southwest to northeast. The elevation of the terrain is 25.0-26.0 m. If the New Nuclear Unit would be built on this site, the foundations of its structures would be laid in a level.

The earth foundation is built of the following soil varieties: sandy alluvial clay with thickness from 4.0 to 6.5 m (layer 3). At the northern area of the site the lower half of the layer is built of alluvial sand (layer 4a). Alluvial gravels with thickness of 7-8 m (layer 4) lay under the clay and sand and underneath lie Pliocene sands with a thickness of 10 to 15 m (layer 6). The latter are deposited over the clays of the Brusartsi Formation, layer 5, and the Miocene sands of the Archar Formation (layer 7), which start approximately from elevation 0.00 m.

The level of the underwater fluctuates in tune with the water level of the Danube River. It comes to the surface or near it.

if it is decided to build on this site, the experience of the preparation of the earth foundation for the Belene Nuclear Power Plant may be used.

Structure of the earth foundation of Site 3

The site is situated on the floodable Terrace T_0 of the Danube Rover to the northwest of units 5 and 6 of the Kozloduy Nuclear Power Plant, south of the cold and hot channels. There are open draining channels on the area of the site. The terrain is flat with a slight slope to the north. The elevation of the terrain is 25.0 – 26.0 m. If the New Nuclear Unit would be built on this site, its facilities would need to have foundations laid in a level.

The earth foundation is made up of the following varieties: sandy alluvial clay with thickness from 3.0 to 5.0 m (layer 3). In the northern half of the site the lower part of the layer is made up of alluvial sand with thickness of 2.5-3.0 m (layer 4a). Alluvial gravels thick 5-8 m (layer 4) lie under the clay and sand under which are Pliocene clays with a thickness of around 15 m (layer 5). The latter are deposited on Miocene sands of the Archar Formation, which start from an elevation of 0.00 m (layer 7).).

The level of the underwater fluctuates in tune with the eater level of the Danube River. It comes to the surface or near it.

3.4.1.6 HYDROGEOLOGICAL CONDITIONS OF THE SITES

3.4.1.6.1 Deep hydrogeology

The area of the potential sites is part of the Lom artesian basin with its characteristic stage disposition of the aquifers and vertical hydrodynamic, hydro-chemical and geothermal zoning. The aquifers, the complexes and the confining formations have wide area distribution; the feeding zone of the deeper underlying aquifers is located along the periphery of the artesian basin. With the deepening of the aquifers the water exchange slows down and the mineralisation and the temperature of the water formed there increases.

An idea of the distribution of deep aquifers is obtained on the basis of the drilling carried out in 1960-1967. (Monov et al., 1969)[54].

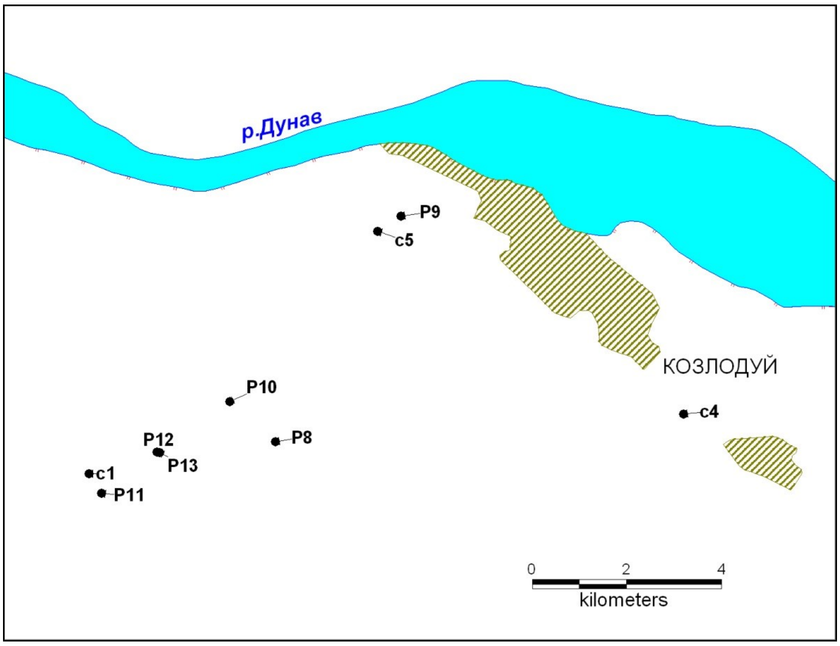

FIGURE 3.4-9: LOCATION OF BOREHOLES MADE IN THE KOZLODUY AREA.

TABLE 3.4-2: INFORMATION ON BOREHOLES MADE IN THE KOZLODUY AREA

Drilling	Location (Municipality)	Year of completion	depth, m	Age of the rocks reached
C-1 Kozloduy	Вълчедръм	1961	705	Eocene
C-4 Kozloduy	Kozloduy	1961	705	Meot
C-5 Kozloduy	Kozloduy	1962	703	Meot
P-8 Kozloduy	Kozloduy	1961	1326.5	Cenon
P-9 Kozloduy	Kozloduy	1961	1343	CenonСенон

[54] Monov, B. D. Vulcheva, D. Monova, Ts. Zheleva. 1969. Report on the results of the drilling studies in the Kozloduy area in 1960-1967. National Geofund, III-218.

Drilling	Location (Municipality)	Year of completion	depth, m	Age of the rocks reached
P-10 Kozloduy	Kozloduy	1962	3110	Early Triassic
P-11 Kozloduy	Valchedram	1964	3800	Middle Triassic
P-12 Kozloduy	Valchedram	1963	4019	Middle Triassic
P-13 Козлодуй	Valchedram	1965	4291	Late Triassic

The analysis of the rocks uncovered in the boreholes (Benderev, 2012)[55], because of their close disposition, show considerable similarity in their geological columns. The geological section is illustrated by the deepest borehole in the area – P-13 (**Table 3.4-3**).

TABLE 3.4-3: GEOLOGIC COLUMN AND HYDROGEOLOGICAL UNITS UNCOVERED BY DRILLING P-13

Interval, m	Absolute depth of upper part, m	Thickness, m	Geological Index	Lithology	Hydrogeological units
3.55-22	119	18.45	Q	Loess, at the foundation sands	Quaternary Aquifer
22-58	100	36	N_2l	Clays with seams of sand	Pliocene aquifer
58-97	64	39	N_2d	Clays with seams of sand	
97-177	25	80	N_2p_2	Sands	Pont aquifer
177-338	-55	161	N_2P_1	Clays with seams of sand	Maeot pont aquifer
338-418	-216	80	N_2m	Clays with thin seams of sands	
418-468	-296	50	N_1s	Clays with thin seams of sands	Sarmat water-confining formation
468-577	-346	109	N_1t	Clays with thin seams of sands	
577-743	-455	166	Pg-E	Clays with seams of sand and marls	Palaeogene water-confining formations
743-882	-621	139	Pg-E	Marls	
882-940	-760	58	Pg-Pc	Marls	
940-1311	-818	371	K_2m	Limestones	Late Cretaceous-Palaeogene aquifer
1311-1486	-1189	175	K_2cp	Clayey limestones	Late-Early cretaceous water-confining formation
1486-1609	-1362	123	K_2sn_1	Sandy limstones, marls, sinstonesчници	
1609-1675	-1489	66	K_2t	Alevrite limestones and marls	
1675-1779	-1549	104	K_2cm	Marls	

[55] Benderev, A. 2012. Report on the deep aquifers in the part of the North-western Bulgaria where the Kozloduy Nuclear Power Plant is.

Interval, m	Absolute depth of upper part, m	Thickness, m	Geological Index	Lithology	Hydrogeological units
1779-2051	-1652	272	K_1ap-al	Marls	
2051-2160	-1916	109	K_1b-ap	Alevrite limestones and marls	
2160-2435	-2024	275	K_1br-h	Limestones, sandy, cavernous	Middle-jurassic – late Cretaceous aquifer
2435-2777	-2283	342	J_3	Limestones, dolomites	
2777-3211	-2625	434	T_3r	Argilites, sandstones, clayey limstones	Late Triassic relative water-confining formations
3211-3586	-3059	375	T_3r	Sandstones aleurolites, argilites	
3586-3619	-3434	33	T_3k-n	Dolomites	Triassic aquifer
3619-3638	-3467	19	T_3k-n	Argilites and sandstones	
3638-3680	-3486	42	T_3k-n	Dolomites	
3680-3741	-3528	61	T_3k	Argilites, sandstones	
3741-3756	-3589	15	T_2l	Limestones, argilites	
3756-3778	-3604	22	T_2a	Limestone	
3778-3811	-3626	33	T_2a	Limestone, Dolomites	
3811-3998	-3659	187	T_2a	Limestone	
3998-4157	-3845	159	T_2a	Dolomites	
4157-4166	-4004	9	T_2a	Aleurolites sandstone and argilites	
4166-4203	-4013	37	T_2a	Limestone	
4203-4243	-4051	40	T_1	Argilites, aleurolites	Early Triassic aquifer complex
4243-4291	-4091	48	T_1	sandstone	

It is seen from **Table 3.4-3** that the deep aquifers in the area are studied to a depth of more than 4000 m. Of them nearest to the surface is the late Cretaceous-Palaeogene – at a depth of more than 800 m. It is isolated from the surface aquifers by water-confining layers with thickness of 500 m, which makes the penetration of water from them into it practically impossible.

