Feasibility Study

-

Chiatura: Reconstruction of Sludge Treatment Technology

Includs:

01_Map of contamination in the Kvirila River
02_Investigation of river Kvirila sediments
03_Field_logbook of documentation points (representative)
04_Design proposal for cleaning the discharged technological water
05_Ghurghumela_Stability Assessment of the Tailing Dam
06_Czech and Georgian legislative
07_Feasibility Study of Reconstruction

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Pardubice 2019, Czech Republic

Print No. **1**

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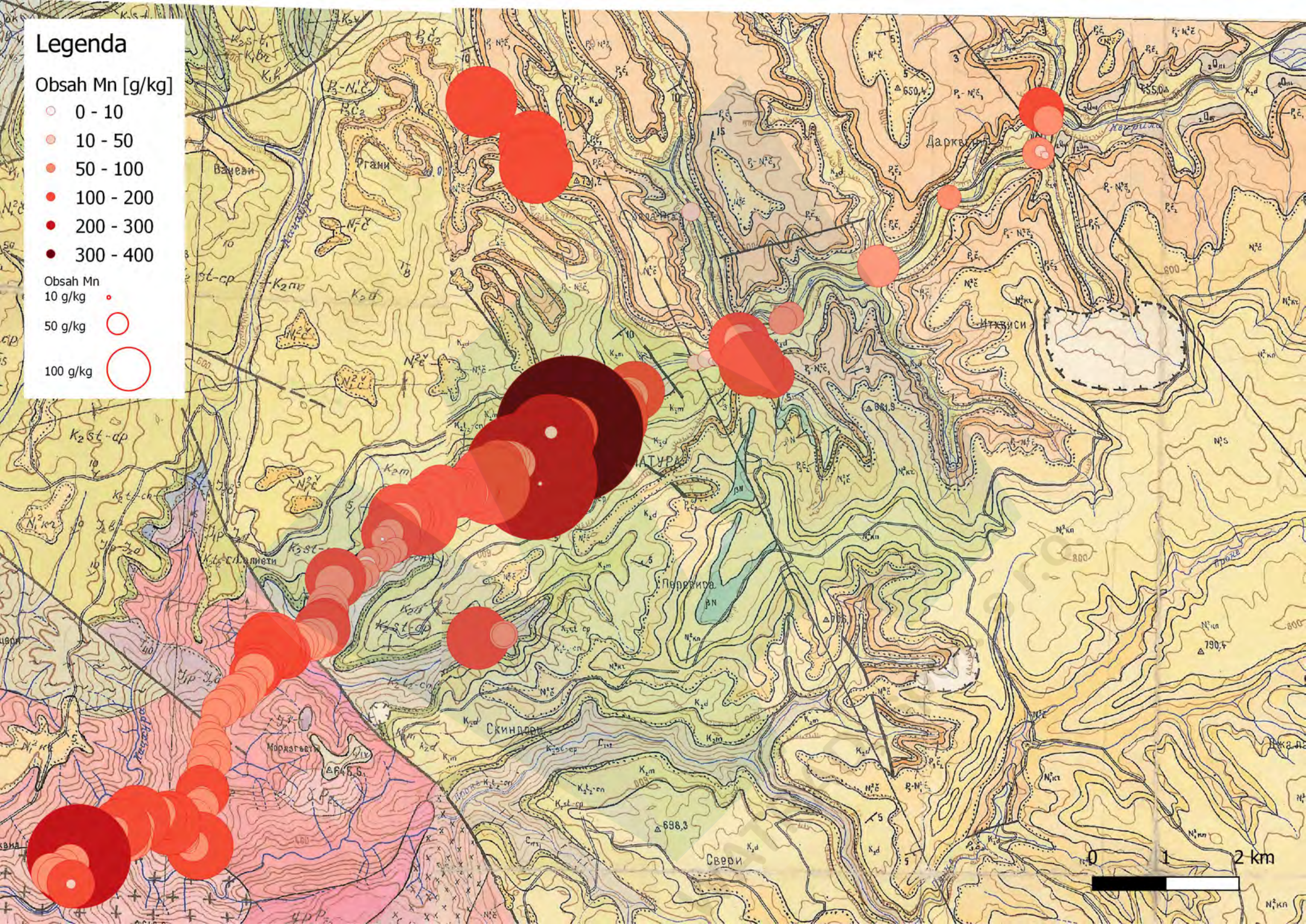
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10 - 50
50 - 100
100 - 200
200 - 300
300 - 400
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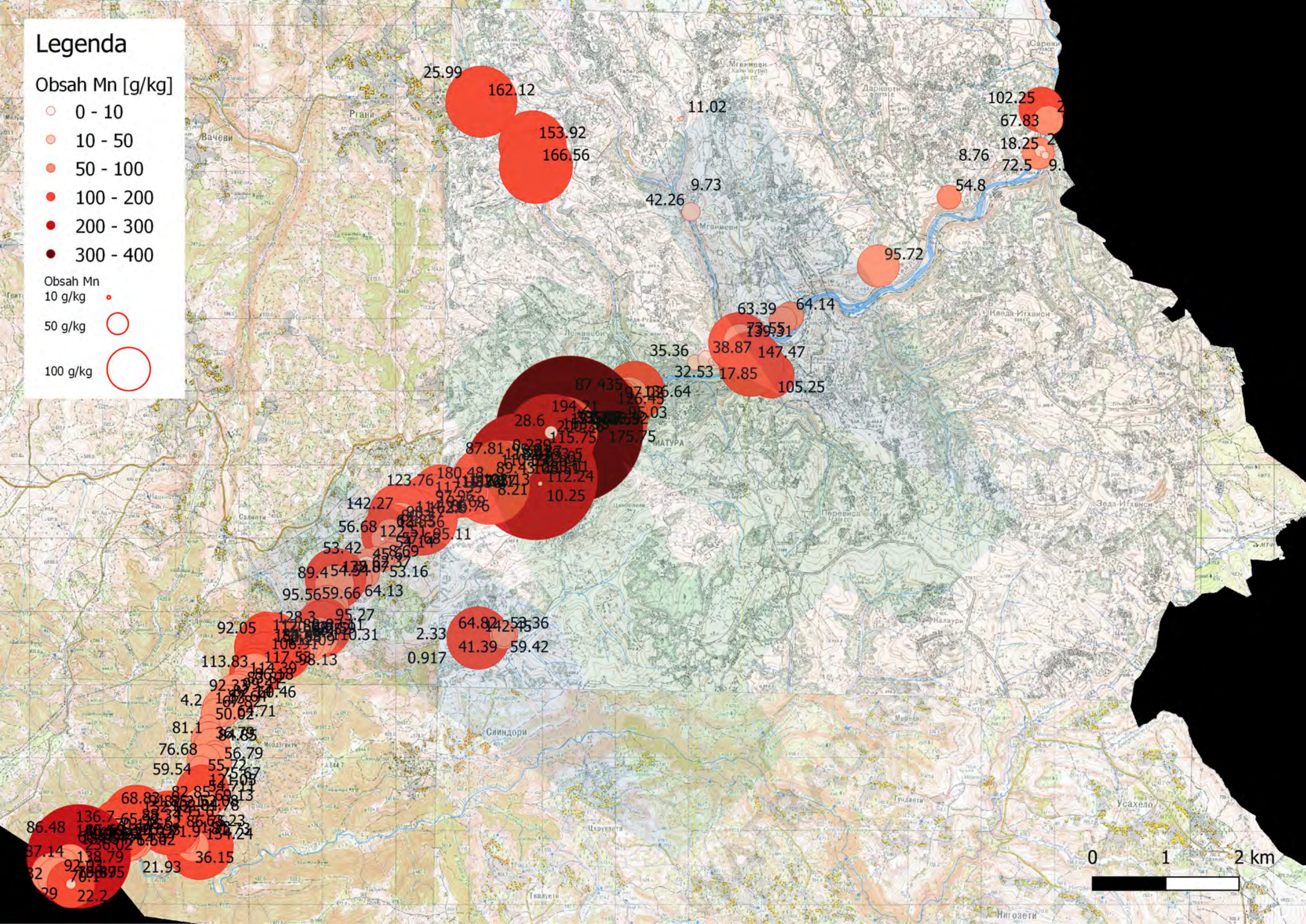
50 g/kg
100 g/kg
0
1
2 km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162.12
153.92
166.56
11.02
9.73
42.26
102.25
67.83
18.25
8.76
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54.8
95.72
63.39
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38.87
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32.53
17.85
105.25
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175.75
87.81
10.25
123.76
180.48
142.27
56.68
95.11
53.42
53.16
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95.56
59.66
64.13
95.27
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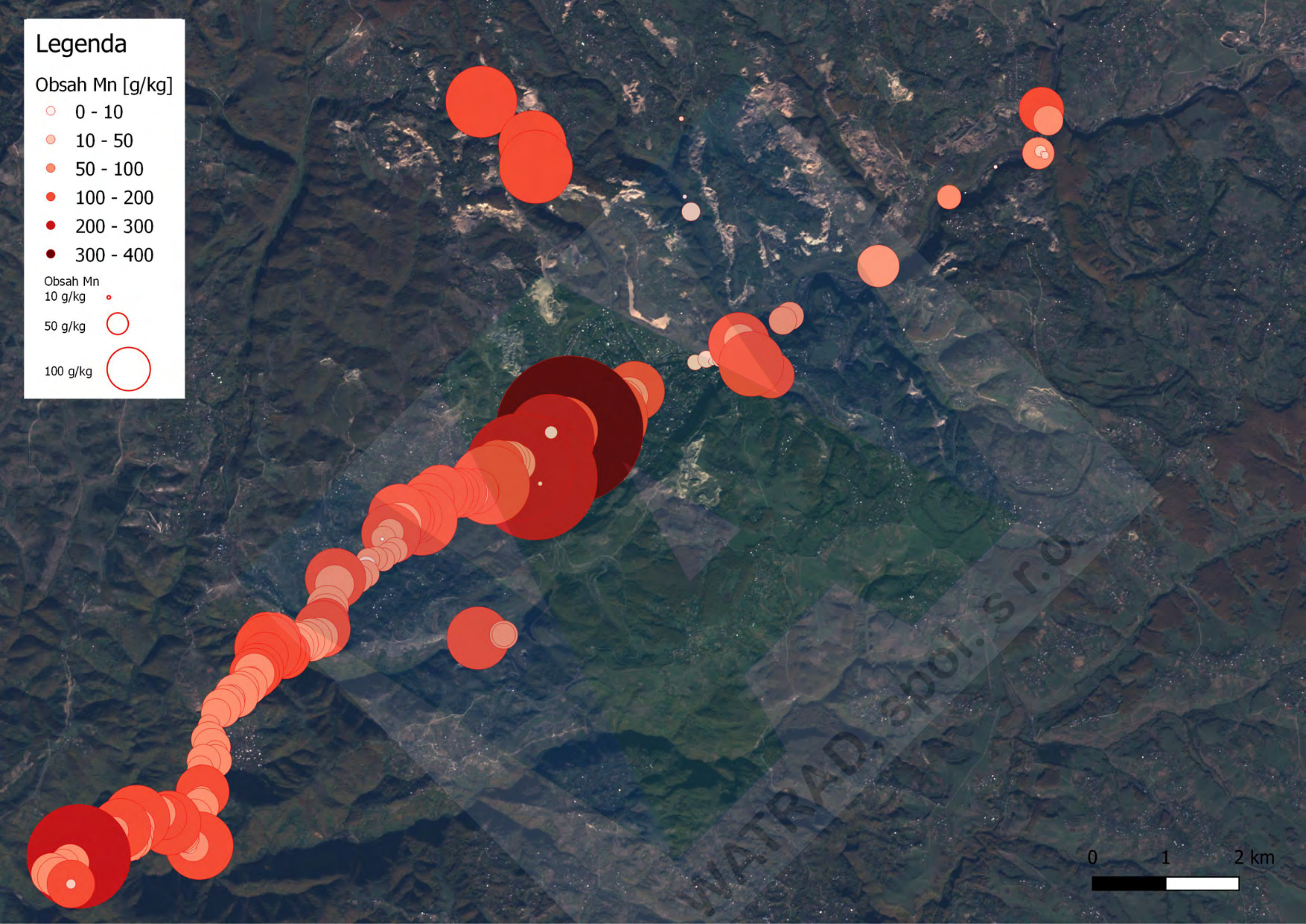

