UNIVERSITY OF PETROȘANI
Faculty of Mining

UNIVERSITATEA DIN PETROȘANI 1948

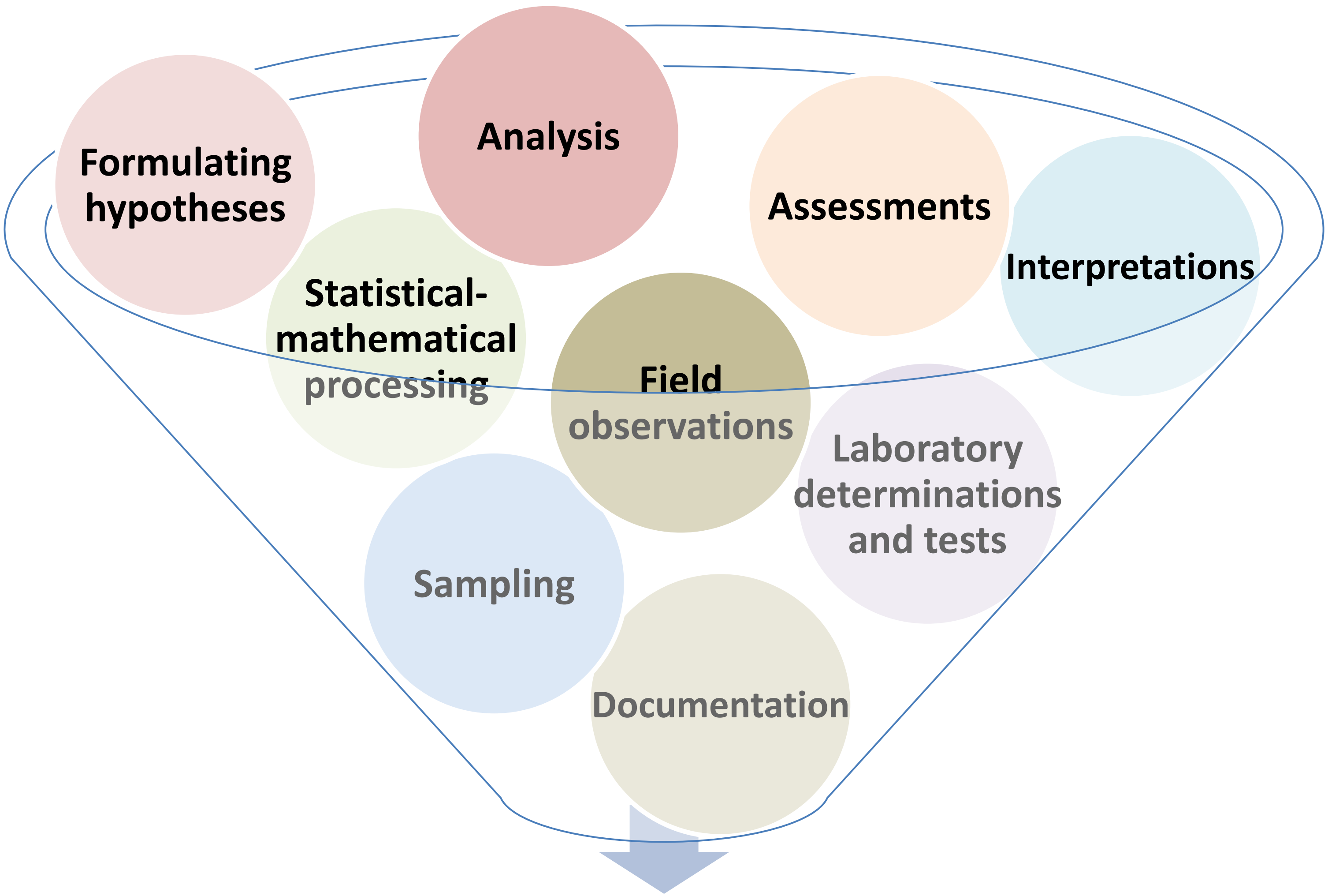
International Conference on RAFF & SUMAD projects' achievements

GEOTECHNICAL RISKS ASSOCIATED WITH THE FLOODING OF FORMER LIGNITE OPEN PITS FROM OLTENIA MINING REGION

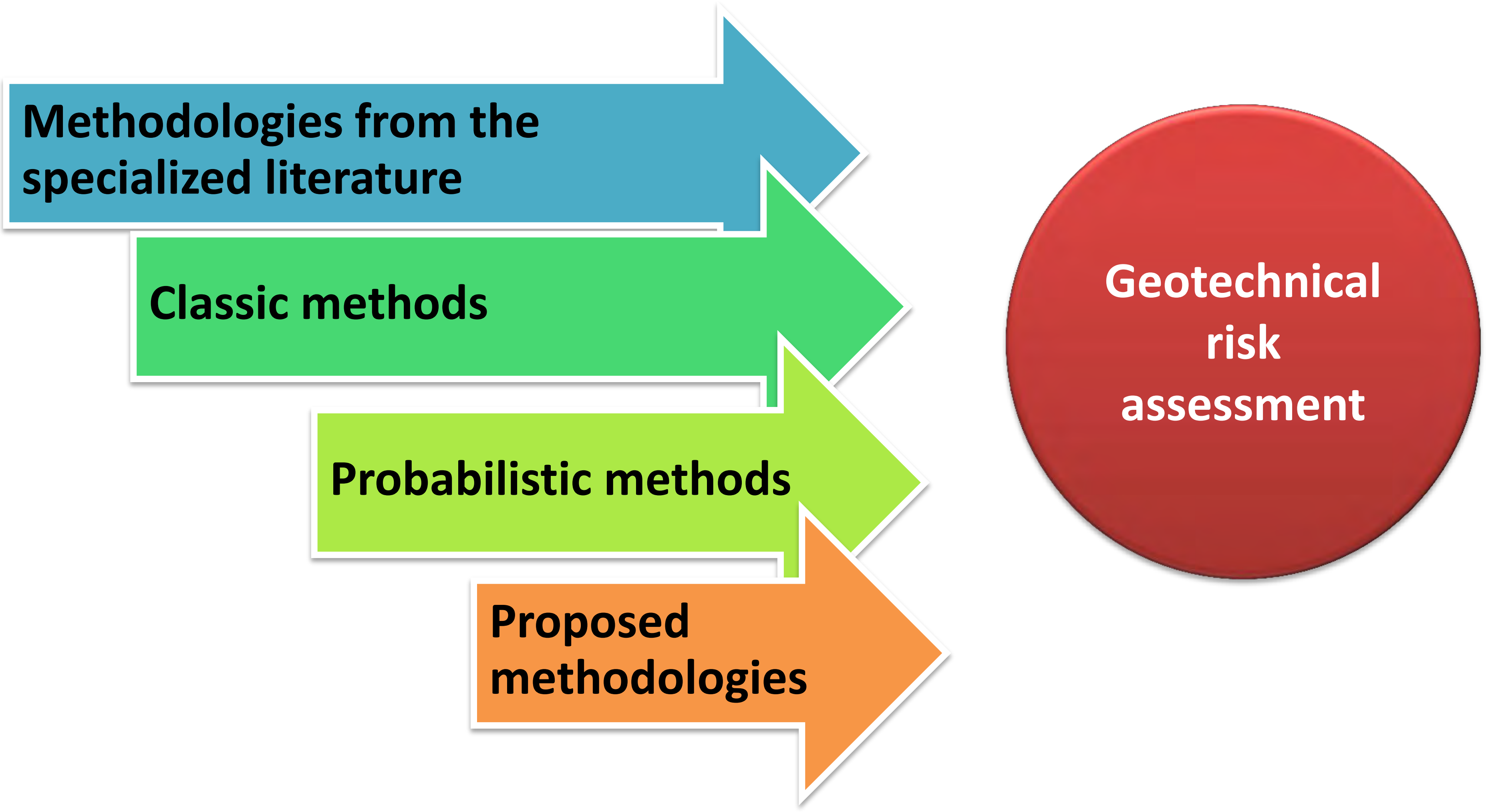
Authors:
Assist. Dr. Eng. APOSTU Izabela – Maria
Prof. Dr. Eng. LAZAR Maria
Lect. Dr. Eng. FAUR Florin