Therefore it may be concluded that as with the already built nuclear facilities Kozloduy Nuclear Power Plant, the new nuclear unit will present no potential risk of radionuclide pollution of the abyssal aquifers.

3.4.1.6.2 Hydrogeology of the subsurface zone

The site of the Kozloduy Nuclear Power Plant , including the potential sites 1, 2, 3 and 4, is located on aquifers, which are part of the following shallow underlying water bodies, according to the Management River Basin Plan for the Danube region water management (as per the Opinion of the Danube Region Basin Directorate, No. 3804/08.01.2013)

→ Underground water body, defined by code BG1G0000QPL023 – porous waters in the Quaternary – between the rivers of Lom and Iskar. The character of the underwater is non-artesian.

→ Underground water body defined by code BG1G0000QAL05 – porous water in the Quaternary – Kozloduy lowland. The groundwater is non-artesian by character;

→ Underground water body defined by code BG1G00000N2034 – porous waters in the Neogene – Lom-Pleven depression. The site of the Kozloduy Nuclear Power Plant sits entirely on this water body lying under the Quaternary aquifer. The underground water body is represented by upper and lower layer, which by character are non-artesian to pressure waters. In the upper layer, pollution of NO_3, Mn etc. has been established, as a result of farming activities.

The outlining of the underground water bodies was done taking into consideration the criteria of the European Framework Directive on waters 2000/60/EC. The work was carried out by a team of the Hydrogeology Section of the Geological Institute of the Bulgarian Academy of Sciences on the basis of a signed contract with the Dutch company "ARCADIS EUROCONSULT BV".

Detailed description of the underground water bodies is made in Section "Underwater" (§ 3.2.2)

In the area of the Kozloduy Nuclear Power Plant sites the shallow groundwater of the first non-floodable terrace of the Danube River (sites 2 and 4) is evident at a distance of 7 – 10 m under the surface, and of the floodable terrace (sites 1 and 3) they are to be found even nearer the surface and fluctuate with the level of the Danube River (water bodies BG1G0000QAL005, BG1G0000QPI023) (Bulgarian Academy of Sciences, 2012[5]). At a depth of 20 – 30 m is the late Miocene aquifer of the so called Archar Formation (water body BG1G00000N2034).

At Terrace T_1, on which sites 2 and 4 are situated, the main hydrogeological units are:

- Unsaturated (aeration) zone. Its thickness is from 7 to 10 m. It is developed in the dust sand loess.
- Water saturated zone. It consists of an aquifer in two layers: upper and lower. The two parts of the aquifer are divided by "non-perfect" water confining formation

The upper layer includes the lower part of the loess, which is clayey (k=0.2 m/d), and mainly the gravel-sandy sediments on the terrace with k=50-80 m/d for the gravel and k=11 m/d – for the sandy sediments. This is the layer in which the aquifer nearest to the surface formed. Its waters have direction southwest-northeast. A small part of the feeding is due to infiltrated precipitations. The main feeder comes from the adjoining slope and by feeding from Pliocene sands, where they contact directly with the alluvium of T_1 and T_0. This is seen at Site 2. The level of the groundwater varies between elevations of 25.0-27.5 m.

The non-perfect water-confining formation are Pliocene clays of the Brusartsi Formation with filtration coefficient of *k=0.1 m/d.* the thickness of the layer is from 11 to 16 m.

The lower highly permeable layer is formed in sandy sediments of the Brusartsi and Archar Formations.

At Terrace T_0 (sites 1 and 3) the main hydrogeological units are as follows:

- Unsaturated (aeration) zone. Its thickness is from 0 to 5 m. It includes sandy alluvial clay.
- Water saturated. Like Terrace T_1, it consists of aquifer in two layers: upper and lower, divided by "non-perfect" water-confining formation

The upper layer contains two sub-layers – clay-sandy with thickness 4-9 m (*k=0.5 m/d)* and gravel-sand – thickness to 13 m (*k*=50-80 m/d). This aquifer is the most water-abundant in the Kozloduy lowland. It feeds on infiltrated surface water of the older terraces of the Danube River and on the lower aquifer – in the easternmost part of the area under study (Site 1), where the alluvial gravel on the terrace lies on sand of the Brusartsi and Archar Formations. The draining of the aquifer is achieved by the draining systems into the Danube River during the period of low water.

The non-perfect water-confining formation – This role is played by the clays of the Brusartsi Formation with filtration coefficient *k*=0.1 m/d. The thickness of the layer is 1 to 16 m. In the area of Site 1 the non-perfect water-confining formation is interrupted and the upper and lower permeable layers are in direct contact.

The lower layer, as with Terrace T_1 is formed in sandy sediments of the Brusartsi and Archar Formations.

The groundwater in the area of the Kozloduy Nuclear Power Plant has been object of constant hydrogeological and radiochemical monitoring.

The hydrogeological studies until now include the link between the surface water and the groundwater.

Feeding and draining of shallow groundwater

The feeding of groundwater in shallow aquifers is done mainly from the slope adjoining the terrace. The feeding source is the under-loess gravels and the flowing waters from the Pliocene aquifer at its contact zones with the alluvial sands and gravels. Feeding is obtained also by infiltration of precipitation waters in the area (Galabov, 1992)[56].

[56] Galabov, M. (leader). 1992. Clarifying the disperse characteristics of the soil and the water environment in the area of the site of the Kozloduy Nuclear Power Plant aimed at analysing the possible ways of migration of radionuclides from the nuclear power plant into the soil and the hydrosphere, Akvater, Sofia.

The natural drainage of the shallow underwater is brought about by the Danube River, feeding the aquifers at high waters, turning the natural flow to the south and creating back water in the contemporary terrace.

Level drawing of the shallow underwater on the terraces of the Danube River is achieved by the work of the draining channels and the operated water abstraction wells.

Hydro dynamic and hydraulic characteristics of the shallow underwater

The filtration stream in the area of the potential sites for New Nuclear Unit has an orientation from south-southwest to north-northeast. The pressure gradient varies between 0.003 and 0.005. In the central parts of the lowland the gradients are lower because of the higher conductivity and the action of the drainage system.

The changes in the levels of the underwater are most significant in the river-side band (no more than 300-400 m from the river), most often being within 2-3 m. The amplitude of the fluctuations gradually decreases deeper in the lowland because of the river getting farther and the action of the drainage channels. A respective delay in the reactions of the aquifers is observed. The course of change of the pressure in the layers follows the one of the changes of the water levels in the Danube River, however it is more gradual and with a lesser amplitude (according to observations of Energoproekt, in the period June-December 1991).

At terrace T_1 the fluctuation amplitudes of the water level are 1 to 3 m, in recent years witnessing certain rises of the level (by about 1-2 m), related to some extent to waters from the nuclear power plant (Galabov, 1992[23]).

Chemical composition of the underwater

The chemical composition, as well as the implemented underwater monitoring programs on the territory of the Kozloduy Nuclear Power Plant are discussed in detail in Section Underwater (§ 3.2.2.). In this chapter only the most necessary information is given to add to the hydrogeological picture of the sites

The waters of the underground water body BG1G0000QPl05 – porous groundwater in the Quaternary – Kozloduy lowland, are characterised by general beta activity and contents of natural uranium under the limit values, according to the requirements of Rules No. 9/16.03.2001 concerning the quality of the drinking water and the specific activity of the examined radionuclides (^{40}K, ^{137}Cs, ^{54}Mn, ^{109}Cd, ^{226}Ra, ^{232}Th, ^{214}Pb, ^{214}Bi) is under the maximum limit values, according to the Rules on the basic norms for radioactive protection, 2012.

The results of the monitoring analysis indicate that all indicators under observation are within norm, according to the quality standards, regulated by Rules 1 (2007) – for study, use and preservation of underwater, as amended – State Gazette No. 15, 2012.

In implementation of the recommendations of the Report on the Environmental Impact Assessment of 1999 and the terms of Decision related to the Environmental impact assessment No. 28-8/2001, the Kozloduy Nuclear Power Plant is making its own non-radiation monitoring.

In order to localise and assess of the eventual impact of the Kozloduy Nuclear Power Plant on the environment and the population, 2 control zones have been defined with different radius: Urgent Protection Measures Zone (2 km) and Preventive Protection Measures Zone (30 km). Object of monitoring is also the territory of the industrial site itself.

Water samples from the drilled wells have been analysed four times a year for general beta-activity and for Tritium contents.

In implementation of the current monitoring program, particular attention is paid also to the drinking water sources in the area of the Kozloduy Nuclear Power Plant. The drinking water for the Town of Kozloduy, the Village of Harlets, the Kozloduy Nuclear Power Plant and the Town of Oryahovo is being examined monthly for beta-activity and Tritium. The elements ^{90}Sr и ^{137}Cs are measured twice a year and four times a year in the drinking water network of the Town of Oryahovo.

The results are similar to the ones of previous years and they are 1000 tomes lower than the provisions of the law, which indicates that the radiation status of the drinking water sources in the area has not been influenced by the Kozloduy Nuclear Power Plant and corresponds entirely to the sanitary norms.

As a whole the radiation characteristics of the aquifer at the income and the outcome of the site have not been influenced by the operation of the Kozloduy Nuclear Power Plant.

Prognosis of the risk of underwater pollution

There exist several ways of radionuclides entry into groundwater: through the aeration zone, through direct entry into the auriferous layer (underground, from buildings and facilities of the nuclear power plant), from rivers and channels, at the areas and in the periods of feeding the groundwater (Galabov, 1992[23]).