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0 - 10
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1
2 km

Investigation of Kvirila River Sediments Contamination

Client:

Pardubice 2019, Czech Republic

Print No. **1**

Content

1. Introduction

The project included mapping the range of manganese ore contents in the Kvirili river sediments. Contrary to the designed works, sediment samples were taken from the Kvirili River only to a depth of 30 cm. In the vast majority, the riverbed is either filled with large, tightly stacked large boulders or straight outcrops. This is due to the property of the river, it is a mountain stream that very sporadically allows sedimentation of float material. There are very frequent increased water flows, which entrain the drifted material and carry it to lower, quieter parts of the flow. The rivers in the side valleys of the Kvirili River have a similar character.

During the summer months of 2019, more than 200 sediment samples were collected over a length of 15 km of the river Kvirila. At the same time, sediment samples were taken in the side valleys where manganese ore enrichment technologies are located. Sediments have always been collected above and below the technology.

All samples were analyzed at the National Environmental Agency of Georgia. Control samples of 10% were analyzed in laboratories of the Geological Institute of the Czech Academy of Sciences in Prague.

2. Field works

2.1 Methodology of field work

Assessment of the state of pollution of the river sediments as a result of manganese ore mining and processing in the municipality of Chiatura was carried out on the basis of field work.

Aim of the field work in the Chiatura mining district was to

- describe Mn-pollution in the river Kvirila and its surrounding in terms of extension and severity,
- identify main Mn-pollution sources and mechanisms,
- learn main principles of groundwater flow in the area.

With regard to the set objectives, there had been carried out terrain reconnaissance first. Subsequently following methodology and scope of field work were proposed.

Scope of field work

The area of the Kvirila river watershed in the Chiatura area was decisive for delimiting spatial extent of the area of interest. The boundaries of the Kvirila River Basin were established on the basis of the digital elevation model ASTER GDEM (NASA and Meti 2015) in the QGIS 3.4 environment (QGIS Development Team 2015). Reconnaissance revealed an upstream boundary of the area of interest. It had been based on the first observed pollution of the river and its sediments by mining waste (see Figure 1).

For the purpose of assessing the state of the river unaffected by mining, the area of interest was moved to the border of the Sach'khere municipality about 3 km upstream of the Juchula stream. The downstream boundary was conventionally set at a distance of 15 km from the center of the town of Chiatura. The delimitation of the area of interest for field work is shown in Figure 2.