- Wroclaw, Poland, 2022-

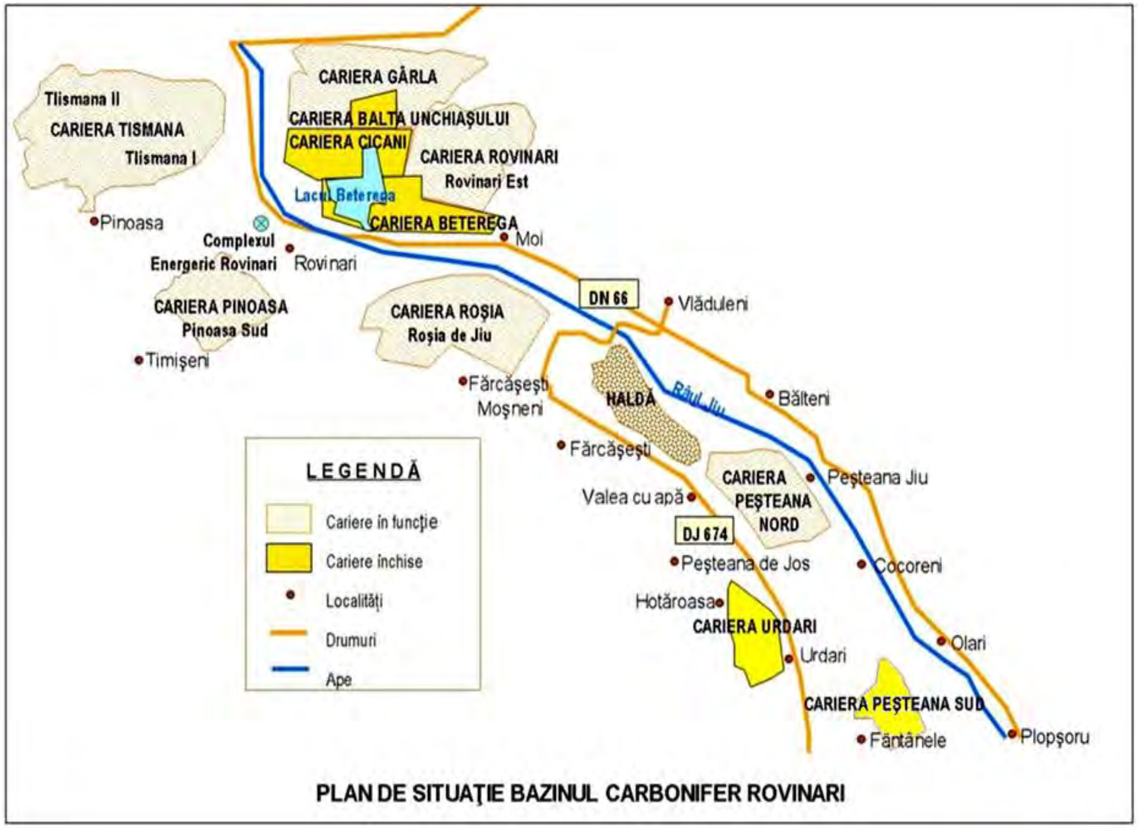
THE PURPOSE AND THE OBJECTIVE OF THE STUDY

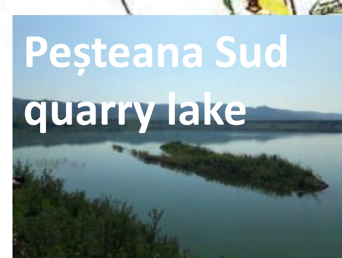


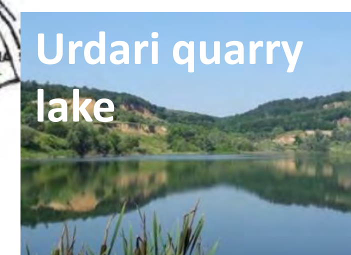
GEOTECHNICAL RISK ASSESSMENT


Methodologies from the specialized literature
Classic methods
Probabilistic methods
Proposed methodologies
Geotechnical risk assessment

DESCRIPTION OF THE OLTENIA COAL BASIN
DESCRIPTION OF THE ROVINARI MINING BASIN







1st step

EVALUATION OF THE OPPORTUNITY OF FLOODING OF FORMER QUARRIES. CASE STUDY: ROVINARI MINING BASIN

EVALUATION OF THE FLOODING OPPORTUNITY

EVALUATION CRITERIA:

C1. Geomorphology and orography of the area;

C2. Configuration of the remaining gap;

C3. Necessity to restore the aquifer resources;

C4. Necessity of appearance of a water mirror in the area;

C5. The hydrology and hydrogeology of the region;

C6. Stability conditions of the final slopes of the remaining gap;

C7. Accessibility and distance to the areas of interest;

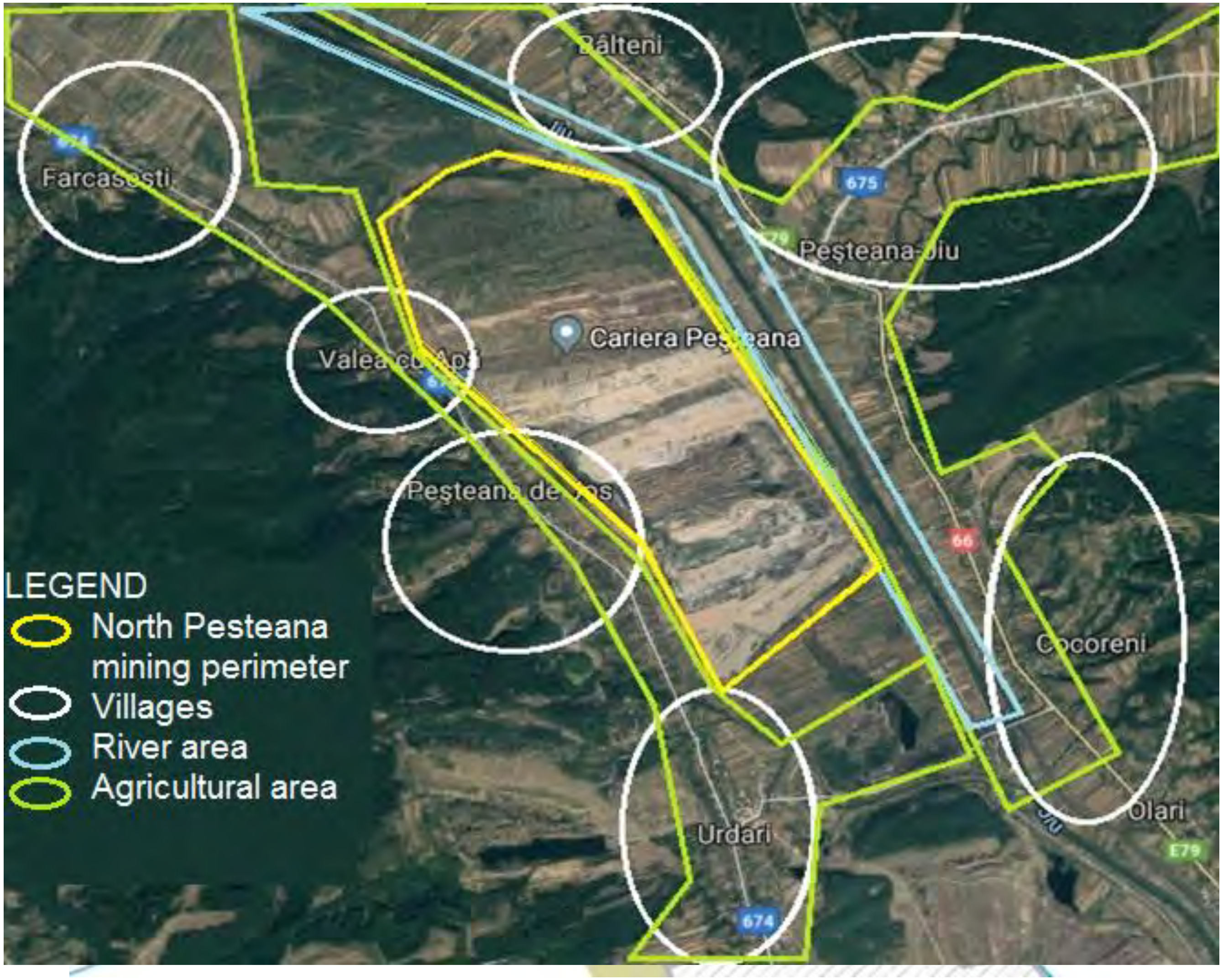
C8. Investments for the recovery and rehabilitation of the remaining gap;

C9. Population requirements.