The entry of radionuclides through the aeration zone can happen where aerosols find way from the air at outpourings on the territory of the Kozloduy Nuclear Power Plant. The penetration of the pollutants depends on the thickness and the filtration ability of the aeration zone, the absorbability of the given component by the environment and by infiltration of precipitations.

At the alluvial terrace (T_0) there is an aeration zone with little thickness (0–5 m), with relatively low conductivity. At the terrace (T_1), located higher and covered by loess materials the thickness of the aeration zone is larger (7-10 m). Therefore the penetration of pollutants is possible at different time of their motion.

Within the boundaries of the Kozloduy Nuclear Power Plant sites, it is possible to have direct ingress of radionuclides into shallow situated auriferous layer at underground outpouring from buildings and facilities of the nuclear power plant. The pollutants distribution and movement depends on the orientation and filtration flow and the absorbability of the given pollutant, making necessary that processes of hyper-dispersion and irreversible elimination (including the decay) is taken into consideration. Under the concrete circumstances, the distribution direction is mostly north-northeast.

Less probable is pollution of groundwater by radionuclides, which found way into the rivers and channels in the area of the Kozloduy Nuclear Power Plant.

3.4.2 NATURAL RESOURCES

3.4.2.1 UNDERGROUND NATURAL RESOURCES

According to the specialised maps[57] pursuant to the Underground Resources Act there is information on the following underground natural resources within the 30 km zone around the Kozloduy Nuclear Power Plant:

– Registered are 10 deposits, which are accounted for at the National Balance of the Reserves and Resources, of natural resources deposits. Five of them have been licensed for operation as concessions.

– The zone includes additional concession area, necessary for operation of gas and condensate from the Koynare deposit, granted by Decision of the Council of Ministers No. 960/16.11.2012 to Direct Petroleum Bulgaria EOOD, City of Sofia.

– On this territory there are valid Permits to search and explore for oil and gas in the Block 1-12, Knezha area, held by Exploration and Production of Oil and Gas AD, City of Sofia and search and explore for industrial materials in the Gladno Pole area, held by Industrial Minerals OOD, City of Sofia.

– Etropolska Argilite Formation gas and condensate deposit, registered as geological discovery under No. 0005/01.07.2010, with Direct Petroleum Bulgaria EOOD, City of Sofia as holder, which is under procedure to have the deposit granted as commercial discovery.

– There no registered deposits of building materials under the Underground Resources Act within the 30 km zone.

– As is seen, there are no registered deposits and valid concessions for underground natural resources on the territory of the four alternative sites.

A list of the deposits of natural resources, which are accounted for at the National Balance of the Reserves and Resources is presented on **Table 3.4-3**.

[57] Letter No 26-A-137/23.04.2013.

TABLE 3.4-4: LIST OF DEPOSITS OF NATURAL RESOURCES, ACCOUNTED FOR AT THE NATIONAL BALANCE OF THE RESERVES AND RESOURCE

Serial No.	District	Municipality	Location, raw material	Section	Cponcessionaire /Decision of the Council of Ministers
1.	Vratsa	Byala Slatina	Tarnava 1415/1978 brick clays	Cays for brick production	
2.	Vratsa	Kozloduy	Butan	Gas	
3.	Vratsa	Kozloduy	Butan	Combustible natural gas	
4.	Vratsa	Kozloduy	Butan-south, condensate	Gas	Exploration and Production of Oil and Gas AD
5.	Vratsa	Kozloduy	Butan-south, Combustible natural gas	Condensate	Exploration and Production of Oil and Gas AD
6.	Vratsa	Oryahovo	Oryahovo, condensate		
7.	Vratsa	Oryahovo	Selanovtsi	Gas	Exploration and Production of Oil and Gas AD
8.	Vratsa	Oryahovo	Selanovtsi, oil	Oil	Exploration and Production of Oil and Gas AD
9.	Vratsa	Hayredin	Monastirishte-Beli Brod	Limestone for tiling	
10.	Vratsa	Hayredin	Monastirishte-Vlashko selishte	Limestone	
11.	Vratsa	Hayredin	Monastirishte – central	Limestone for tiling	Monolit AD
12.	Vratsa	Hayredin	Obroka	Limestone for tiling	
13.	Montana	Lom	Lom basin – eastern part	Lignite roads	
14.	Lom	Knezha	Bardarski geran	Gas and oil	Exploration and Production of Oil and Gas AD
15.	Pleven	Knezha	Marinov Geran	Gas	Exploration and Production of Oil and Gas AD
16.	Pleven	Knezha	Marinov Geran	Condensate	Exploration and Production of Oil and Gas AD

At the moment of preparation of the Assignment for the territory of the four sites, there are no data on availability of underground natural resources. For the purposes of the Report of the Environmental Impact Assessment, additional studies will be carried out by the National Geological Fund, including examination of data from data bases and specialised maps and registers of the Ministry of Economy and Energy

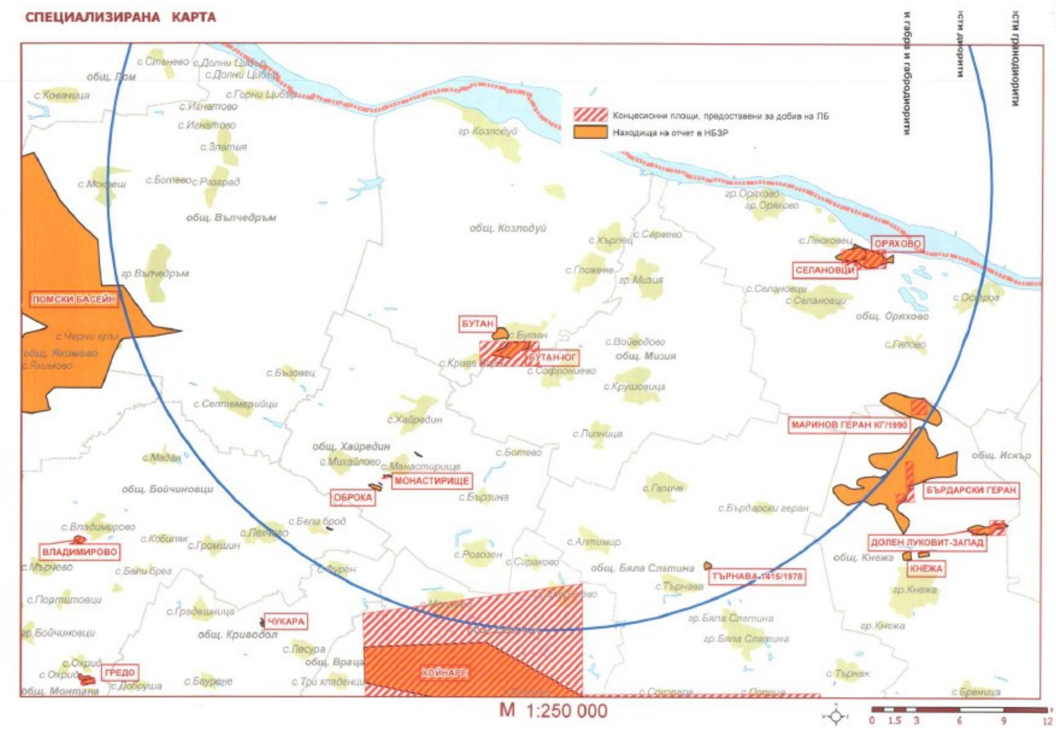

FIGURE 3.4-10: SPECIALISED MAP WITH DATA ON THE UNDERGROUND RESOURCES DEPOSITS (REPORT TO THE NATIONAL BALANCE OF THE RESERVES AND RESOURCES) AND ON THE CONCESSION AREAS GRANTED WITHIN THE 30 KM ZONE AROUND THE KOZLODUY NUCLEAR POWER PLANT

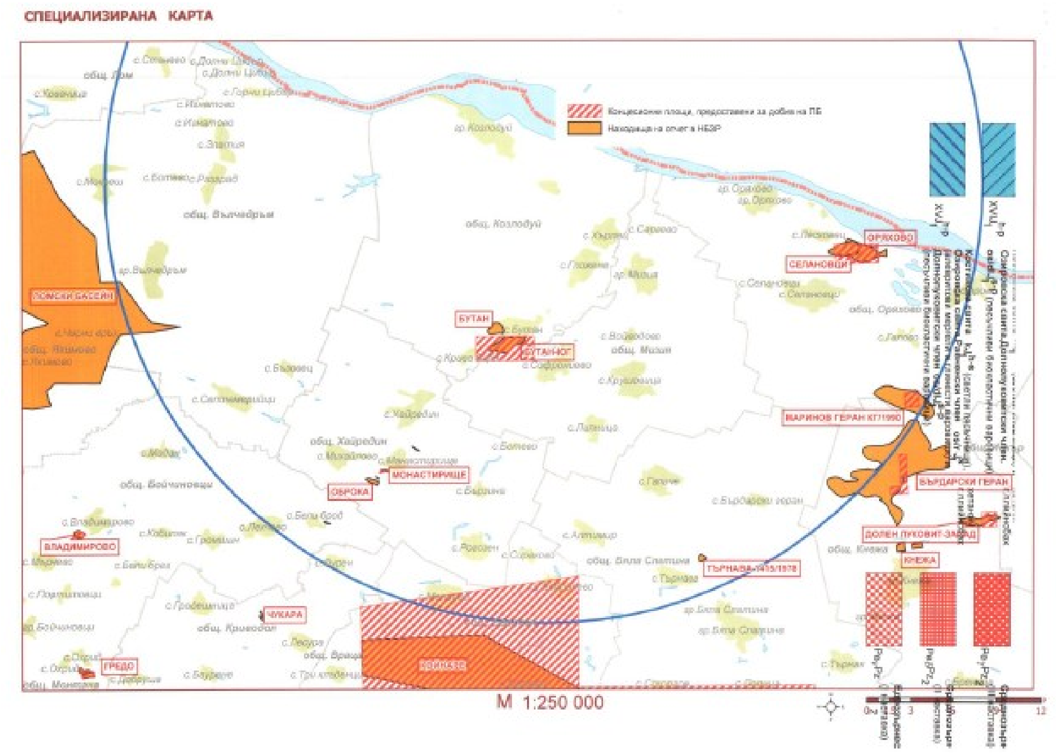

FIGURE 3.4-11: SPECIALISED MAP WITH DATA ON THE PERMITS FOR SEARCH AND EXPLORATION AND ON REGISTERED GEOLOGICAL DISCOVERIES WITHIN THE 30 KM ZONE AROUND THE KOZLODUY NUCLEAR POWER PLANT