Figure 1: The first observed pollution of the Kvirila River by mining waste through its left tributary Juchula

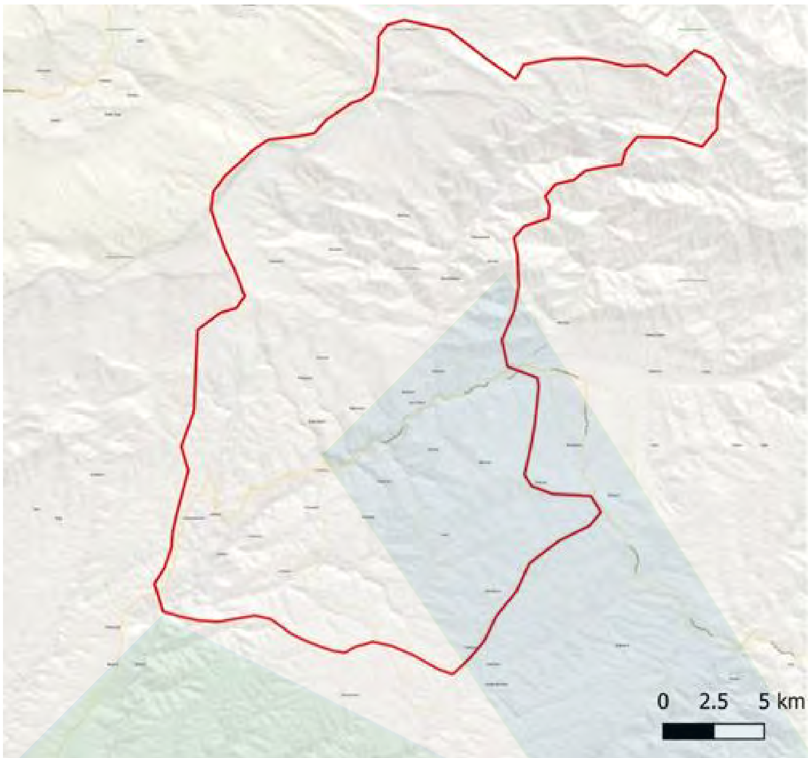

Figure 2: Delimitation of the area of interest for field work (topographic basis BingMap, © Microsoft 2019)

In the area of interest following activities there were taken

- systematic riverbed sediment sampling,
- additional soil and ore sampling,
- surface water sampling,
- pollution sources sampling,
- on site pollution source identification,
- digital field mapping,
- unstructured interviews with locals,
- hydrogeology and topographic data acquisition,
- overall photo documentation.

There were sampled

- bed sediments from the river Kvirila and its tributaries,
- sediment from an abandoned tailing dam
- deposits of fresh and processed ore,
- soil from the layers above the manganese ore,
- rock samples from local were limestone quarry,
- polluted water from the Kvirila river and its tributaries,
- water from the Kvirila river and its tributaries upstream the polluted area,
- technology water in a processing plant.

2.2 Mapping and spatial data collecting

Overall field work schedule had been prepared using printed Google provided satelite imagery (Orto photomaps) (Google 2019). The prints were also carried in field to maintain basic orientation and keep overall picture. Positioning and features of all samples, pollution sources, important objects as well as pictures taken were logged digitally using SW Maps application (see Figure 2) (Ltd. 2019) using Honor 6X smartphone. Coordinates of sampling site was verified by Garmin eTrex handheld GPS device.

For the SW Maps app three various templates were prepared to describe

- soil and sediment samples (see Table 1),
- water samples (see Table 2),
- objects of interest (see Table 3).

In addition to the custom templates, the application native template was utilized for georeferenced picture documentation. Hi resolution picture documentation was also taken using Canon DSLR camera.

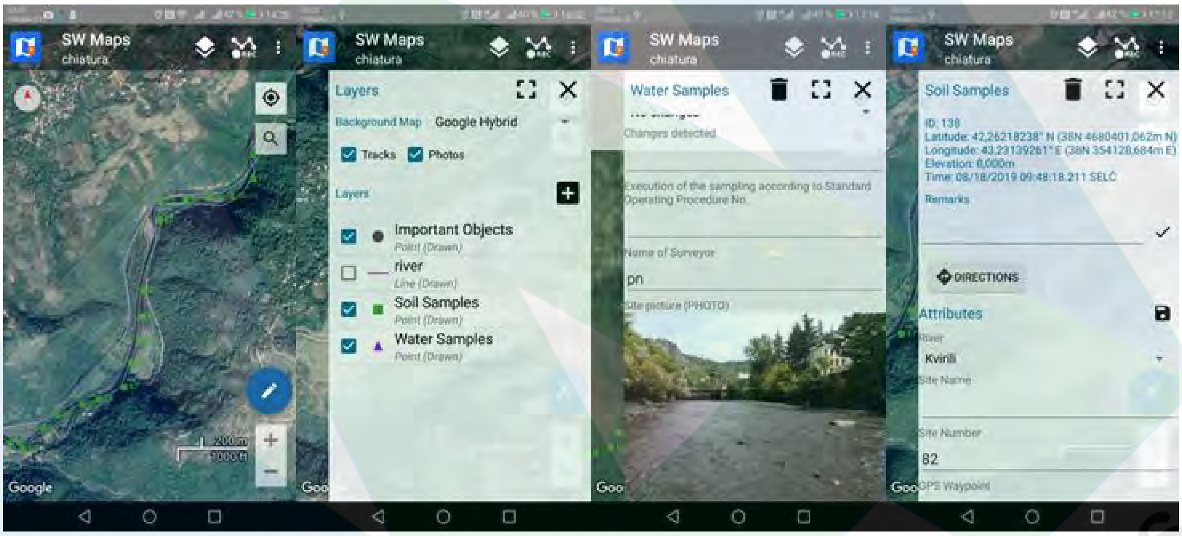

Figure 3: Spatial data were collected using SW Maps on an android device.

Tab. 1: Surface water sampling – field protocol

Field	Type	Input
Site Name	text	operator, optional
Site Number	integer	operator should be consistent with Garmin GPS waypoint numbering
Latitude WGS84	real	automatically by internal GPS unit
Longitude WGS84	real	automatically by internal GPS unit
River	text	operator, optional
Sampling Date	date	operator
Sampling Time	time	operator
GPS Waypoint	integer	operator based on the relevant Garmin GPS waypoint number
Site Picture	image file	operator using device camera
Sample Picture	image file	operator using device camera
Note	text	operator, optional

Tab. 2: Surface water sampling – field protocol (based on the NEA standard field water sampling protocol)

Field	Type	Input
Site name	text	operator, optional
Site Number	integer	operator should be consistent with Garmin GPS waypoint numbering
River Basin / River	text	operator
Latitude WGS84	real	automatically by internal GPS unit
Longitude WGS84	real	automatically by internal GPS unit
Sampling Date	date	operator
Sampling Time	time	operator
GPS Waypoint	integer	operator based on the relevant Garmin GPS waypoint number
Stream Order	text	operator, optional
River Type	text	operator, optional
Estimated Discharge	real	operator, optional
Colour (please describe)	text	operator, optional
Light Condirions	integer	operator, selection from list
Precipitation	integer	operator, selection from list
Air temperature	integer	operator, selection from list
Wind	integer	operator, selection from list
Water temperature [°C]	real	operator, optional
pH value	real	operator, optional
Electrical condicrivity at 20°C [mikroS/cm]	real	operator, optional
Dissolved oxygen [mg/l]	real	operator, optional
Oxygen saturation [%]	real	operator, optional
Turbidity of water	integer	operator, selection from list
Smell (please describe)	text	operator, optional
Preservation meadures for chemical / biological smaples carried out according to the specifications of laboratory	confirmation	operator, optional
Deviating preservation measures	confirmation/text	operator
No changes in the conditon of zhe samplinf site or its surrounding compared to the situation as documented in master data sheet	confirmation	operator
Changes detected	text	operator
Execution of the sampling according to Standard Operating Procedure No.	integer	operator
Site Picture	image file	operator using device camera
Sample picture	image file	operator using device camera
Name of Surveyor	text	operator, prefilled

Tab. 3: Objects of interest – field protocol

Field	Type	Input
Name	text	operator
Latitude WGS84	real	automatically by internal GPS unit
Longitude WGS84	real	automatically by internal GPS unit
Description	text	operator
Object picture	image file	operator using device camera

2.3 Sampling

The sampling, storing and transport methods were selected with respect to the following laboratory analyses. All method were discussed and agreed on with respective laboratories (the NEA laboratory in Tbilisi and the laboratory of Institute of Geology of the Czech Academy of Sciences in Prague).