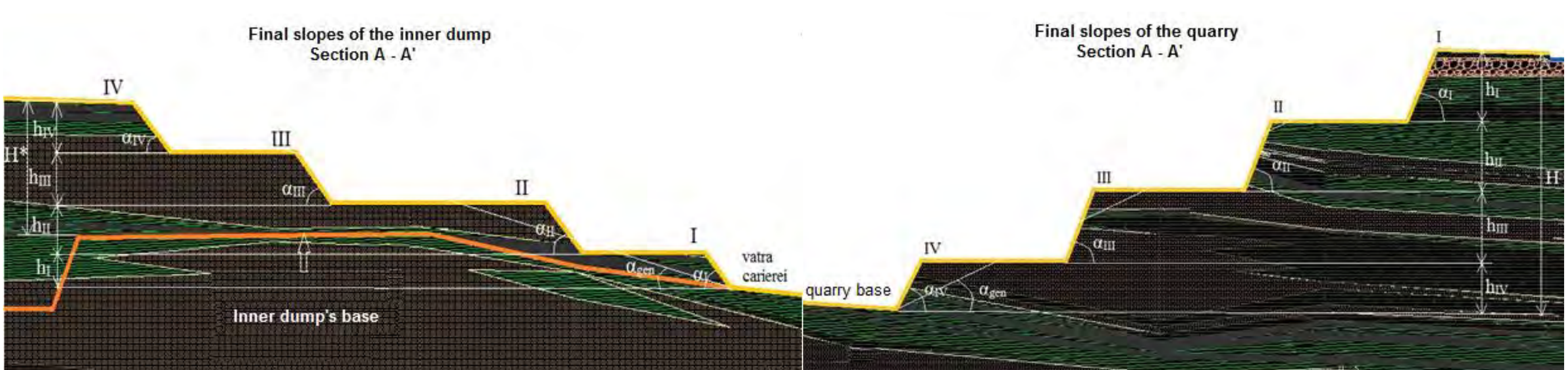
2nd step

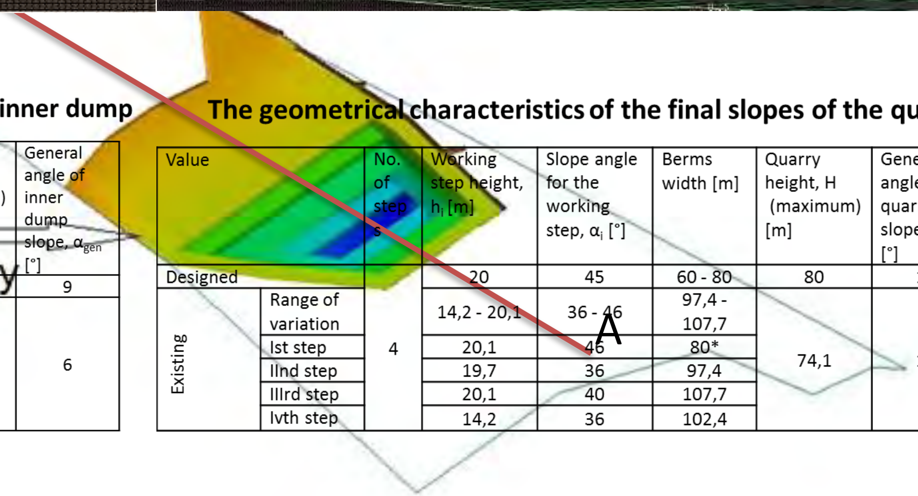
RESEARCHES, STUDIES AND PRELIMINARY ANALYSIS NECESSARY TO EVALUATE GEOTECHNICAL RISKS. CASE STUDY: THE REMAINING GAP OF THE NORTH PESTEANA QUARRY

DESCRIPTION OF THE REMAINING GAP OF NORTH PESTEANA QUARRY



FINAL CONFIGURATION OF THE REMAINING GAP





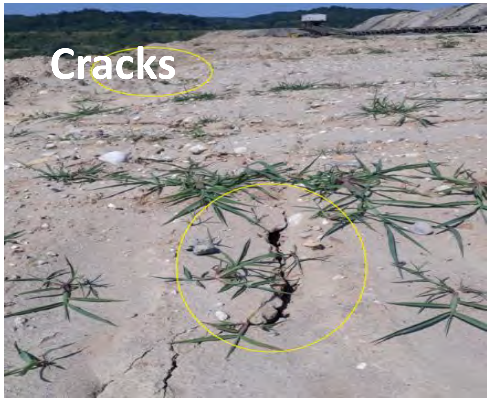
The geometrical characteristics of the final slopes of the inner dump

Value		No. of steps	Dumping step height, h_i [m]	Slope angle for the dumping step, α_i [°]	Berms width [m]	Dump height, H (maximum) [m]	General angle of inner dump slope, α_{gen} [°]
Designed		4	10 - 15	18 - 27	> 100	105	9
Existing	Range of variation		10,2 - 15,1	25 - 27	> 100	39,5*	6
	Ist step		10,2*/10,5	25*/26	100,4		
	IInd step		15,1	26	174,6		
	IIIrd step		14,8	27	102,5		
	Ivth step		14,9	26	181**		

The geometrical characteristics of the final slopes of the quarry

Value		No. of steps	Working step height, h_i [m]	Slope angle for the working step, α_i [°]	Berms width [m]	Quarry height, H (maximum) [m]	General angle of quarry slope, α_{gen} [°]
Designed			20	45	60 - 80	80	14
Existing	Range of variation	4	14,2 - 20,1	36 - 46	97,4 - 107,7	74,1	10
	Ist step		20,1	46	80*		
	IInd step		19,7	36	97,4		
	IIIrd step		20,1	40	107,7		
	Ivth step		14,2	36	102,4		