3.4.2.2 BUILDING MATERIALS (RIVER COARSE AGGREGATE AND SAND)

The coarse aggregate and sand are some of the building materials, which are used in all main stages of the construction of the New Nuclear Unit from the preparation of the site, through the building of the underground and surface communications to the main surface construction of buildings and facilities on the selected site. The building qualities of the materials according to the specificity of the facility and the respective building works will be dealt with in the concrete technical design, related to the realisation of the investment proposal in the next stages of design. The delivery to the construction site of the necessary quantities of river coarse aggregate and sand will have to be carried out by regulated, pursuant to the Waters Act, ballast providers in or out of the area. The regulation is resolved statutorily in the Waters Act. The permits regime is managed by Executive Agency for Exploration and Maintenance of the Danube River – Ruse for production of sand and coarse aggregate, by the Ministry of Environment and Water where the materials are provided by dams pursuant to Annex 1 of the Waters Act and by the Danube Region Water Management Basin Directorate – for ballast aggregate providers along the inland rivers.

3.4.3 SEISMIC RISK RELATED TO THE AREA O THE SITES OF THE KOZLODUY NUCLEAR POWER PLANT

The earthquakes, as potential external factors for the safety of the nuclear power plant are object of great attention worldwide. At the beginning of 1990 the Council of Ministers[58] gave permission to organise and carry out international expert examinations referring to the current Kozloduy Nuclear Power Plant and the designed Belene Nuclear Power Plant. Based on this decision in June 1990 in Sofia an expert mission of the International Atomic Energy Agency (IAEA) was organised. The experts of IAEA recommend performing studies and expert examinations in accordance with the contemporary standards for seismic safety on the site of the nuclear power plant.

According to the recommended activities a program was drawn "Studies and activities aimed at enhancing the safety of the site of the Kozloduy Nuclear Power Plant and the designed Belene Nuclear Power Plant – 1991-1992", the program has several annexes concluded thereto and the activities of its implementation continued to the end of 1995.

In fulfilment of this program field and chamber geological and geomorphological research has been carried out in the region and the sub-region of the Kozloduy Nuclear Power Plant with view to define the principal geological structures and assess their Neogene-Quaternary activities. The activity of the established fault structures (like the Ogosta, South Moesian etc) during the Quaternary has been established, their seismic potential has been evaluated and their stability during the present geological period has been proven. Maps have been drawn of the individual tectonic regions, a Neo-tectonic and seismic-tectonic map of the regional area, which are based on the newest studies and results and summarise

[58] Letter No. 198-0514-6189/04.01.1990 of the Council of Ministers concerning organising and holding of international expert examinations of the operating Kozloduy Nuclear Power Plant and the Belene Nuclear Power Plant, currently under design,1990.

the previous regional studies concerning the Kozloduy Nuclear Power Plant. The site of the nuclear power plant has been located in the relatively firmest area of the south-western part of the Moesian platform. There are no fault structures with any significant energy potential in the 30 km zone (no data on availability of active "capable" fault).

One principal recommendation of IAEA was the building of a Local Seismic Network around the site of the Kozloduy Nuclear Power Plant. This is a basic requirement of IAEA for the sites of nuclear power plants[59]. The Local Seismic Network around the site of the Kozloduy Nuclear Power Plant, which had been designed and built in accordance with the norms of IAEA[60], became operable in 1997 and is situated in the sub-regional area around the site of the nuclear power plant. The purpose of the Local Seismic Network is to monitor the weak seismicity and to define precisely the main dynamic and kinematic parameters of the seismic event occurring in the sub-region of the Kozloduy Nuclear Power Plant. The conclusion for the seismic tectonic stability of the local zone around the nuclear power plant is confirmed also by the collected data base of the highly sensitive local seismic network, which has been in operation in the past 15 years – **in the 30 km zone around the site not a single earthquake has been localised.**

3.4.3.1 ASSESSMENT METHODOLOGY FOR SEISMIC HAZARD

The seismic hazard assessment of the territory in our country is of particular importance, having in mind the fact that the country is situated in the highly active Aegian seismic zone, which is part of the Alpine-Himalayan earthquake belt. The seismic hazard can be determined by the methods of seismic geographic demarcation, seismic hazard and seismic risk. For the whole territory of the country a prognostic **seismic zoning** was made on the basis of a complex analysis of geological, geophysical, seismological and other data by a team of Bulgarian and foreign experts. The results are presented in the publication of Bonchev et al., 1982, as maps, amid which is a complex map of the possible centre zones and maps of the earthquake liability. The first map gives idea of the location and the probable power of expected earthquakes. Zones are outlined with various magnitude intervals. This map does not allow evaluating the intensity according to the macroseismic scale directly.

Various types of maps have been created, among them maps of the earthquake liability for a period of 1000 years and 10,000 years. Since 1987 the first of them is normative for seismic construction[61]. It is taken into consideration when designing buildings, dams, nuclear power plants and other engineering structures. With view to the harmonisation of the Bulgarian standards with the European standards it was necessary instead of using the intensities according to the macro seismic scale, to use accelerations (displacements,

[59] IAEA Safety Guides, No. 50 – SG – S1, Earthquakes and associated topics in relation to nuclear power plant siting. Vienna,1991.

[60] IAEA-TECDOC-343, Vienna, 1991.

[61] Norms for designing buildings and facilities in earthquake areas, Council for territorial and urban planning, construction and architecture of the Bulgarian Academy of Sciences, Sofia, 1987 r.

velocities) of the oscillations of particles in the distribution of the seismic waves. Since 2012 the maps of the **seismic hazard** of the new seismic zoning (2009) are part of the draft of National Annexes to the European Standards for design and implementation of building works (Eurocode 8)[62], published for discussion (and two year joint use with the current norms).

The Seismic hazard is an assessment of the probability the power of the earth motion at a given point of the earth surface to exceed a defined value during a definite period of time. The earth motions may be expressed by maximum acceleration, maximum velocity or maximum displacement of the oscillation of particles, caused by the seismic waves. In recent times the basic **maximum earth acceleration** is accepted as perimeter for assessment of the earth motion.

There exist various methodologies for assessment of the seismic hazard, each one having its advantages and shortcomings. The earliest method was the observation, later there developed the **deterministic,** static, probabilistic, time-dependent seismic hazard, spectral hazard method. Each of these methods underwent various modifications in the endeavour to eliminate its shortcomings. The **probabilistic** methods occupy a special place. On their behalf they can be divided into historical and deductive. Venetiano and others in 1984 proposed the historical method, which needs only a catalogue of historical earthquakes, suitable functions of attenuation of the earth motions in the researched area and responding function of the site. This historical method later was further developed and in 1995 Frankel presented a probabilistic method for evaluation of the seismic hazard, which is based on spatial diffusion seismicity. As parameter characterising the earth motion was chosen the maximum earth acceleration (PGA). On the other hand, the deductive methods, in addition to the catalogue of historical earthquakes and suitable attenuation functions of the earth motion, require description of the possible faults and earthquake zones and the parameters describing the seismicity of these faults and of the seismic sources and their characteristics (parameters of seismicity). The basics of the deductive methods were introduced by Kornel in 1968. There exist various modifications and applications of this method, but the evaluation of the seismic hazard on the basis of an outline of the seismic sources continues even today to be connected with a number of inaccuracies caused by the lack of quality geological and seismological data.

The methodology for re-evaluation of the seismic hazard on the site of the Kozloduy Nuclear Power Plant in 1991-1992 would undergo a few stages. The first stage is the creation of the **seismic tectonic** model for the territory of Bulgaria and the neighbouring seismic zones, which exert influence on the Bulgarian territory. The basis for the creation of this model is the information from the seismic regionalisation on the 1987 norms. The seismic tectonic model determines the type, geometry and the physical characteristics of

[62] Draft of National Annexes to the European standards for design and implementation of building work (Wurocodes): Seismic regionalisation of the Republic of Bulgaria harmonised with the requirements of Eurocode 8 (Part 3) – http://www.mrrb.government.bg/?controller=articles&id=492

the seismic centres, which influence the seismic hazard for the site of the Kozloduy Nuclear Power Plant. According to type the seismic sources in the model are: point, line, area and dispersion. The geometry of the source includes the location (coordinates), form, depth etc. The physical characteristics are determined by the maximum magnitude, which the source may generate and the frequency of occurring earthquakes with magnitude above a certain level (the law of repeatability). All characteristics of the model are defined with their distributions. The establishment of **laws of attenuation** of the impact (the accelerations) is the second stage of the activities in the evaluation of the hazard. Because of lack of statistics of the Bulgarian records, suitable characteristics from other seismic regions have been used. Concerning the centre of Vrancea, separate laws of attenuation have been used, because of the very specific character of attenuation. Two types of law of attenuation have been accepted: one for interfocus earthquakes and one for all the rest, each type being presented at least by two laws with the respective evaluations. The estimation of the assessment of the seismic hazard (acceleration) is made by the method of Cornell, respectively its realisation in the EQRISK programme of McGuire. **The seismic hazard is the probability the power of the earth motion at a given point of the earth surface to exceed a given value during a definite period of time.** The distribution of the hazard is described usually either by its probabilistic distribution function P(x), or by its probabilistic excess function v(X).