The Kvirila River in the Chiatura mining district is a typical braided river with rubbly riverbed. Because of the sediment character (see Figure 4), it was virtually impossible sample deeper riverbed parts with manual tools. Moreover during several test to penetrate deeper the probes were damaged. Riverbed samples were taken from surface (depth 0 – 0.2m) only. The sampling step was about 100m as the river flows. The distance between two following sampling points was paced and controlled by point to point measurement using Garmin eTrex handheld GPS device. In case it was impossible to take a sample due to limited accessibility to the river, depth of water or lack of sediment sand to clay sediment, sample was taken as close as possible to the intended sampling point.

Figure 4: Typical riverbed sediment of the Kvirila River

Sediments from the abandoned tailing dam were taken from side of a survey pit and deeper using soil probe.

Sediment and soil samples were individually sealed in a labeled plastic sampling bag sealed and protected by another sealed sampling bag (see Figure 5).

Water samples were taken into clean plastic bottles. The bottles were flushed three times before the samples were taken (see Figure 5).

Figure 5: Part of the sediment and water samples prepared for transport to the laboratory.

2.4 Primary documentation

All samples were logged into a digital field logbook and as a waypoint into a Garmin eTrex handheld GPS device. The data were stored in the respective devices and backed up every evening using Google Drive cloud service. Later on virtual and printed field logbooks were prepared to sum up the field work outputs. Figure 6 points out spatial distribution of sediment and water samples, other objects of interest and georeferenced picture documentation.

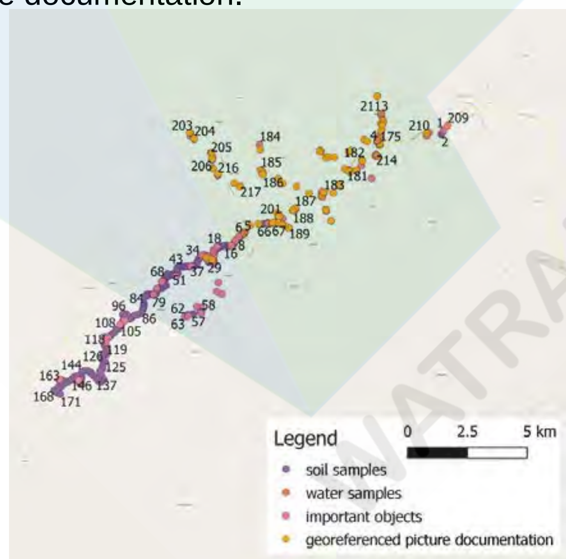

Figure 6: Spatial distribution of samples, mapped and documented objects.

2.5 Spatial data

Topography and elevation were obtained online from respected sources including Openstreet project, Google maps, Bing Maps or Landsat Imagery. Offline topographic map in scale 1 : 25 000 had been provided by the NEA. Elevation data were gained from ASTER GDEM model (NASA and Meti 2015).

Online geology maps were gain via the Onegeology WMS service, offline geologic map in scale 1 : 25 000 had been provided by the NEA.

Hydrology and hydrogeology data were gained partly from the Georgian Manganesse at the meeting hold in in their Chiatura office and partly from published documents. Some data are also based on observations the mapping team made during the field work.

Pollution data came from the sampling (riverbed sediment pollution, water pollution), published documents (water pollution) and the Georgian Manganesse (location of processing plants).

Spatial data were visualized in QGIS (QGIS Development Team 2015). Georeferencing had been used when necessary. Digital elevation model (NASA and Meti 2015) was employed to get terrain profile data.

2.6 Laboratory analyses

Preparation of and homogenization the sediment samples of the samples were undertaken in the NEA laboratory in Tbilisi where subsequently all samples were also analyzed for Mn content. About one tenth of the samples were also analyzed in the laboratory of Institute of Geology of the Czech Academy of Science in Prague. Both laboratories applied same methodology. The water samples were analyzed in the ASL laboratories in Prague following standard procedure for contaminated water.

2.7 Results

Concentration of Mn in the sediment (riverbed sediment and tailings) were found very high (see Table 5 and Figure 7). The highest concentration found in the riverbed sediment was 335.2 g/kg (that is 33.52% of Mn). The lowest concentration (sample #19) in the visually contaminated part of the river was found only 0.239 g/kg. Such value, even lower than values in the visually unpolluted upstream part of the river (about 0.8 g/kg), is unlikely. Average concentration of Mn was found about 96 g/kg (that is 9.6 %) – see Table 4.

Tab. 4: Mn concentration in the riverbed sediments - basic statistics (concentrations are in g per kg)

	all riverbed data in polluted part	riverbed data in polluted part without #19
average	95.4	96.0
median	89.3	89.4
minimum	0.2	8.2
maximum	335.2	335.2
standard deviation	46.3	45.8

Tab. 5: Mn concentration in the riverbed sediments

sample #	riverflow distance from start	Mn [g/kg]
1	0	0.785
2	221	0.819
175	3116	2.03
176	3154	67.83
179	3605	9.38
182	4287	8.76
187	8365	64.14
188	8500	63.39
201	9270	73.55
200	9319	139.31
67	9745	32.53
66	9848	17.85
65	9929	38.87
64	10085	35.36
5	11099	136.64
6	11194	87.435
7	11306	95.03
8	11378	97.02
9	11515	126.45
10	11650	194.21
11	11747	175.75
12	11816	77
13	11893	116.32
14	12017	132.59
15	12124	95.14
16	12225	93.26
17	12252	335.17
18	12327	152.6
19	12424	0,239
20	12469	153.95
207	12494	28.6
21	12552	200.36
22	12637	93.5
23	12749	115.75
24	12844	89.43
25	12959	112.24
26	13019	93.01
27	13155	280.01
28	13278	108.51
29	13394	150.09
30	13481	243
31	13550	87.37
32	13657	87.81
33	13743	95.01
34	13862	118.07
35	13961	110.53
36	14047	8.21
37	14137	180.48
38	14285	86.76
39	14336	102.13
40	14433	87.81
41	14525	112.17
42	14627	111.75
43	14724	119.36
44	14826	123.76
46	15055	117.35
47	15176	97.96
48	15258	107.69
49	15357	95.11
50	15414	162.8
51	15514	122.51
52	15588	114.21
53	15751	142.27
54	15856	98.17
55	15936	89.3
68	16027	62.83
56	16028	134.56
69	16127	56.68
70	16128	8.69
71	16406	57.68
72	16511	54.14
73	16603	53.16
74	16710	54.54
75	16832	53.42
76	16934	45.6
77	17026	62.37
78	17144	64.13
79	17233	59.66
80	17339	77.8
81	17460	138.07
82	17554	89.4
83	17865	95.56
84	17979	95.27
85	18086	110.31
86	18182	128.3
87	18273	87.11
88	18389	97.59
89	18466	88.52
90	18587	96.9
91	18674	98.13
92	18787	114.39
93	18828	112.09
94	18909	84.45
95	19017	120.02
96	19153	112.89
97	19233	92.05
98	19370	135.55
101	19461	106.91
103	19690	117.53
104	19759	113.83
105	19762	92.33
106	19861	60.46
107	19942	86.18
108	20053	83.82
109	20152	99.41
110	20237	64.71
111	20318	82.14
112	20414	87.64
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117	20797	36.79
118	20879	81.1
119	20994	84.85
120	21089	56.79
121	21206	75.67
122	21353	76.68
123	21442	59.54
124	21539	55.72
125	21658	69.13
126	21789	121.05
127	21877	54.711
128	21983	82.85
129	22100	52.08
130	22155	81.78
131	22381	63.23
132	22532	81.73
133	22656	154.24
134	22745	71.9
135	22791	36.15
136	22883	61.33
137	22997	86.75
138	23109	76.54
139	23200	145.6
140	23306	102.04
141	23415	82.21
142	23524	68.83
143	23640	91.85
144	23769	152.17
145	23882	88.34
146	23986	78.62
147	24071	76.98
151	24154	90.6
152	24204	60.18
153	24366	136.7
154	24477	65.47
155	24588	70.145
156	24703	69.34
157	24778	96.33
158	24855	82.95
159	24944	105.86
160	25029	85.19
161	25147	86.48
162	25225	140.56
163	25263	138.79
164	25362	154.54
165	25455	236.02
166	25601	87.14
167	25685	70.1
168	26357	93.32
169	26449	92.03
170	26554	62.29
171	26653	73.87