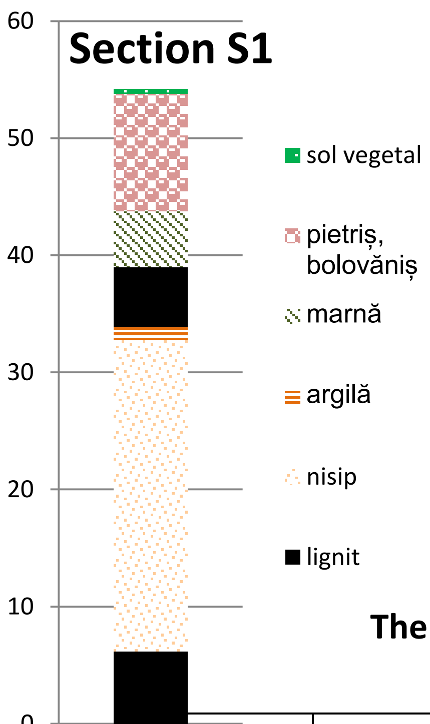
FIELD RESEARCH AND OBSERVATIONS

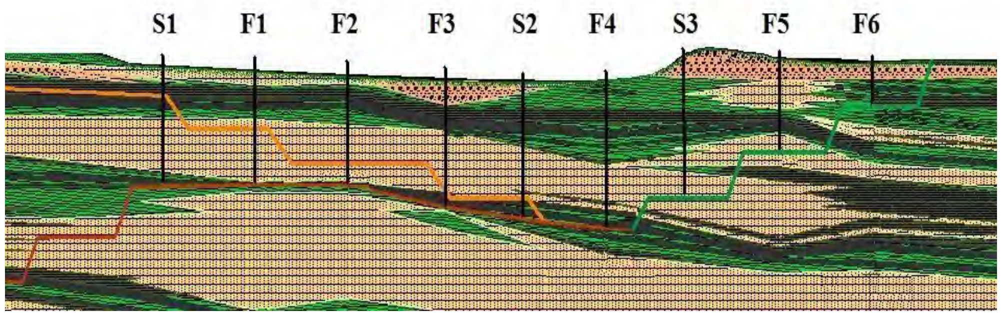


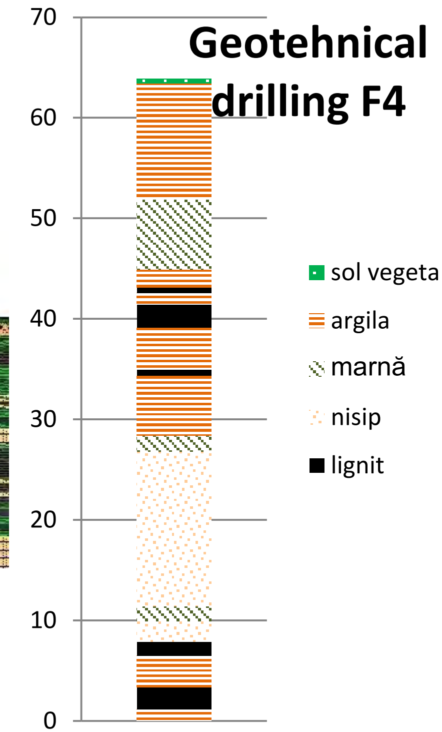
HYDROLOGICAL AND HYDROGEOLOGICAL CHARACTERISTICS

Location of the aquifer horizon	Description	Debit (m^3/zi)	Filtration coefficient (m/zi)
Base of Ivth layer	- insufficient researched horizon; - horizon composed of fine-medium or coarse sands with general extension and very large thicknesses, over 70 m; - horizon fed by precipitation and shallow water in the outcrop areas; - the artesian aquifer horizon had the initial piezometric level between 144.77 - 151.2 m; - the initial piezometric pressures was between 72.7 - 147.2 mCA; - the current piezometric level is lowered by approx. 50 m, the current quotas being between 90.42 - 105.5 m; - the large infiltration surface and the permanent character of the power sources contribute to the accumulation of huge reserves of groundwater under pressure;	3,.1 – 179.7	0.25 – 7.3
Range of layers IV - V	- horizon stucked in sands with reduced thicknesses in the western and northern part of the perimeter with 0.2 - 4.5 m, which grow to the south up to 10-20 m; - sands with a coarser grain size, fine and medium fine sands; - the initial hydrostatic level between the elevations 144.71 - 160.91 m;	3.13 – 84.1	0.25 – 7
Range of layers V - VI	- horizon stucked in sands with thicknesses up to 10-20 m, with rare thickening up to 34 m; - the initial piezometric level (ascensional or slightly artesian) was located between the 139.45 - 144.86 m; - the hydrostatic pressure considered at the roof of the Vth layer varies between 33.91 - 90.15 mCA, increasing from N to S;	4.5 – 102.2	0.45 – 6.52
Range of layers VII - VIII	- horizon with reduced development; - horizon stucked in sands with irregular development, comprising 1 - 3 lenses with a thickness between 0.5 - 20 m; - the horizon consists of fine and very fine sands, less medium or even coarse sands, with frequent lateral crossings to clay sands and clays; - the initial hydrostatic level (ascensional) was located between the dimensions of 136.55 - 138.55 m; - the initial hydrostatic pressures measured at the level of the roof of the coal layer VII had values between 38 - 48 mCA;	8.94 – 28.6	0.62 – 1.71
Range of layers VIII - X	- partially eroded horizon; - the initial (upward) hydrostatic level between 131.13 - 141.05 m; - the direct sources of water (groundwater, surface and precipitation) and indirect (exchange of water with the other horizons) causes a high degree of flooding of the deposit;	-*	-*
The roof of the Xth layer	- the horizons have an extremely restricted spread, being eroded for the most part; - the sands in which these horizons are bordered have a discontinuous development, in the form of lenses with thicknesses of 1 - 6.5 m, with rare thicknesses up to 10 m;	-*	0.1 – 4.8
Phreatic layer	- partially feeds some lower pressure aquifers; - the hydrostatic level of the groundwater aquifer layers is located between the levels 142.04 - 134.8 m; - the hydrostatic level quotas shows a decreasing tendency from N to S;	10.7 - 309	3.8 - 43

THE PERCENTUAL PARTICIPATION OF THE ROCKS IN THE INNER DUMP DEPENDING OF THEIR NATURE







The cumulative thickness and the participation percentage of the rocks in the dump depending to their nature

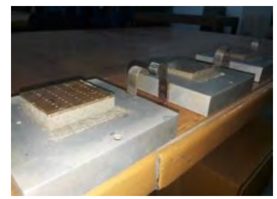
Geotehnical drilling/Section	Drilling depth [m]	Cumulative thickness (excluding lignite) [m]	Gravel, boulders		Sand		Clay		Marl		Vegetal soil	
			[m]	[%]	[m]	[%]	[m]	[%]	[m]	[%]	[m]	[%]
S1	50.88	44.608	0	0	25.82	57.88	11.496	25.77	6.6	14.80	0.692	1.55
F1	49.32	44.292	0	0	32.324	72.98	7.248	16.36	4.32	9.75	0.4	0.90
F2	46.24	42.452	0	0	26.46	62.33	11.028	25.98	4.564	10.75	0.4	0.94
F3	54.2	42.888	10.012	23.34	26.572	61.96	1.14	2.66	4.764	11.11	0.4	0.93
S2	58	48.280	4.4	9.11	22.968	47.57	14.46	29.95	6.052	12.54	0.4	0.83
F4	63.96	56.936	0	0	17.488	30.72	29.028	50.98	10.02	17.60	0.4	0.70
S3	60.28	56.976	9.684	17.00	16.824	29.53	24.152	42.39	5.748	10.09	0.568	1.00
F5	39.76	37.424	8.44	22.55	19.332	51.66	6.216	16.61	2.836	7.58	0.6	1.60
F6	19.48	18.100	5.948	32.86	-	0	6.392	35.31	4.96	27.40	0.8	4.42
Total	442.120	391.956	38.484	9.82	187.788	47.91	111.160	28.36	49.864	12.72	4.660	1.19

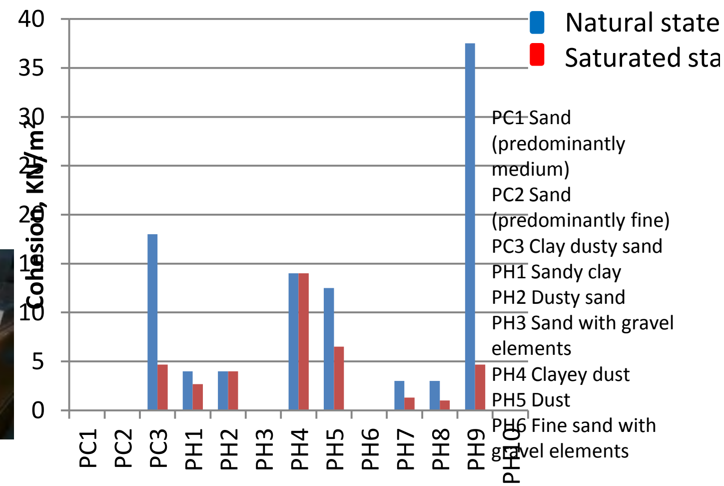
GEOTECHNICAL CHARACTERISTICS OF THE ROCKS





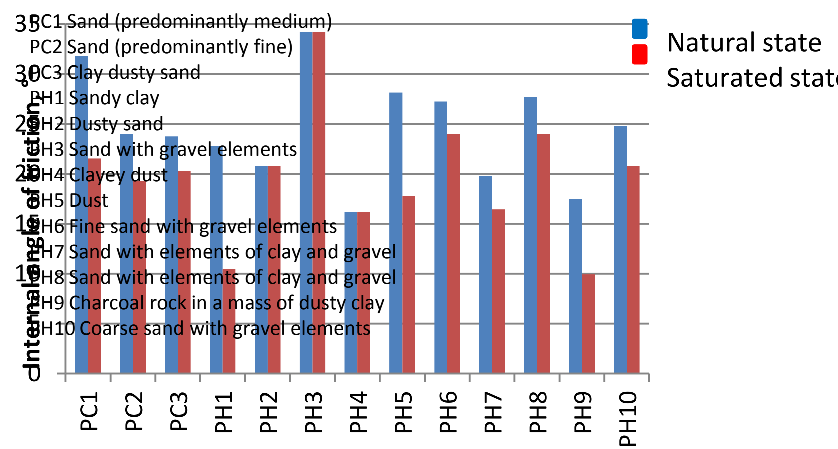




The values of the geotechnical characteristics of the rocks in natural and saturated state