The seismic hazard of the site of the Kozloduy Nuclear Power Plant is connected with the seismic hazard curves, indicating the yearly excess probability as function of the size of the maximum acceleration. The frequency of excess v(X) is function of the inaccuracies of time, power and localisation of the possible future earthquakes and also of the level of earth motion, which may be exceeded for the site in consideration. As noted the seismic tectonic model and the attenuation laws are burdened with inaccuracies. The inaccuracies may be accounted for in two ways: use of the "logical tree" or according to the method of "Monte Carlo". The evaluation of the Kozloduy Nuclear Power Plant was made through the "logical tree" for a number of combinations of various inaccuracies and respectively the same set of curves of the seismic hazard for maximum acceleration was obtained. All calculations have been made with attenuation laws for the level of free surface. The calculation procedures take into account the statistics of results too, obtaining mean (most probable) evaluations and evaluations with different intervals of reliability. The methodology of the probabilistic analysis of the seismic hazard is based on the standardised mathematical model of Cornell and the program products of McGuire, 1976 and Toro and McGuire, 1988, later improved by Solakov and other, 2001.

The seismic risk is defined by the seismic hazard and by the vulnerability of the facilities and the administrative structure of management of the building and the operation of the nuclear power plant as a result of the earthquake impact. It is quite achievable from engineering constructive and administrative point of view to have this risk minimised even where there is active fault near-by. The eventual pollution with radionuclides, susceptible by the partial vulnerability of weak elements of the engineering constructive and administrative system should not be allowed irrespective of the price. There exist a number of real negative examples from the operation of nuclear capacities in the world up to now. The seismic risk is controllable by man and needs to be minimalized. According to the assessment of seismic risk, measures are recommended for ensuring the engineering constructive entirety of the structures and the infrastructure, including the entirety of the administrative structure for management of the nuclear power plant, which will allow to withstand the maximum possible impact of the projected seismic event without damaging their constructive entirety and without permitting continuous loss of operability.

3.4.3.2 CURRENT DESIGN-BASED SEISMIC CHARACTERISTICS OF THE SITE OF THE KOZLODUY NUCLEAR POWER PLANT

3.4.3.2.1 Analysis of the seismicity

As was noted above, the first stage of the assessment of the seismic hazard is the construction of seismic tectonic model in the regional and local zones around the site of the Kozloduy Nuclear Power Plant. The basis for construction of this model is the analysis of the seismicity in the region under study. At the next stage the results of the tectonic and geomorphological studies will be used to substantiate the potential possibilities of the model.

Detailed seismicity of the region has been researched by the Geophysical Institute of the Bulgarian Academy of Sciences in 1990-1992. A catalogue of earthquakes was used, which embraces the period from 375 AD to 1990. The catalogue data was unified and standardised in accordance with the current requirements.

The greater part of the observed seismic events is linked with the well-known eight seismogenous districts: Sofia, Maritsa, Gorna Oryahovitsa, Kresna, Negotino-Trayna and Kampuling-Vrancea (shallow and medium deep) and local. The spatial, time and energetic characteristics of these districts are studies in detail. The Sofia seismic zone is located at a minimum distance of 80 km from the Kozloduy Nuclear Power Plant. The maximum epicentre intensity (I_0) of the 9th degree (MSK) has been documented for this zone, based on earthquakes in 1641 and 1858. The observed maximum effect on the site of the Kozloduy Nuclear Power Plant from earthquakes in the Sofia zone is $I_{koz} = 3$ (MSK).

Earthquakes in the 150 km region are generated in the earth crust at a depth to 50 km. The maximum density of the hypocentres of the earthquakes is observed in a deep layer between 5 km and 25 km. Powerful interfocus earthquakes, with explicit macroseismic effects (effects at long distances) are generated at depths from 90 km to 230 km in the seismic zone of Vrancea, which is at a distance of 240 km.

The sources of seismic hazard are earthquake zones outside the area of the site of the Kozloduy Nuclear Power Plant. The zone with the greatest effect on the hazard of the site of the Kozloduy Nuclear Power Plant is the Vrancea zone in neighbouring Romania, which has generated events with magnitude M > 7. The maximum macroseismic effects on the site $I_{koz} = 6 – 7$ have been recorded as a result of the earthquake in 1977 with M = 7.2 and $I_0 = 8.0$. The effects are due to the specifics of the source processes (strong prolongation of the isoseismic field to southwest).

The most powerful earthquakes outside the defined zones are: the event in North Greece in 1828 with M = 7.5 and I_0 = 10.0 and the earthquake in the region of Dulovo in 1882 with M = 7.3 and I_0 = 7.8 with observed macroseismic effects on the site of the Kozloduy Nuclear Power Plant – I_{koz} = 5 – 6.

According to the maps of shake-susceptibility with period of 1000 years (which is valid until 2014) (**Figure 3.4-12**) and 10,000 years, the area of the nuclear power plant may be subjected to earthquake impacts of the VII degree according to the scale MShK-64, and the buildings and structures are secured by K_c = 0.10[63] to prevent such earthquakes.

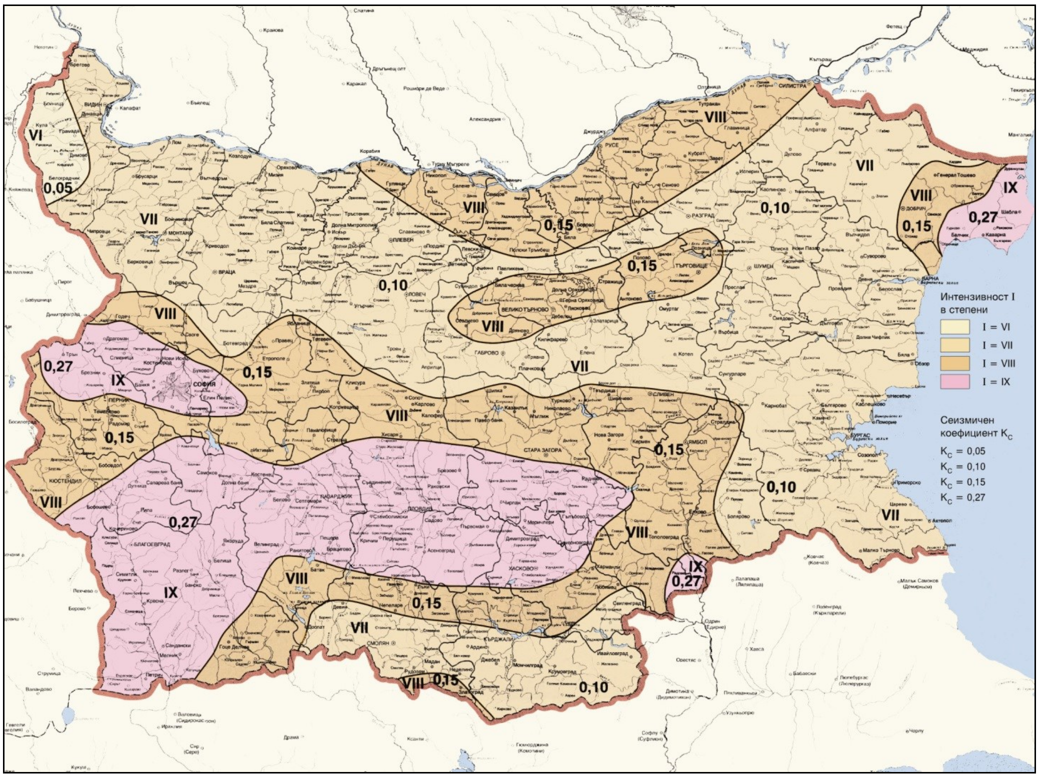

FIGURE 3.4-12: MAP OF SEISMIC REGIONALISATION OF THE REPUBLIC OF BULGARIA FOR A PERIOD OF 1000 YEARS

On recommendation of IAEA the impact of local earthquake was studied additionally. The local centres are with documented earthquakes with M < 4 and fall into the category of background seismicity.

The site of the Kozloduy Nuclear Power Plant is situated in the middle of a stable area in the south-western part of the Moesian platform, which is characterised by extremely low seismic activity. In the period of the regional instrumental registration of earthquakes (1976-1998), on the whole area of the 30 km zone only 3 earthquakes occurred on Bulgarian territory with magnitude M < 2.0 and one in Romania with magnitude M = 3.6.

63 Rule No. RD-02-20-2/2012 on designing buildings and structures in earthquake areas

Upon installation of highly sensitive local seismic network it was established that in the period 1997 – 2012 not a single seismic event with the lowest possible magnitude has been registered in the local zone. For this area there are no documented historical earthquakes. The lack of documented seismic activity and the extremely weak sporadic seismic occurrences characterise it as seismically "t**he calmest"** area in the 320 km region..