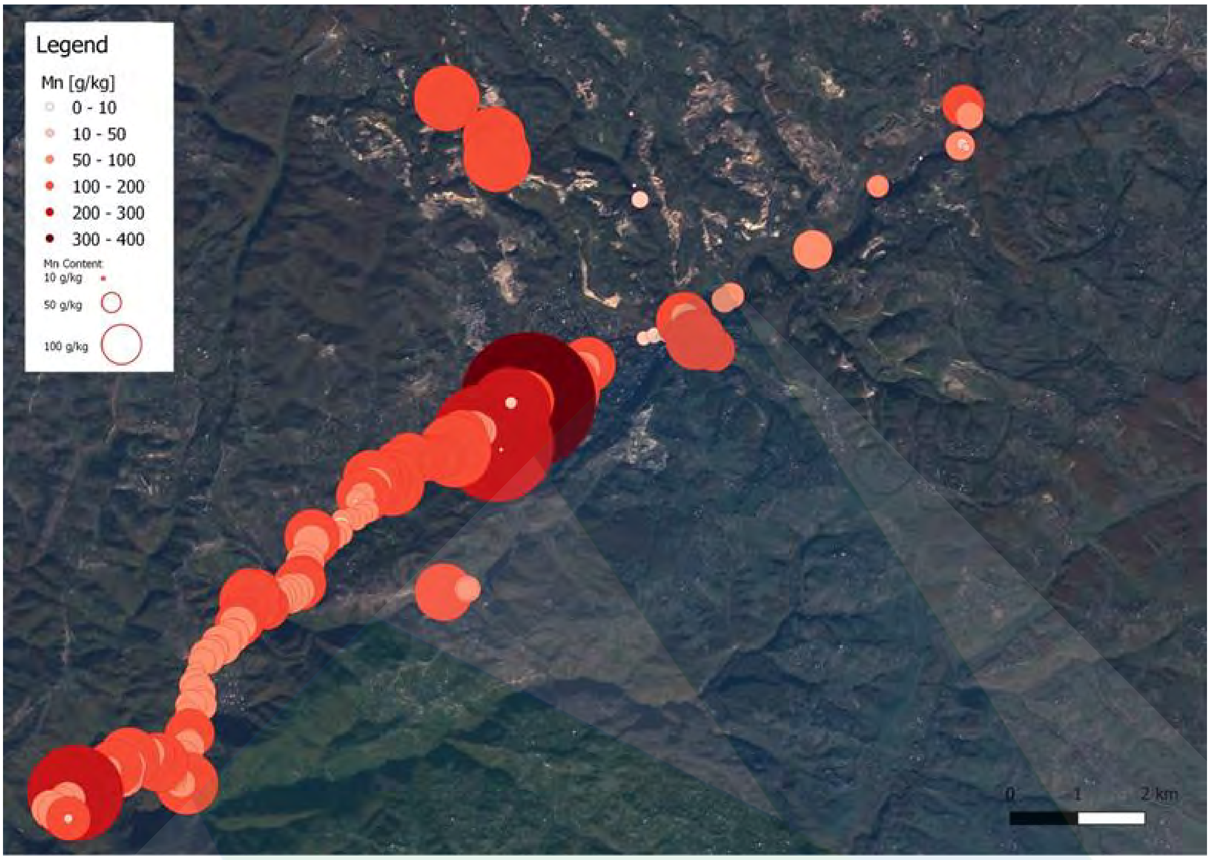

Figure 7: Mn concentration in the riverbed sediments and tailings

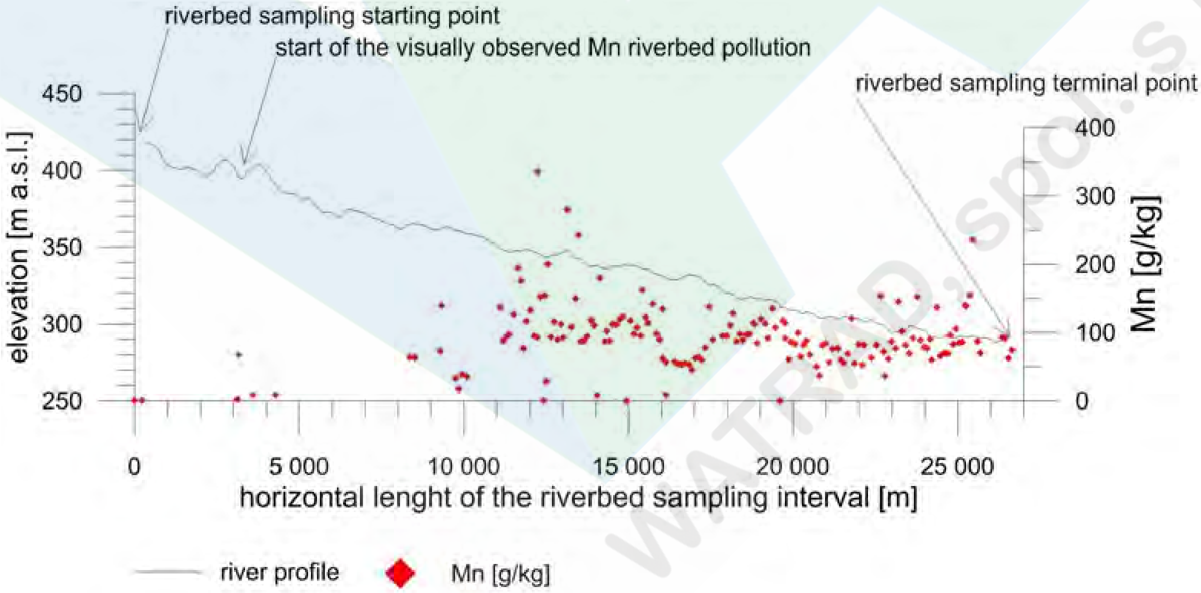

Figure 8: Mn concentration in the riverbed sediments along the Kvirila River profile

Mn concentrations vary substantially from place to place. Rather weak negative correlation between the river gradient and Mn content (see Figure 8) points out slower parts of the river where transported the Mn particles are likely sediment. Bulk of the riverbed is however formed by gravel with sand particles filling space between the cobles (see Figure 4). In some cases pure Mn ore congregates had been found in the sand-gravel sediment (Figure 10) In lower gradient parts small sand beaches can be found. Were the flow speed falls even more, mud pools and wallow are present (see Figure 9). Mostly fine Mn particles of course also sediment when flow slowdowns locally due to turbulent flow behind obstacles or when polluted water is being filtered through mostly gravel-sand riverbed or bank.

Figure 9: Sand beaches and wallows are to be found in lower gradient parts of the Kvirila river.

Figure 10: Sand-gravel sediment with congregates of pure Mn ore (MnO_2).

Another important factor in sedimentation of Mn particles would be flooding. Figure 10 present a typical sand formed riverbank of the Kvirila river. Growing concentrations on Mn up to 1 m above the normal water level (see Figure 11) point out lot of Mn material is probably transported and sediment during weekly water discharge and floods. It is likely all floodplain is to various extend contaminated. Concentration up 10 g/kg (1%) Mn should be expected there.