Samp. no.	Nature of the rocks	Numidity, w [%]		Volumetric weight, γ_a [kN/m³]		Cohesion, c [kN/m²]		Internal friction angle, φ [°]	
		w_{nat}	w_{sat}	w_{nat}	w_{sat}	w_{nat}	w_{sat}	w_{nat}	w_{sat}
PC1	Sand (predominantly medium)	7,49	28,98	16,10	19,32	0	0	31,78	21,55
PC2	Sand (predominantly fine)	3,65	28,12	15,72	19,43	0	0	24	19,29
PC3	Clay dusty sand	23,53	24,08	19,70	19,79	18	4,67	23,75	20,3
PH1	Sandy clay	21,68	23,78	19,52	19,86	4	2,67	22,78	10,48
PH2	Dusty sand	23,27	23,88	20,56	20,36	4	4	20,81	20,81
PH3	Sand with gravel elements	22,87	23,41	20,69	20,41	0	0	34,22	34,22
PH4	Clayey dust	22,47	22,44	20,21	20,20	14	14	16,17	16,17
PH5	Dust	20,58	28,65	17,77	18,96	12,5	6,5	28,15	17,74
PH6	Fine sand with gravel elements	5,65	27,69	15,99	19,33	0	0	27,25	24
PH7	Sand with elements of clay and gravel	15,19	27,48	17,59	19,47	3	1,3	19,8	16,43
PH8	Sand with elements of clay and gravel	18,59	24,5	18,82	19,76	3	1	27,7	23,99
PH9	Charcoal rock in a mass of dusty clay	27,97	34,17	17,40	18,24	37,5	4,67	17,48	9,93
PH10	Coarse sand with gravel elements	7,24	21,11	17,71	20,00	0	0	24,8	20,81



STATISTICAL-MATHEMATICAL PROCESSING

The average values of the geotechnical characteristics of the in-situ rocks

Nature of the rocks	Volumetric weight ɣa [kN/m^3]	Cohesion c[kN/m^2]	Internal friction angle φ [°]
marly rocks: marl, clayey marl, sandy marl	19.12	42.92	19.83
clayey - dusty rocks: clay, greasy clay, dusty clay, brownish clay, dust, clayey dust, sandy clayey dust, soft plastic to consistent, with high to medium compressibility, high to very high plasticity, moist to saturated	19.64	41.07	19.43
sandy rocks: fine sand, clayey sand, dusty sand, soft plastic to consistent, with high to medium compressibility, medium plasticity (sandy clay), moist to saturated, sometimes dry	19.44	7.58	27.66
boulder, gravel, wet to very wet	21.41	0	35
lignite, wet to very wet	12.33	213.05	35.44
vegetal soil	14.7	24	20

The values of the geotechnical characteristics of the waste rocks and of the mixture of rocks

Nature of the rocks	Percentage participation [%]	Volumetric weight ɣa [kN/m^3]	Cohesion c[kN/m^2]	Internal friction angle φ [°]
Marly	12.72	18.3	36.4	17.75
Clayey	28.36	18.05	24.48	18.60
Sandy	47.91	17.11	3.33	25.79
Boulder, gravel	9.82	20.86	0	34
Vegetal soil	1.12	14.7	24	20
Mixture of rocks	**100**	**17.87**	**13.45**	**23.75**

STABILITY ANALYSIS OF THE FINAL SLOPES

Sets of values subject to stability analysis

Hypotheses	Mixture of waste rocks	In-situ rocks
I (unfavorable)	Average values-σ (γ_a=16.33 kN/m^3; c=8.93 kN/m^2; φ=19.41°)	Average values (Sand γ_a=19.44 kN/m^3; c=7.58 kN/m^2; φ=27.66° Clay γ_a=19.64 kN/m^3; c=41.06 kN/m^2; φ=19.43° Marl γ_a=19.12 kN/m^3; c=42.92 kN/m^2; φ=19.83° Vegetal soil γ_a=14.7 kN/m^3; c=24 kN/m^2; φ=20° Lignite γ_a=12.33 kN/m^3; c=213.05 kN/m^2; φ=35.44°)
II (favorable)	Average values (γ_a=17.87 kN/m^3; c=13.45 kN/m^2; φ=23.46°)	
III (most favorable)	Average values + σ (γ_a=19.40 kN/m^3; c=17.98 kN/m^2; φ=27.52°)	

I
Before
Drained rocks

II
During
Saturated rocks

III
After
Submerged slopes

Stability conditions for individual steps/system of steps

Fs = 1,25 ÷ 1,5 **Fs > 3**

COMPARISON OF SITUATIONS:
DRAINED ROCKS - SATURATED ROCKS - SUBMERGED SLOPES

The values of the stability coefficients for the final individual steps of the quarry

Step	Stability coefficient values *		
	Naturally drained rocks	Rocks saturated with the influence of water in pores	Submerged slopes
I	1.235	1.109	1.478
II	1.605	1.218	2.355
III	1.259	0.790	1.712
IV	1.660	0.972	2.362

** circular sliding surface;*

The values of the stability coefficients for the final individual steps of the dump

Step	Stability coefficient values *		
	for γ_a=17.87 kN/m^3; c=13.45 kN/m^2; φ=23.46°		
	Nat	Sat	Sub
I	1.771	1.588	2.720
II	1.538	1.199	2.009
III	1.792	1.250	2.164
IV	1.492	1.150	1.951

** circular sliding surface;; Nat - Naturally drained rocks; Sat - Rocks saturated with the influence of water in pores; Sub - Submerged slopes*

3rd step

GEOTECHNICAL RISKS ASSESSMENT. CASE STUDY: FLOODING OF THE REMAINING GAP OF NORTH PESTEANA QUARRY

GEOTECHNICAL RISK ASSESSMENT
CASE STUDY: FLOODING OF THE REMAINING GAP OF NORTH PESTEANA QUARRY

$$\mathbf{R = Pr \cdot V}$$

R – geotehnical risk;
V – vulnerability of the objectives in the area according to the technical state of the final slopes and of the inner dump;
Pr – probability of manifestation of geotechnical phenomena;

THE RISK OF SLIDING OF THE FINAL SLOPES

Classification of rock masses / deposits according to the nature of the objectives in the area and establishment of the vulnerability of the objectives (Lazăr et al., 2015)

Stability degree / - Nature of objectives in the area - The characteristics of the environment	1. Massive / rock deposits with significant volume and active displacement	2. Massive / rock deposits that can enter dangerous movements due to some factors	3. Massive / rock deposits with displacements that can be limited by arrangements or by exploitation technology	4. Stabilized massive / rock deposits, at which landslides are unlikely
1.-Housing and social constructions. - Forests, running and/or standing waters, high land	1.1.	1.2.	1.3.	1.4.
2.-Industrial constructions and installations, intensive communication routes, water courses. - Arable areas, wooded areas, watercourses, productive land	2.1.	2.2.	2.3.	2.4.
3. - Communication routes with restricted traffic or restricted movement of persons - Wooded pastures with varying degrees of consistency, restricted water resources, low value land	3.1.	3.2.	3.3.	3.4.
4. Non-built areas with sporadic access of people - Waste lands, unproductive, pastures with bushes	4.1.	4.2.	4.3.	4.4.

where: V = 1 – very low vulnerability; V = 2 – reduced vulnerability; V = 3 – medium vulnerability; V = 4 – high vulnerability; V = 5 – very high vulnerability

=> V = 3,5 (hazard groups 2.3 și 1.3, according to the nature of the objectives)