The seismic tectonic characteristics of the regional and local area of the Kozloduy Nuclear Power Plant have been defined on the basis of complex geologic, geophysical, geodesic, geomorphological, seismic seismologic and other studies[64].

The analysis of the tectonic processes in the Moesian platform is subject to the principal pattern of the latest tectonic cycles. The tectonic denivellations are observed only along the boundary of the platform. The tectonic processes reached an end at the end of the Triassic and the beginning of the Jurassic. The additional information on the tectonics of the regional area has been obtained from the geological and geophysical transverse section built on the data of the research of the three regional profiles: Mokresh-Shabla, Petrich-Nikopol and Madan-Strazhitsa-Ruse, and for the deep structure and deep fault tectonics – through the results of the magnetic telluric drilling , gravimetrical, geomagnetic and other measurements and the analysis of the peculiarities of the marcoseismic fields and the seismic conductivity of the seismic energy in the different zones. The most apparent fault system – the North Fore-Balkan (Belogradchik flexure), cannot be recognised on any ground as seismic lineament. It has characteristics of seismic activity at the disjuncture at Krivodol with the Ogosta northeast fault, at Chiren with the Chiren north-eastern fault and at Gabare Drashan with the Dolen Lukovit fault – all they are outside the 30 km zone of the nuclear power plant. According to data from gravimetrical and geomagnetic studies no abnormal objects have been established in the 30 km local area around the site of the Kozloduy Nuclear Power Plant. A gravitation transition has been registered outside that zone with orientation northwest-southeast – the South Moesian fault, which in general reflects the Belogradchik flexure on the space under consideration.

The established direct dynamic link between the general structural development of the territory and the formation of its relief serves as a geomorphological evaluation of the neotectonic activity of the territory. The local territory enjoys a calm tectonic regime, which is reflected in the sub-horizontal distribution of the geomorphological levels. Here one finds only the mentioned fault lines with sub-equatorial orientation. They have been recognised as active during the Old Cimmerian phase and thereafter they became passive, fossilised under the influence of the powerful Cretaceous-Palaeogene and Neocene-Quaternary cover. The same conclusion is reached upon analysis of the disposition of the river-valley network and the number of the hypsometric-Quaternary terrace complex in the crosswise developed valleys of the rivers Ogosta and Skat.

[64] Study and actions to enhance the safety of the sites of the Kozloduy Nuclear Power Plant – 1991-92, Geomorphology, Neotectonics, Sofia, 1992.

These characteristics of the 30 km zone are illustrated best by the neotectonic and geomorphologic studies of the Gorna Vila Frank morpho-structural level and by the disposition and development of the river terraces of the Danube River and its left and right tributaries, which have the same elevation on both sides of the river.

In the local territory of the Kozloduy Nuclear Power Plant there is no geological-geomorphological data whatsoever, showing any active fault structures of Quaternary age, while the lineaments are poorly exhibited or are almost absent.

It has been established by seismic studies that in the 30 km zone **there are no faults** of Jurassic-Palaeogene age. The Neocene and Quaternary deposits lie almost horizontally with lack of surface signs of tectonic upending. The available data reject the existence of "capable" fault, i.e. visible surface structure with seismic potential, as well as structures in the meaning of the definition given in в Safety Guide 50-SG-S1 (rev.1) of IAEA.

The seismic tectonic model of the local area (30 km zone) is built with the use of standard formalised procedure for integration of all available seismological and geologic-physical data. In the provided map the complex lineament zones are marked according to data for the Triassic-Jurassic fault system. The lineament zones express the highest degree of heterogeneity of the physical parameters in the earth crust and therefore they are considered zones of potential instability. The lack of evidence for Quaternary activity and motion in the local area and the fact, that on Bulgarian territory only three micro earthquakes have been registered with magnitude $M < 2.0$ (on Romania territory – only 1 earthquake with magnitude $M=3.6$) give ground to conclude that in the entire local area no earthquake may be expected with $M_{max} > 4.0$. The results obtained are in accordance with the seismic regionalisation of the Republic of Bulgaria.

To summarise the results, the following main conclusions have been made:

- → The territory under study lacks large fault structures with high energy potential (there are no data on availability of active "capable" fault).
- → The site of the Kozloduy Nuclear Power Plant is situated in the relatively most stable part of the Moesian platform. This conclusion is confirmed by the collected data base from the local seismological network around the site, operating for 15 years on end.

3.4.3.2.2 Design-based seismic characteristics of the site of the Kozloduy Nuclear Power Plant

The impact of the seismic events through the evacuation of the seismic hazard is found for two design levels, in accordance with the recommendations of IAEA. These are the level of design earthquake and the maximum estimated earthquake. For these levels (depending on the defined seismic category) corresponding structures, systems and components are ensured to guarantee the safe operation of the nuclear power plant. The other structures, systems and components are supplied under the requirements of the civil norms.

The results of the seismic hazard for the site of the Kozloduy Nuclear Power Plant allow determining the seismic characteristics of the earth layers initial oscillations at earthquakes with the intensity of the design-based earthquake (DE) (Seismic level 1 according to the definition of "Seismic Design and Qualification of Nuclear Power Plants", Safety series No. NS-G-1.6, IAEA, Vienna, 2003) with frequency 10^{-2} events per year and the maximum estimated earthquake (MAE) (Seismic level 2 according to the definition of "Seismic Design and Qualification of Nuclear Power Plants", Safety series No. NS-G-1.6, IAEA, Vienna, 2003) with frequency 10^{-4} events per year on empty field of the site:

- Value of maximum acceleration (PGA) for DE (SL-1) with period of repeatability 100 years – 0.l g;
- Value of maximum acceleration (PGA) for MAE (SL-2) with period of repeatability 10 000 years – 0.2 g;
- Design wrapping reaction spectre for empty surface;
- Three-component accelerograms (continuation 61 s), measuring the geological conditions on the site.

The effects of the local earthquakes M = 4.5 under the site at a depth of 5 km and M=5.0 at a distance of 5.0 km and depth of 5.0 km on the structures and the equipment have been examined separately. Determined are the maximum acceleration (PGA) for the two seismic levels, reaction spectre for empty surface and the corresponding three-component accelerograms (continuation 20 s). These characteristics were reviewed and confirmed by the IAEA experts in the period 1992 – 1995.

The deterministic approach for the maximum acceleration evaluation of the seismic sources – Vrancea – interfocus, shallow earthquakes (all shallow sources) and the local zone was applied as well. The results are presented in the Report of the Geophysical Institute of the Bulgarian Academy of Sciences in 1992. For each seismic source the maximum expected magnitude is correlated to the nearest point of the site, taking account also of the size of the source. The determination of the maximum acceleration has been done by application of suitable attenuation laws taking into account the local conditions. The maximum acceleration, determined by the deterministic method, is considerably lower than the one determined by the probabilistic evaluation of the seismic hazard (1.35 – 1.7 times).

The earth layers dynamic characteristics of the building site of the Kozloduy Nuclear Power Plant, in accordance with which the geotectonic model of the "empty surface" profile was worked out, were determined experimentally. Terrain measurements have been carried out to determine the distribution velocity of the seismic waves by direct and return seismic log measurement, as was made the seismic profiling.

It was established that the transverse spread in clays with lower velocity of 170 m/s and higher – 680 m/s in the marls, while the velocity of the longitudinal waves is 470 m/s in clays and 2,700 m/s in marls. The range of change of the cutting deformations is 10^{-6} to 10^{-1} cm/cm. For each lithological variety, the link between these deformations and the cutting module coefficient G/G_{max} (0.0 до 1.2) and the coefficient of attenuation D (0÷40 %) has been shown graphically. The studies of the Bulgarian Academy of Sciences summarise the data on the geotechnical seismic model of the "empty surface" profile, which are valid for building sites and, irrespective of the non-homogenous geological conditions, allow the determination of the inter-relation "soil – structure". These data are used in the analysis in the project "Benchmark study for the seismic analysis and testing of WWER-Type NPP" of IAEA and the Modernisation program of unit 5 and 6 and other, with the participation of European and American companies with rich experience in seismic design and seismic re-assessment of nuclear power plants.

3.4.3.2.3 Complex criteria for selection of one of the four potential sites

The selection of one of the four potential for building the New Nuclear Unit based on seismic tectonic, geological and hydrogeological signs, will be made according to the Rules of the Nuclear Regulatory Agency of 2004 for ensuring the safety of nuclear power plants and on the following documents of IAEA: Safety Guide Series NS-R-3, 2003 и NS-G-3.6, 2004; Specific Safety Guide Series SSG-9, 2010 и SSG-18.

The selection of the criteria was made while taking into account the following conditions of the sites:

→ The tectonic and seismic conditions of the four sites are the same – no existence of active tectonic faults in the 30 km (Bulgarian) zone has been proven and the seismic hazard of the four sites would not differ substantially from the seismic hazard of the Kozloduy Nuclear Power Plant (at relatively close geological characteristics of the earth foundation). The local changes in the reaction wrapping spectres and the synthetic accelerograms at noticeable differences in the surface geologic foundation of each site are taken account of in the specialised design studies of "Risk Engineering".

→ Prior to the building works at each of the sites there exists possibility to apply methods for improvement the earth foundation, so that its carrying capacity would be in accordance with the load and the subsidence would be within the admissible limits.

Under the described conditions for selection of one of the four sites applicable are the following criteria:

→ Depth of the underwater level.