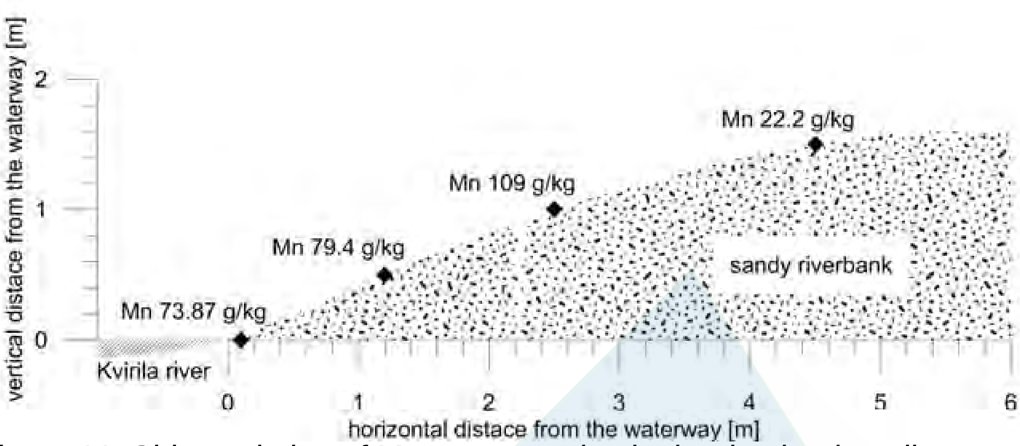

Figure 11: Side evolution of Mn concentration in the riverbank sediment at the end of area of interest.

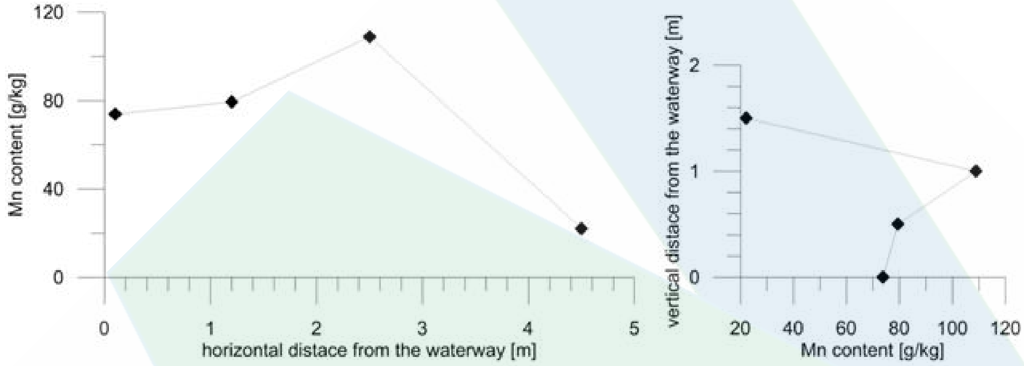

Figure 12: Horizontal and vertical change of the Mn concetration in the riverbank sediment an the end of area of interest.

Figure 13: Heavily polluted area of riverbed and floodplain sediments

Another area where high Mn concentration was expected is abandoned tailing dam on the south outskirts of the town of Chiatura (Figure 14). The solid part of the dam tailings had been sampled, the observed Mn concentrations were found ranging from 41.39 to 151.48 g per kg (see Table 6). Lower concentration is to be found in first 2.5m (see Figure 16). The observation suggests the tailing dam either had been covered by low concentration material or Mn has been transported downwards by infiltrating rainwater. Sediments from the stream on the discharge from the tailing dam show rather low Mn concentration (see Table 7). This result suggests the tailing dam retains Mn sufficiently well.

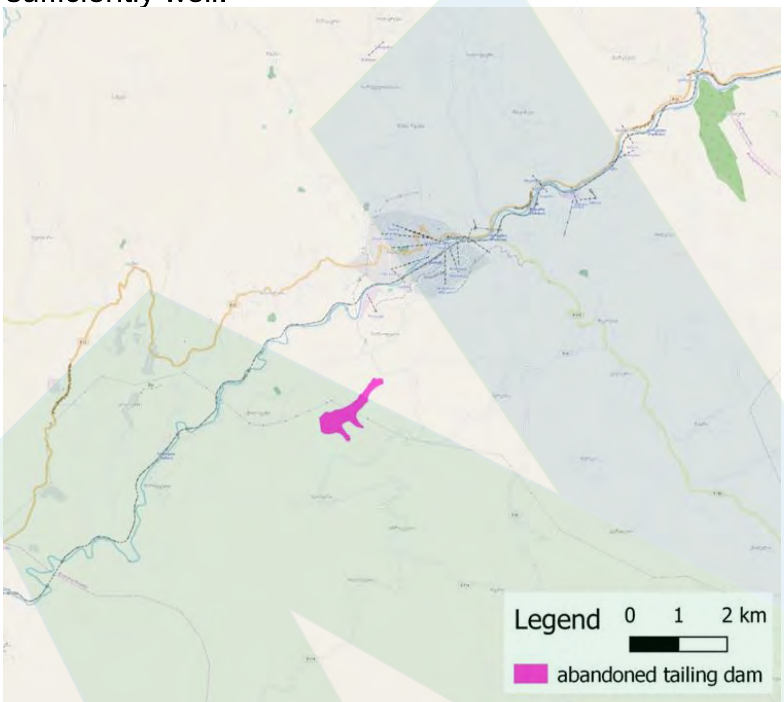

Figure 14: Position of the tailing dam south of the town of Chiatura

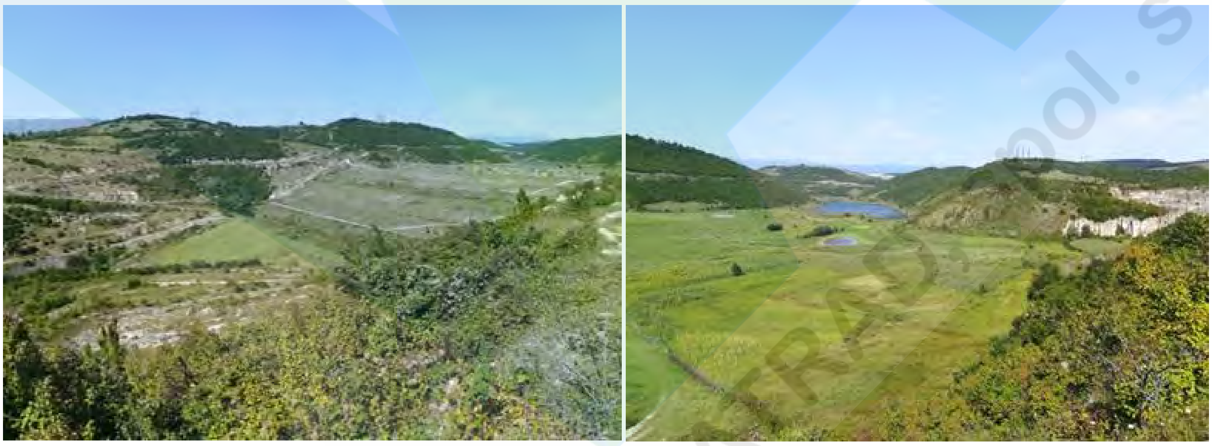

Figure 15: Ghurghumela pound - abandoned tailing dam south of the town of Chiatura