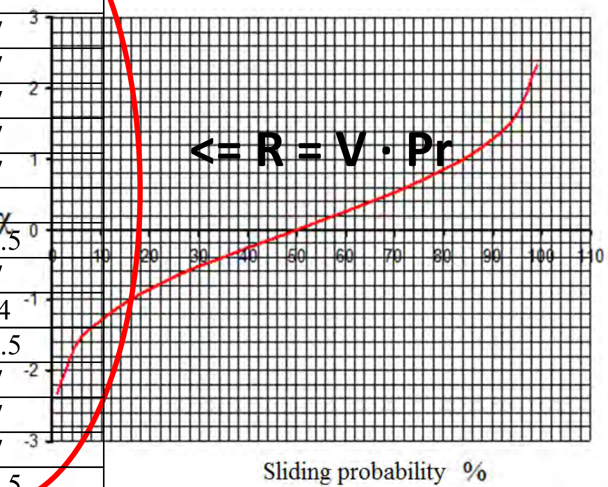
DETERMINING THE PROBABILITY OF SLIDING

Determining the risk of sliding the slopes

Step		Vulnerability	Probability Pr_{al} [%]	Probability Pr	Risk
Natural state					
Quarry	I	3,5	37	3	10.5
	II		24	2	7
	III		27	2	7
	IV		23	2	7
Dump	I		19	2	7
	II		20	2	7
	III		18	2	7
	IV		22	2	7
Saturated state					
Quarry	I	3,5	52	3	10.5
	II		31	2	7
	III		67	4	14
	IV		51	3	10.5
Dump	I		23	2	7
	II		33	2	7
	III		30	2	7
	IV		35	3	10.5

The values of the necessary elements to determine the sliding probability of the slopes

Step		LS_1	LS_2	LS_3	LS_4	LS_m	σ_{LS}	K_{LS}	χ	Pr_{al}, %
Natural state										
Quarry	I	-0.336	-0.124	0.528	0.582	0.163	0.432	2.657	-0.376	37
	II	-0.051	0.185	1.010	1.381	0.631	0.861	1.364	-0.733	24
	III	-0.162	-0.043	0.568	0.952	0.329	0.561	1.705	-0.586	27
	IV	0.126	0.168	1.151	1.612	0.764	0.896	1.303	-0.767	23
Dump	I	0.151	0.371	1.150	1.338	0.753	0.905	1.202	-0.832	19
	II	0.014	0.219	0.784	0.921	0.485	0.615	1.269	-0.788	20
	III	0.179	0.430	1.160	1.461	0.808	0.961	1.191	-0.840	18
	IV	-0.022	0.179	0.803	1.111	0.518	0.691	1.335	-0.749	22
Saturated state										
Quarry	I	-0.352	-0.142	0.154	0.242	-0.025	0.238	-9.709	0.103	52
	II	-0.268	-0.105	0.573	0.868	0.267	0.540	2.021	-0.495	31
	III	-0.537	-0.439	0.016	0.296	-0.166	0.377	-2.272	0.440	67
	IV	-0.457	-0.343	0.198	0.469	-0.033	0.383	-11.508	0.087	51
Dump	I	0.010	0.126	0.855	0.875	0.467	0.615	1.318	-0.759	23
	II	-0.241	-0.084	0.434	0.571	0.170	0.381	2.239	-0.447	33
	III	-0.221	-0.056	0.564	0.838	0.281	0.518	1.841	-0.543	30
	IV	-0.276	-0.129	0.427	0.705	0.182	0.439	2.417	-0.414	35



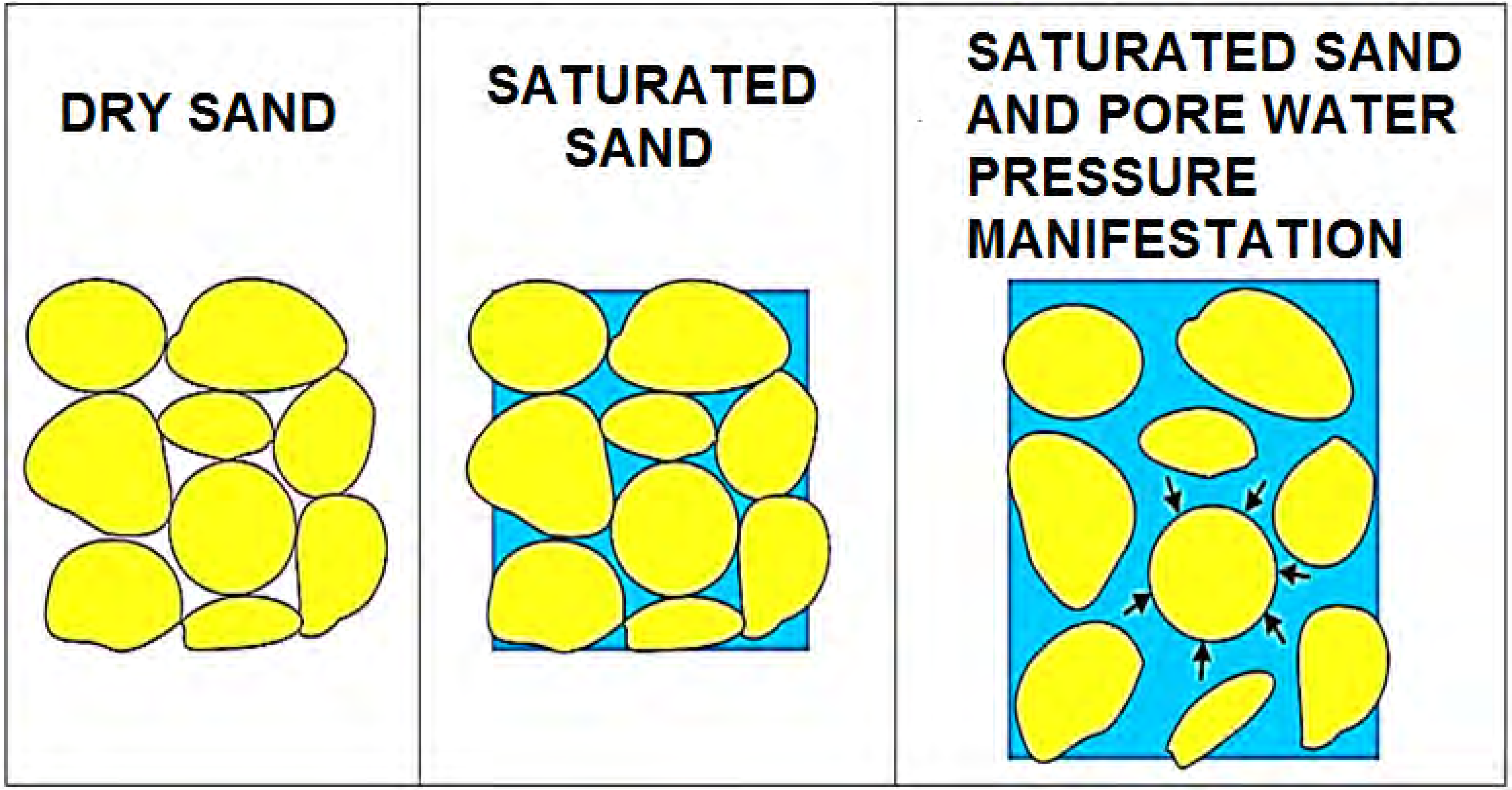
Graphical representation of the sliding probability according to the parameter χ