→ Risk of uplift of the underwater level on the site following rise of the level of the Danube River by extreme combination of hydrological and climatic circumstances (destruction of the "Iron Gates" in combination with extreme precipitations in the water catchment of the river)

→ Risk of occurrence of secondary deformations in the earth foundation at seismic impacts on the structures (the greater the elastic module of the foundation and lower level of the underwater, the lesser the deformations would be).

→ Retaining ability of the earth foundation against migration of radionuclides (the lower the filtration coefficient and greater sorption capacity of the soil, the larger its retaining ability).

3.4.3.3 ENDOGENOUS (SEISMIC TECTONIC) GEOLOGICAL PROCESSES

The Kozloduy Nuclear Power Plant is situated in calm tectonic area of the earth crust – in the Moesian platform. In the 30 km zone of the nuclear power plant no active faults have been proven. In relation to the seismic and tectonic conditions the project sites have the same parameters as the sites of the existing energy units.

In case of realisation of the investment intention no noticeable modification of the endogenous parameters of the geological environment is expected. The selection of the site is subject of a linked project, which is implemented parallel to this Environmental Impact Assessment and the assessment will be made pursuant to Article 25, item 1 of the Rules to ensure safety of the nuclear power plants (2004). In the course of building, the impact is connected with the removal of the soil stratum and other exogenous parameters of the geological environment.

The influence of the endogenous processes on the safe and long-term functioning of the New Nuclear Unit, which can be source of harmful consequences for the environment, will be taken into account in more detail in the Report on the Environmental Impact assessment, in the section on the analysis of the seismic hazard. There is no doubt that the design solution will be continuation of the principles of the existing sites of the nuclear power plant and will continue to develop them in a modern way. In the framework of the linked procedures the three-dimensional solution of the new building will be developed with view to the existing buildings and the general final image of the energy object. The building structures will respond to the technological tasks and, according to the requirements, will withstand external seismic impacts, continuing the principles of design and building of the existing sites of the Kozloduy Nuclear Power Plant.

The studies of the Geophysical Institute at the Bulgarian Academy of Sciences related to seismic safety of the site of the Kozloduy Nuclear Power Plant, adopted by missions of IAEA in 1992 reached the conclusion that once per 100 years a design-based earthquake can be expected with acceleration 0.1 g, and the maximum estimated at 0.2 g – one per 10,000 years. The studies contain summary of the data for the engineering geological conditions at the site, the physical and synthetic accelerograms, which are necessary for the solution of the problem of the soil – structure interaction.

The recent studies of the National Institute of Geophysics, Geodesy and Geography of the Bulgarian Academy of Sciences (successor of the Geophysical Institute of the BAS), carried out in connection with the new seismic regionalisation of the territory of Bulgaria, categorically supported the principal conclusion for maximum acceleration of the design-based earthquake, obtained as a result of specialised studies for seismic safety of the Kozloduy Nuclear Power Plant in the 90's of the last century.

FIGURE 3.4-13: NORMATIVE MAP OF THE SEISMIC RISK FOR A PERIOD OF REPEATABILITY OF 95 YEARS

According to a Draft of National annexes to the European standards for design and implementation of building works (Eurocodes), it is expected that the new maps of seismic regionalisation will become obligatory for design work from January 2014. It is seen at the map of the distribution of the maximum expected acceleration for a period of 95 years (Seismic regionalisation of the Republic of Bulgaria, harmonised with the requirements of Eurocode 8[65]), that the site of the Kozloduy Nuclear Power Plant is in an area of acceleration values less than 0.09 g for a period of 95 years (100 years-5%) – **Figure 3.4-13**. This fact confirms the main conclusion of the specialised studies on the seismic safety of the Kozloduy Nuclear Power Plant for maximum acceleration value 0.1 g of the design-based earthquake (for a period of 100 years)

The picture of the three-dimensional distribution of earthquakes with magnitude above 4.0 in the regional area of the Kozloduy Nuclear Power Plant, used for assessment of the seismic hazard in the new seismic regionalisation (in force since 2012) is presented on **Figure 3.4-14**. In the compiled catalogue for assessment of the power of earthquakes, magnitude along surface waves Ms has been used. In order to reach homogenisation of the catalogue, the magnitude evaluations, provided by various sources have been compared and adjusted. The catalogue has been checked for duplication of events. The aftershock events have been identified and removed by applying the magnitude-dependent space and time window of the Balkan region. The final catalogue contains more than 3300 independent events with M>4.0. The three-dimensional epicentres distribution of these earthquakes in the selected three-dimensional window is presented on **Figure 3.4-14**.

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[65] http://www.mrrb.government.bg/?controller=articles&id=492

An aseismic area is clearly outlined on the figure; the site of the nuclear power plant is located on its central part. In this way the results obtained from the study of the seismic hazard in the new seismic regionalisation can be viewed as yet one more confirmation of the conclusion already made, that from a seismologic point of view the local 30 km and sub-regional 50 km area around the site of the Kozloduy Nuclear Power Plant pertain to the calmest areas of the central Balkans territory.

At the same time Bulgaria as a whole, no doubt, should be considered among the risk earthquake zones on the earth. In previous centuries Bulgaria has been subjected to very powerful earthquake impacts. In historical aspect it is worth noting the earthquakes in 1818 (VIII-IX MSK) and 1858 (with magnitude around M=6.5 and IX degree MSK), which occurred near the City of Sofia. The 1858 event caused serious destructions in Sofia and led to the emergence of thermal springs in the western part of the city. At the beginning of the XX century, from 1901 to 1928, 6 very powerful earthquakes shook the territory of Bulgaria. These were some of the most significant earthquakes, which happened in Europe in the XX century.

The analysis of the picture of seismicity on the territory of the neighbouring countries, presented on **Figure 3.4-14**, show that they have significant influence on the assessment of the seismic hazard on the territory of Bulgaria. Quite strong is the seismic influence of the inter-focus earthquakes in the area of Vrancea, Romania. In most part the earthquakes in the central Balkans are shallow-focus to a depth of 60 km, which enhances the impact quite much, but only near the epicentre. However, some of the earthquakes, which occurred in the boundaries of the Balkan Peninsula have focus at a depth of 100-200 km (the so-called inter-focus earthquakes) and are typical for the region of Vrancea (Romania). Powerful earthquakes from such foci have unfavourable consequences at great distances, as is the example with the impact on Bulgaria caused by the earthquake in Vrancea in 1977. The analysis made on the basis of the Romanian data, received at the Ministry of Environment and Forests from the Republic of Romania in implementation of this contract for environmental impact assessment, allow to conclude that the catalogue data, provided additionally, would not change the existing assessment of the seismic hazard, concerning the influence of the most-notable seismic influence, exerted by the seismic zone of Vrancea on the site of the Kozloduy Nuclear Power Plant.

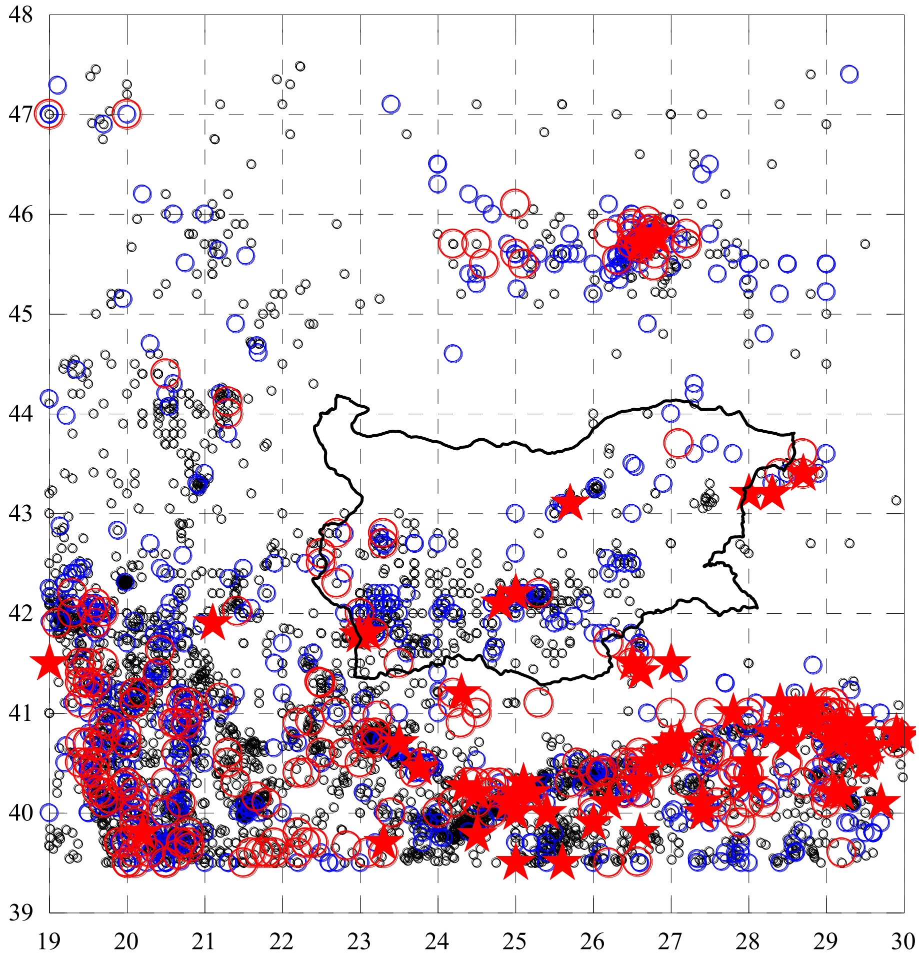

FIGURE 3.4-14: MAP OF THE SEISMICITY IN THE SELECTED THREE-DIMENSIONAL WINDOW (M>4.0) AT THE NEW SEISMIC REGIONALISATION OF THE REPUBLIC OF BULGARIA