Tab. 6: Mn concentration in the tailing dam

Latitude	Longitude	Depth [m]	Site #	Mn [g/kg]	Location
42.25644	43.25953	0.2	58	59.42	Inner part of the tailing dam
42.25644	43.25953	0.75	59	41.39	
42.25644	43.25953	1.5	60	64.82	
42.25644	43.25953	2.2	61	53.36	
42.25644	43.25953	2.9	99	150.98	
42.25644	43.25953	3.4	100	151.48	
42.25597	43.25531	0.2	57	142.45	West part of the tailing dam

Tab. 7: Mn concentration on the discharge point from the tailing dam

Latitude	Longitude	Depth [m]	Site #	Mn [g/kg]	Location
42.25498	43.25114	0	62	2.33	Sediment on discharge from the tailing dam
42.25495	43.25115	0	63	0.917	

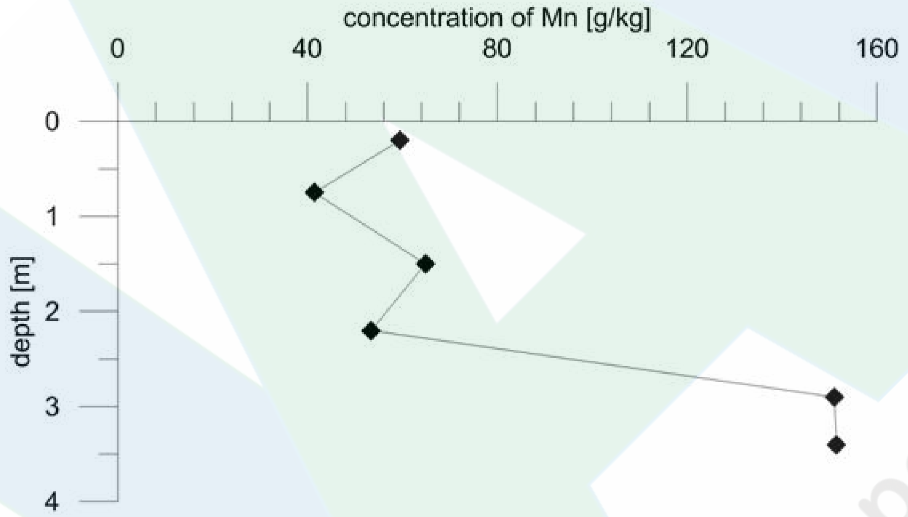

Figure 16: Vertical distribution of Mn in the tailing dam south of the town of Chiatura

In addition to the abandoned tailing dam number of technology structures both active and abandoned was observed in the area. These were

- mining operation sites (see Figure 17),
- active processing plants of various scale (see Figure 18),
- ore transport routes, including roads, cable cars and material free-falls (see Figure 19),
- permanent and temporal ore deposits (see Figure 20),
- ore crushers (see Figure 21),
- active technology water ponds and piping (see Figure 21),
- abandoned tailing ponds and piping (see Figure 22),
- active technology water discharge points (see Figure 23).

Figure 17: Mining operation sites above the town of Chiatura

Figure 18: Mn ore processing plants – principal processing plat governed directly by Georgian Manganese (left), small scale processing plant allegedly governed by a subcontractor (right)

Figure 19: Ore transport routes – cable car (left), Mn ore colored road (right)

Figure 20: Mn ore deposits – both permanent

Figure 21: Mn ore processing technology – ore crusher Georgian Manganese (left), active ore crushed and tailing pond (right)

Figure 22: Abandoned tailing pond (left) and tailing canal (right).

Figure 23: Active polluted technology water discharges.

Filed mapping suggests the principal source of surface water and sediment Mn contamination is in fact ore processing and storage. In the processing plants technology water is just used and then untreated discharged into the river and its tributary streams (see Figure 24). With the constant influx of fine Mn particles the river quickly change color to dark grey (see Figure 25). Another source of fine Mn particles are ore deposits situated on the riverbank or in some cases forming the riverbank (see Figure 26). Analyses of surface water pointed out there are significant Mn pollution in river water (see Table 8). In addition to Mn, highly toxic Ba is also present. High concentration of Ba is not surprising since Ba substitute Mn in some ore minerals.

Tab. 8: Surface water pollution (DIS - Dissolved Inorganic Substances,TSS - Total Suspended Solids).

Sample No.	209 *Kvirila - clean water upstream Chiatura*		212 *Polluted water downstream refinery plant (right side tributary)*		213 *Polluted process water ("schlam") on the output of rafinery plant*		218 *Kvirila in the town*		General discharge standards for mining operations in the Czech Republic
Parameter	homogenised sample	filtered sample	homogenised sample	filtered sample	homogenised sample	filtered sample	homogenised sample	filtered sample	
pH (-)	7.38	-	7.97	-	7.75	-	7.75	-	6 - 9
TSS (105 °C)	33.00	-	442	< 5	8080	< 5	13500	-	40
TSS (550° C)	29.40	-	389	< 5	7130	< 5	12200	-	-
DIS (550°C)	109.00	-	166	149	206	159	234	-	-
Chloride (Cl^-)	1.97	-	10.7	11	3.59	4.78	4.87	-	-
Nitrate ($NO3^-$)	< 2	-	< 2	< 2	< 2	-	< 2	-	-
Sulphate (SO_4^{2-})	17.00	-	31.9	29.4	22.8	20.9	67.6	-	-
Carbonate (CO_3^{2-})	0.00	-	0	0	0	0	0	-	-
Bicarbonate (HCO_3^{2-})	139.00	-	172	170	169	170	198	-	-
Al	0.12	-	9.83	0.102	3440	0.412	89.7	-	-
As	< 0,01	-	< 0,01	< 0,01	1.14	< 0,01	< 0,01	-	0.5
B	0.028	-	0.081	0.108	1.56	0.103	0.131	-	-
Ba	0.00646	-	2.66	0.3	477	0.553	16.6	-	-
Be	< 0,00020	-	< 0,00020	< 0,00020	0.0822	< 0,00020	0.0025	-	-
Ca	36.90	-	56.9	46.3	1360	51.9	116	-	-
Cd	< 0,0020	-	< 0,0020	< 0,0020	0.0632	< 0,0020	< 0,0020	-	-
Co	< 0,0020	-	0.0138	< 0,0020	2.73	< 0,0020	0.110	-	-
Cr	< 0,0020	-	0.0125	0.0025	3.98	0.0051	0.111	-	-
Cu	0.0023	-	0.0218	0.0870	6.29	< 0,0020	0.307	-	1
Fe	0.114	-	12.3	0.0242	2520	0.175	94.0	-	3.0
Hg	< 0,010	-	< 0,010	< 0,010	< 0,010	< 0,01	< 0,010	-	-
K	0.91	-	3.49	0.674	381	0.875	15.8	-	-
Li	< 0,0020	-	0.018	< 0,0020	2.7	0.0136	0.122	-	-
Mg	4.68	-	12.8	8.84	734	5.01	42.8	-	-
Mn	0.0045	0.00053	23.0	0.0209	9900	0.0962	476	0.00487	1.0
Mo	< 0,0030	-	< 0,0030	< 0,0030	1.07	< 0,003	0.0429	-	-
Na	12.60	-	20.3	18.2	47.6	12.9	14.8	-	-
Ni	< 0,0050	-	0.127	< 0,0050	32	< 0,005	1.55	-	-
P	< 0,050	-	0.756	< 0,050	95	< 0,05	5.12	-	10
Pb	< 0,010	-	< 0,010	< 0,010	1.84	< 0,1	< 0,1	-	0.5
Sb	< 0,020	-	< 0,020	< 0,020	< 0,20	< 0,02	< 0,2	-	-
Se	< 0,030	-	< 0,030	< 0,030	4.61	< 0,03	< 0,3	-	-
V	< 0,0020	-	0.0765	< 0,0020	20.7	< 0,002	0.843	-	-
Zn	< 0,0030	-	0.0348	0.0468	8.78	0.0694	0.392	-	3

Figure 24: Juchula stream 100m upstream (left) and downstream (left) Mn ore processing plants. These pictures were taken about 1200 m from each other.