<= R = V · Pr

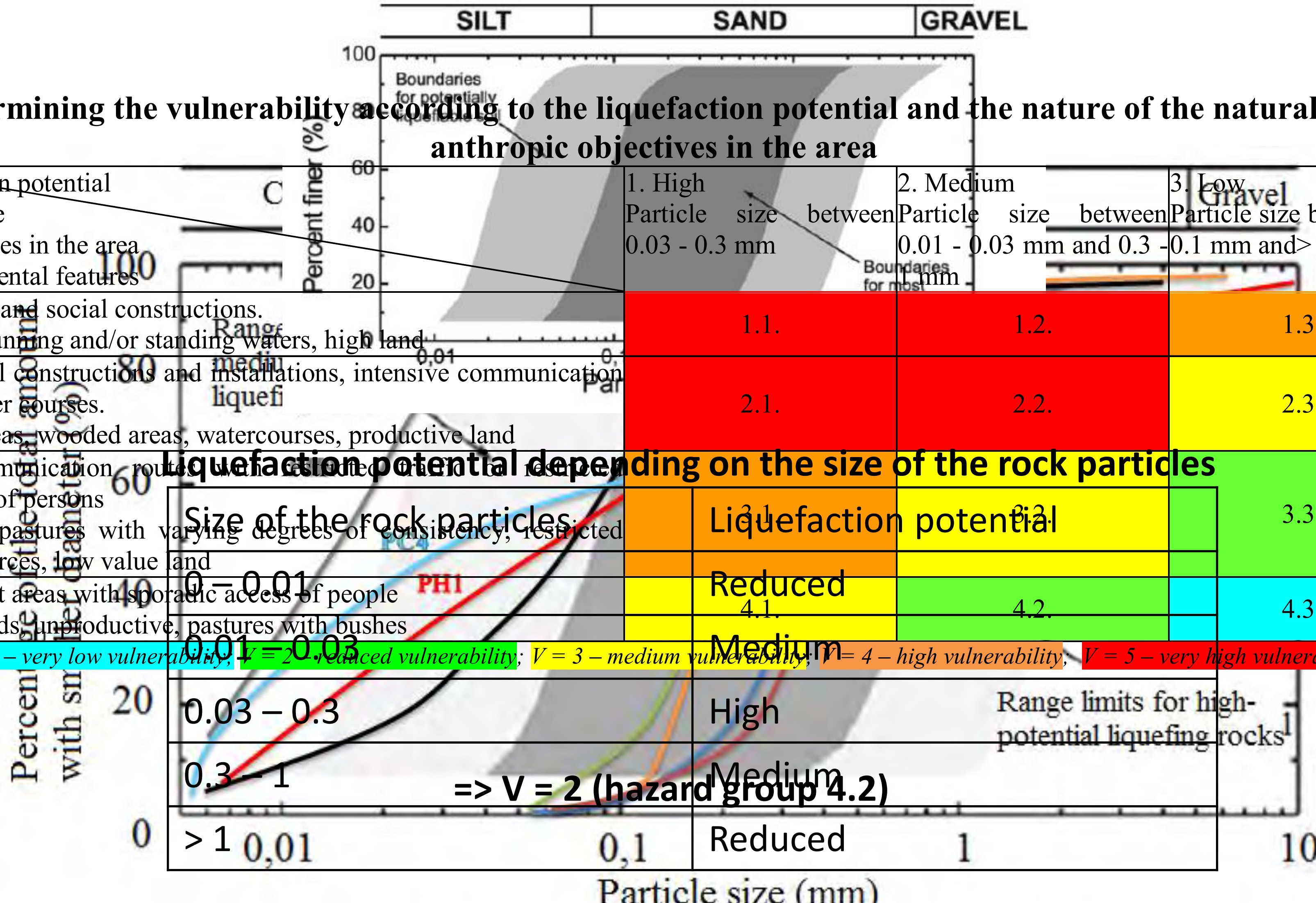
- For R = 1 → very low risk of sliding;
- For R = 2÷4 → low risk of sliding;
- For R = 5÷9 → medium risk of sliding;
- For R = 10÷15 → high risk of sliding;
- For R = 16÷24 → very high risk of sliding;
- For R = 25 → extremely high risk of sliding.

⇒ Pr = 2 ÷ … **and the humidity of the rocks)**

LIQUEFACTION RISK OF THE WASTE ROCKS



DETERMINATION OF VULNERABILITY



Determining the vulnerability according to the liquefaction potential and the nature of the natural and anthropic objectives in the area

Liquefaction potential - The nature the objectives in the area - Environmental features	1. High Particle size between 0.03 - 0.3 mm	2. Medium Particle size between 0.01 - 0.03 mm and 0.3 - 1 mm	3. Low Particle size between 0 - 0.1 mm and> 1 mm
1.-Housing and social constructions. - Forests, running and/or standing waters, high land	1.1.	1.2.	1.3.
2.-Industrial constructions and installations, intensive communication routes, water courses. - Arable areas, wooded areas, watercourses, productive land	2.1.	2.2.	2.3.
3. - Communication routes with restricted traffic or restricted movement of persons - Wooded pastures with varying degrees of consistency, restricted water resources, low value land	3.1.	3.2.	3.3.
4. Non-built areas with sporadic access of people - Waste lands, unproductive, pastures with bushes	4.1.	4.2.	4.3.

where: V = 1 – very low vulnerability; V = 2 – reduced vulnerability; V = 3 – medium vulnerability; V = 4 – high vulnerability; V = 5 – very high vulnerability

Liquefaction potential depending on the size of the rock particles

Size of the rock particles	Liquefaction potential
0 – 0.01	Reduced
0.01 – 0.03	Medium
0.03 – 0.3	High
0.3 – 1	Medium
> 1	Reduced

=> V = 2 (hazard group 4.2)

The granulometric distribution of sands prone to liquefaction (Marto et al., 2013)

DETERMINATION OF LIQUEFACTION PROBABILITY

Estimation of liquefaction probability

Description / Evaluation criteria	Very high probability of liquefaction	High probability of liquefaction	Medium probability of liquefaction	Low probability of liquefaction	Very low probability of liquefaction
	Almost sure the waste material will liquefy	It is very likely that the waste material will liquefy	Liquefaction or not of the waste material is equally probable	It is unlikely that the waste material will liquefy	Almost sure that the waste material will not liquefy
	$P_L > 0.85$	$0.65 < P_L \leq 0.85$	$0.35 < P_L \leq 0.65$	$0.15 < P_L \leq 0.35$	$P_L \leq 0.15$
	Pr=5	Pr=4	Pr=3	Pr=2	Pr=1
The predominant granulometric fraction	100% sand	50-100% sand + important dust fractions	50-100% dust + important sand fractions	50-100% clay	100% clay
The degree of nonuniformity The type of granulometric curve	very uniformly very steep slope	uniform steep slope	medium uniformity balanced slope	nonuniform smooth curve	very nonuniform very smooth curve
The degree of loosening	= 1,31 - 1,38 initial	= 1,16 - 1,31 < initial, > remanent	= 1,10 - 1,16 remanent	= 1,005 - 1,10 < remanent	= 1,005 non-loose
The degree of saturation	saturated		very moist	moist	dry
Roughness	reduced	medium			high
Rounding degree	rounded	subrounded - subangular			angular