In order to study in greater detail the weak seismicity in the sub-region around the nuclear power plant, on the recommendation of IAEA, a local seismological network was designed and built around the site of the Kozloduy Nuclear Power Plant. The local seismological network was situated in the sub-regional 50 km area around the site of the nuclear power plant. The purpose of the local seismological network is monitoring the weak seismicity and precise definition of the main dynamic and kinematic parameters of the seismic events, occurring in the sub-region of the Kozloduy Nuclear Power Plant. The observations made during the years after the installation and commissioning of the highly sensitive local seismic network in 1997 showed that not a single seismic event of the lowest possible magnitude has been registered in the local 30 km zone. It becomes clear from the series of reports of the Geophysical Institute of the Bulgarian Academy of Sciences (now National Institute of Geophysics, Geodesy and Geography of the Bulgarian Academy of Sciences) that upon about fifteen years of operation and subsequent modernisation, the Kozloduy local seismological network fulfills its principle purpose – together with the posts of the National Operational Seismological Information System – to ensure reliable registration and localisation of the weak seismicity on local and sub-regional level. The registered seismicity in the period 1997 – 2012 and the studies carried out do not contradict the existing seismicity assessment in the sub-regional 30 and 50 km zones around the Kozloduy Nuclear Power Plant. During the said period there is no evidence of seismicity in the 30 km zone. The study of the three-dimensional variations of the density function in the regional 1.5° area confirms that the 30 km zone around the Kozloduy Nuclear Power Plant is part of the seismically calmest part of the territory of Bulgaria. The picture of the epicentre distribution of the earthquakes around the local seismological network for the last accounted year (up to the month of July 2012) illustrates the extremely **calm** regime of the region in the part nearer to the nuclear power plant – **Figure 3.4-15**.

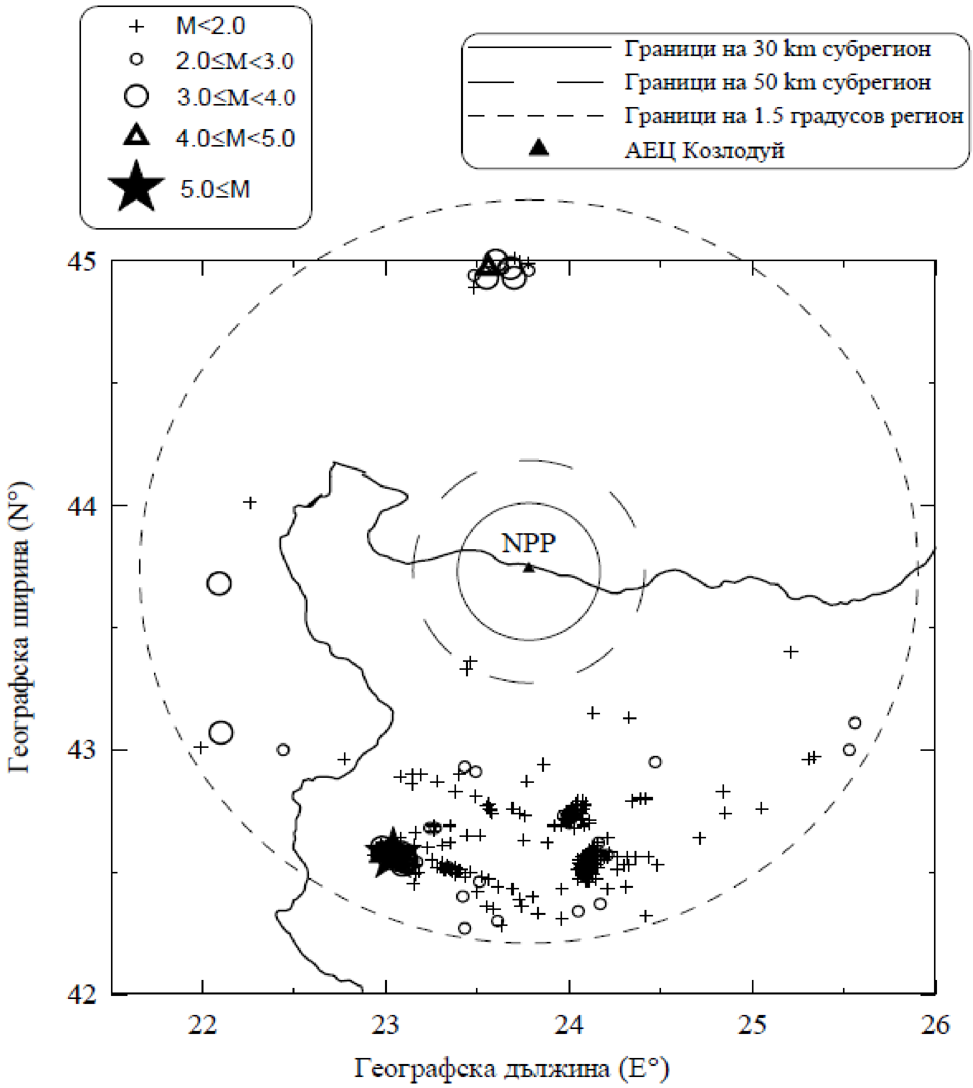

FIGURE 3.4-15: SEISMICITY IN THE 1.5° REGION AROUND THE KOZLODUY NUCLEAR POWER PLANT (ALL EVENTS LOCALISED IN THE PERIOD 01.07.2011 – 30.06.2012)

The extremely low level of the registered seismicity in the 50 km area around the Kozloduy Nuclear Power Plant during the period of operation of the Local Seismological Network (15 years) and the lack of events in the 30 km zone does not allow categorical conclusion concerning the characteristics of the seismic regime and correction of the assessment for the maximum possible magnitudes, based on seismological data. According to the recommendations of IAEA (eg. IAEA, Safety Guide No 50-SG-S1, 1991), this type of assessments necessitate longer period of monitoring, which considerably exceeds the 15 years of operation of the Kozloduy Local Seismological Network.

In order to study the behaviour of the structures and the systems in the energy units during earthquake Risk Engineering made detailed analyses in connection with TOB and VAB. They are presented in the Report "*Assessment of the reaction of the capacity of building constructions of blocks 5 and 6 of the Kozloduy Nuclear Power Plant and determination probabilistic characteristics of the fragility of the elements for the purposes of VAB level 1, taking account of the seismic initiators*" and have been discussed in the Environmental Impact Assessment of blocks 5 and 6 in 1994. Assessment has been made of the reaction of the building constructions, determined as probabilistic characteristics of the fragility of elements, a probabilistic analysis has been made for failure of critical elements of the constructions in the event of earthquake and the behaviour of the energy units in the event of earthquake has been modelled according to the method "tree of events".

In order to prevent damage to the active zone or in order to reduce the consequences of an eventual damage, the protection functions, which need to be implemented in case of emergence of various initial events, have been defined. During the building of the "tree of failures" conservative assumptions have been made and no operators' actions in case of earthquake and the so-called passive failures of the equipment – as a result of the destruction of the building construction, have been included. This has been done with grouping the elements according to the design criteria, seismic qualification method and the reaction characteristics.

The summarised evaluation of the strains and displacements of the construction of the reactor section of unit 5 during an earthquake indicated good behaviour of the unit and reliability of the construction at maximum estimation of seismic impact.

The study in the project "Benchmark study for the seismic analysis and testing of WWER-Type NPP", in which surveying has been made of the building constructions and equipment under seismic impact, initiated by the explosions at a distance of about 2 km southwest of the site of Electric generation – 2 is of extreme importance. The dynamic characteristics of the shell and the equipment of the reactor section and the turbine island of unit 5, the accelerations and the amplitude-frequency characteristic of the different types of equipment – for instance the Main Circulation Pumps etc. have been determined. Proposals have been made for technical solutions.

Units 5 and 5 of the Kozloduy Nuclear Power Plant have been equipped with devices for industrial seismic protection, which automatically switches off the reactors in case of earthquakes with accelerations higher than the prescribed (0.05g). Since 1993 a system of accelerographs for seismic control of equipment and construction has been put into operation. It switches on accelerographs of the type ETNA (6 devices) and SSA-2 (4 devices) located on the empty fields and at various elevations on units 3 and 5. The system ensures seismic control of the equipment and constructions, registration and archiving of data. The scheme of disposition of the accelerographs has been approved by IAEA. There are time-tables elaborated for monthly, half-yearly and yearly check-ups. Each activity is implemented on the basis of written procedures and in accordance with the quality assurance system. Each check-up is documented by an Act. The activities are carried out by qualified staff. The acts are archived in the file of each device.

Geodesic measurements of constructions and equipment are being carried out at the Kozloduy Nuclear Power Plant according to an approved time schedule. The territory of the company is subject to cadastre servicing. The management of the resource includes passport-description, status control and development of the engineering building facilities through specialised monitoring and measurements, programs for complex and 72-hour tests of newly built facilities and equipment, testing after repair works and reconstruction, development and/or ensuring measures of corrections to the facilities, control of the changes. According to the program for modernisation of units 5 and 6 and the Investment program, seismic qualification of all control signal valves was made by SSEL.