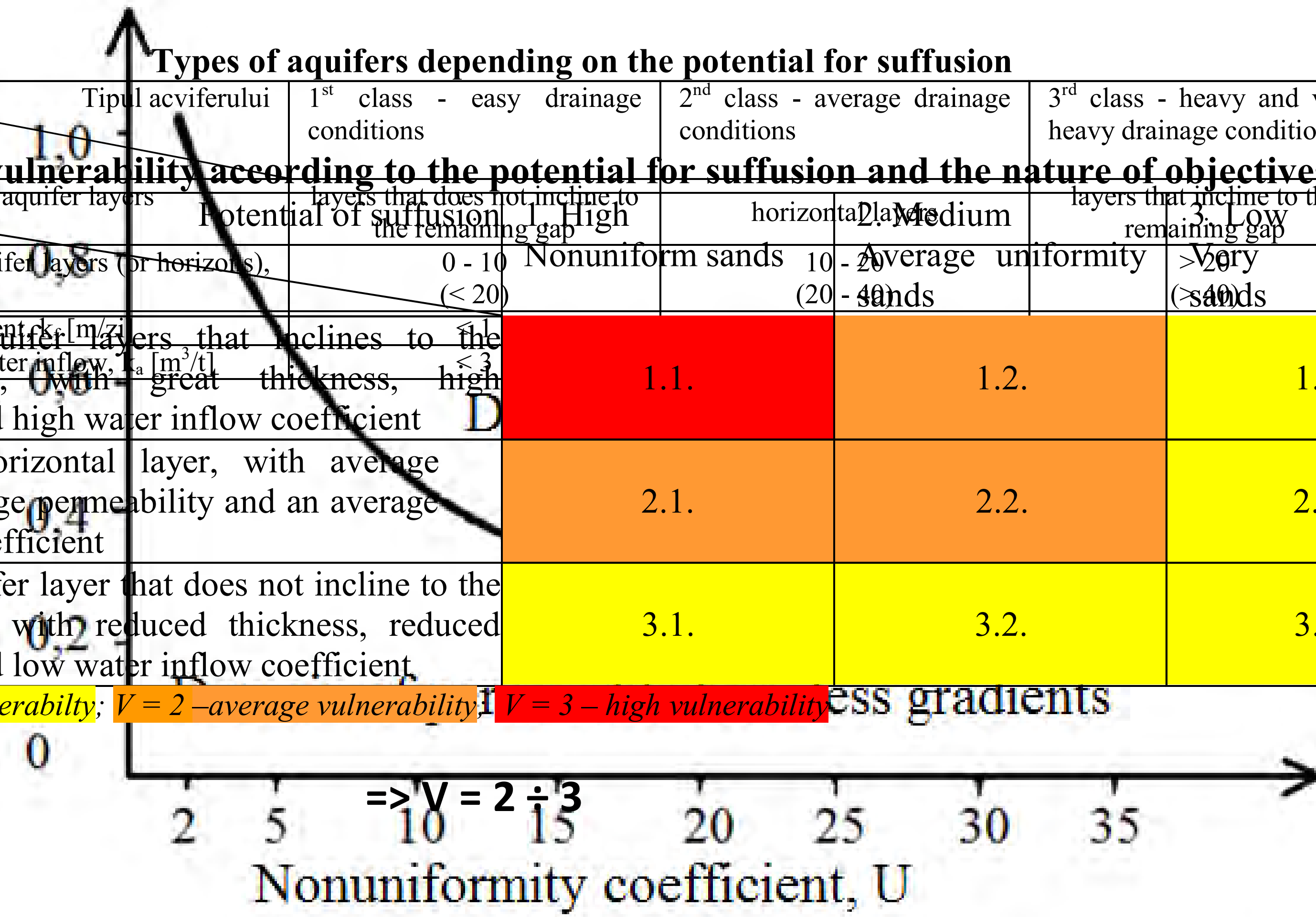
=> Pr = 3÷4

R = V·Pr

R = 2 · (3÷4) = 6÷8

- For R = 1 → very low risk of liquefaction;
- For R = 2÷4 → low risk of liquefaction;
- For R = 5÷9 → medium risk of liquefaction;
- For R = 10÷15 → high risk of liquefaction;
- For R = 16÷24 → very high risk of liquefaction;
- For R = 25 → extremely high risk of liquefaction.

SUFFUSION RISK OF IN-SITU SLOPES



Types of aquifers depending on the potential for suffusion

Tipul acviferului / Characteristics	1st class - easy drainage conditions	2nd class - average drainage conditions	3rd class - heavy and very heavy drainage conditions
Inclination of the aquifer layers	layers that does not incline to the remaining gap	horizontal layers	layers that incline to the remaining gap
Thickness of aquifer layers (or horizons), M [m]	0 - 10 (< 20)	10 - 20 (20 - 40)	> 20 (> 40)
Filtering coefficient, k_f [m/zi]	< 1	[illegible]	[illegible]
Coefficient of water inflow, I_a [m^3/t]	< 3	[illegible]	[illegible]

Establishing the vulnerability according to the potential for suffusion and the nature of objectives in the area

Type of aquifer / Potential of suffusion	1. High Nonuniform sands	2. Medium Average uniformity sands	3. Low Very uniform sands
3rd class - aquifer layers that inclines to the remaining gap, with great thickness, high permeability and high water inflow coefficient	1.1.	1.2.	1.3.
2nd class - horizontal layer, with average thickness, average permeability and an average water inflow coefficient	2.1.	2.2.	2.3.
1 st class - aquifer layer that does not incline to the remaining gap, with reduced thickness, reduced permeability and low water inflow coefficient	3.1.	3.2.	3.3.

where: V = 1 – low vulnerabilty; V = 2 –average vulnerability; V = 3 – high vulnerability

=> V = 2 ÷ 3

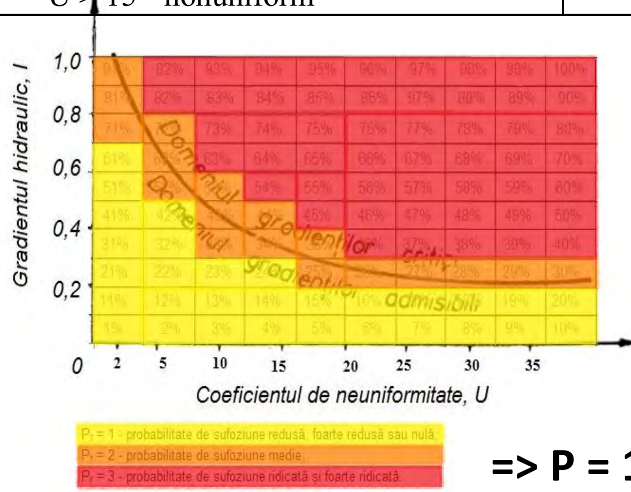
Correlation between the hydraulic gradient and the nonuniformity coefficient (Istomina, 1957)

Highlighting areas of suffusion potential

DETERMINATION OF SUFFUSION PROBABILITY

Suffusion potential according to the non-uniformity coefficient of the rocks under the conditions of a critical hydraulic gradient

Nonuniformity coefficient, U	Hydraulic gradient, I	Suffusion potential
U < 5 - very uniform	Icritical	low
U = 5 - 15 - medium uniformity		medium
U > 15 - nonuniform		high



=> P = 1

$R = V \cdot Pr = (2 \div 3) \cdot 1 = 2 \div 3$

- For R = 1 → low risk of suffusion;
- For R = 2÷3 → medium risk of suffusion;
- For R = 4÷5 → high risk of suffusion;
- For R = 6÷8 → very high risk of suffusion;
- For R = 9 → extremely high risk of suffusion.

Location of dewatering drilling for groundwater from the phreatic aquifer and the Motru complex

Determination of hydraulic gradient

Aquifer		Borehole	Distance between the boreholes	Level/pressure diference	Hydraulic gradient I	Hydraulic gradient I_{med}
Freatic aquifer		FT21-FT20	150	0,85	0,005667	0,007619
		FT22-FT21	150	1,30	0,008667	
		FT23-FT22	150	1,60	0,010667	
		PC6-PC2	356	1,60	0,004494	
		PC8-PC4	291	0,73	0,002509	
		PA6-PC6	178	1,90	0,010674	
		PA6-PC2	424	3,50	0,008255	
		PA6-PC3	457	4,13	0,009037	
		PA6-PC4	649	5,60	0,008629	
The Motru complex	Between layers VII-VIII of lignite	PC8-PC4	291	8,58	0,029485	0,019982
		PA6-PC4	649	6,8	0,010478	
	Between layers IV-V of lignite	PC8-PC4	291	13,35	0,045876	0,031890
		PA6-PC4	649	11,62	0,017904	
Artesian from the bad of IVth layer of lignite		RA1-RA3	280	0,41	0,001464	0,001464

CONCLUSIONS AND FINAL PROPOSALS

- Considering that each remaining gap is unique from the point of view of their characteristic conditions (location, configuration, morphological, geomorphological, orographic, hydrological, hydrographical, hydrogeological, stability, accessibility conditions etc.) it is recommended to adapt / correlate the existing conditions so that it is possible to evaluate the flood opportunity according to the methodology developed.
- Improving the methodology for evaluating the opportunity of flooding the remaining gaps by completing the evaluation criteria.
- It is necessary to carry out the necessary works in order to increase the stability reserve, taking into account the future external or internal influences, but especially the influence of water.
- Considering the negative effects of geotechnical phenomena, especially under the conditions of flooding, it is proposed to apply the appropriate measures in order to improve the rock characteristics and to increase the stability of the final slopes of the remaining gap.
- Establish an efficient set of measures for the concomitant reduction of the risks of sliding, liquefaction and suffusion under the conditions of flooding the remaining gaps in an acceptable period of time.
- It is recommended to monitor the rise of the water level in the lake and the possible signals announcing the possibility of occurrence of one of the three types of analyzed risks.
- Conducting the geotechnical risk assessment study for any of the remaining gaps in the lignite quarries in Oltenia for which the flooding is opportune, in order to increase the security degree of the objectives in the areas of influence.


Thank you
for your attention!
Urdari quarry lake