Figure 25: Relatively clean water of the Kvirila river mixing with polluted Juchula stream (top left) and later with direct discharge of technology water (top right), clean leftbank stream flows to the already polluted Kvirila river (bottom left), the Kvirila river upstream the Chiatura mining district (municipality of Sach'khere, bottom right).

Figure 26: Mn ore deposit forming a riverbank.

Combination of analytic data, field observation and information from the NEA points out to wider picture of Mn sediment contamination in the Chiatura mining district (see Figure 27). Heavily polluted sediments are to be found on the floodplain (about 433 ha) and probably also on the processing site and along respective roads (approximately 10 ha). Another obvious area of heavy Mn pollution would the abandoned tailing dam (about 48 ha). This fact is probably not understand by local population since the place is being used as common ground for cattle and corn and sunflower fields can be found directly on the main body of the solid tailings.

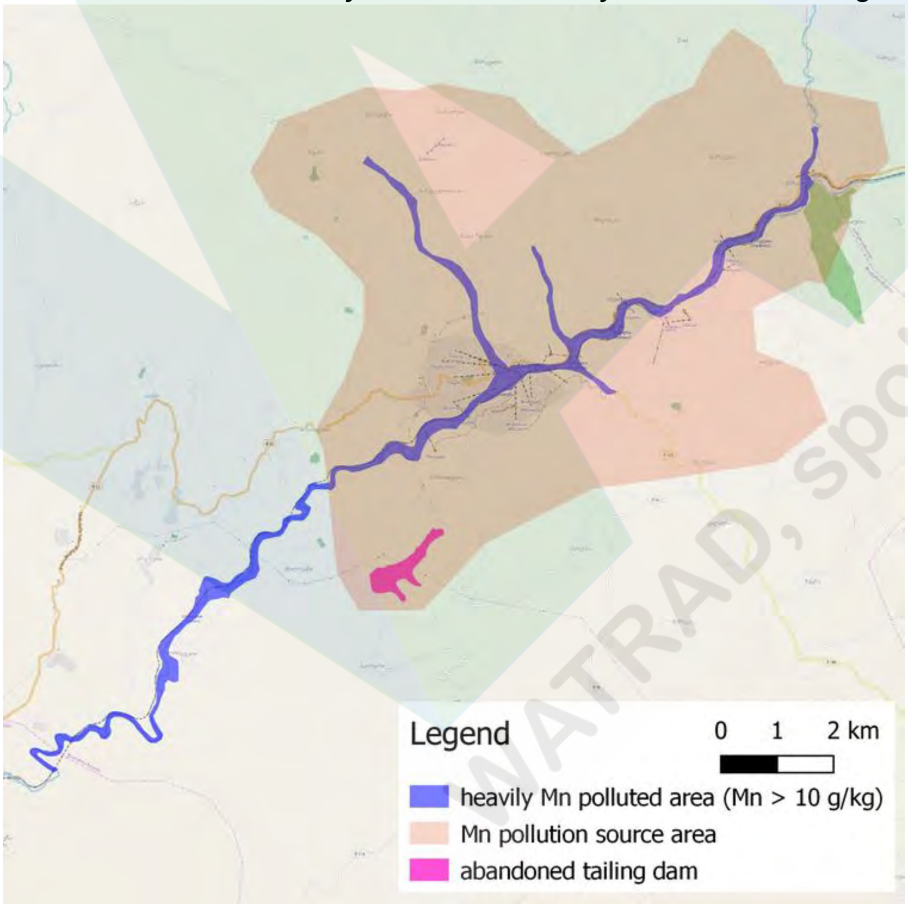

Figure 27: Mn contamination in surface sediments in the Chiatura mining district

Mn contamination source area (at least 68 km2) covers wider surroundings of the town of Chiatura. In the area activities including indiscriminate mining, decentralized ore processing, careless ore transport and storage as well as direct discharge of untreated Mn highly polluted technology water induce omnipresent Mn sediment and soil Mn contamination. The results suggest Mn contamination is accompanied by Ba contamination.

The Chiatura Mn deposit is sitting just above karsted limestones. Groundwater survey results provided by Georgian Manganese pointed out number of karst related spring and a rapid groundwater flow. Figure 28 presents tracer test based concept of groundwater flow in the area. Figure 29 points out clearly a relationship between carts and spring in the area as well as tectonic foundation of some springs. Periodic Mn contaminations of lower situated drinking water sources suggest there is a hydraulic connection between the deposit and karst. Rainwater infiltrating the deposit mobilize Mn. Moreover open pit mining eases forming of infiltration ponds (see Figure 30). Sinkholes as well as tectonics bring the polluted infiltrated water into groundwater. We have observed the layers above karst system have been disturbed to the great extend probably making the changes irreversible. Unless great effort is applied including substantial reclamation works and possibly redepositing of great masses, springs in lower part of the Chiatura mining district cannot be considered safe.

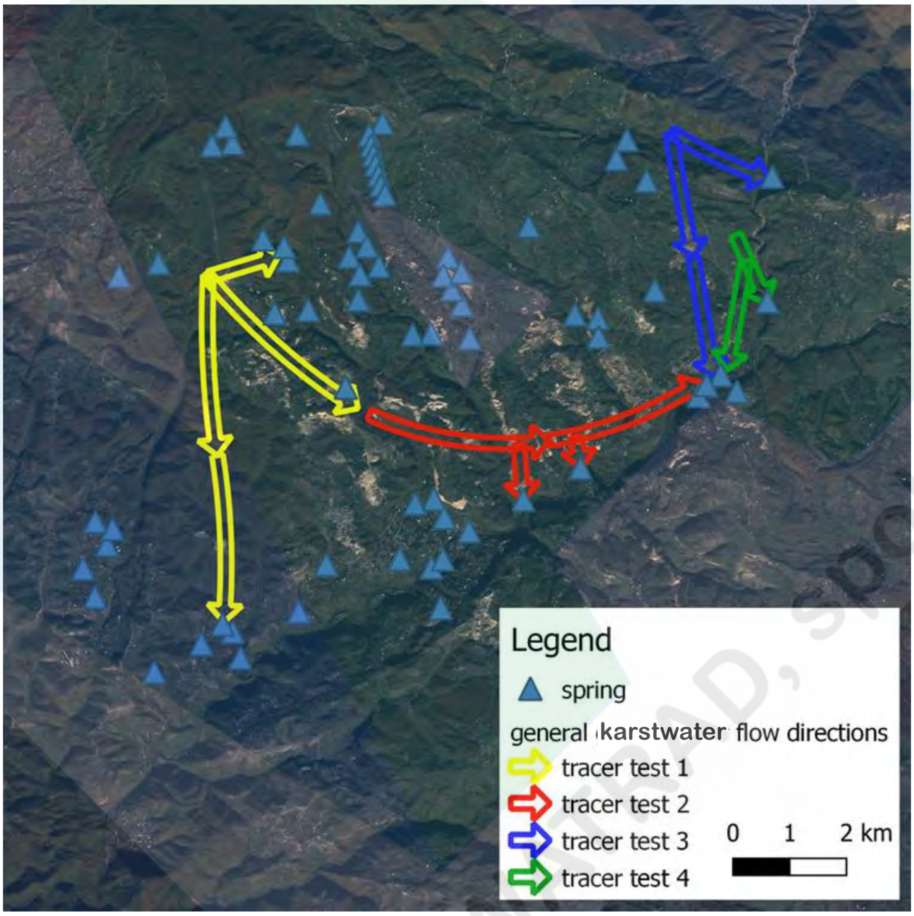

Figure 28: Karstwater flow in the area as interpreted from spring mapping and tracer tests (groundwater flow data provided by Georgian Manganese)

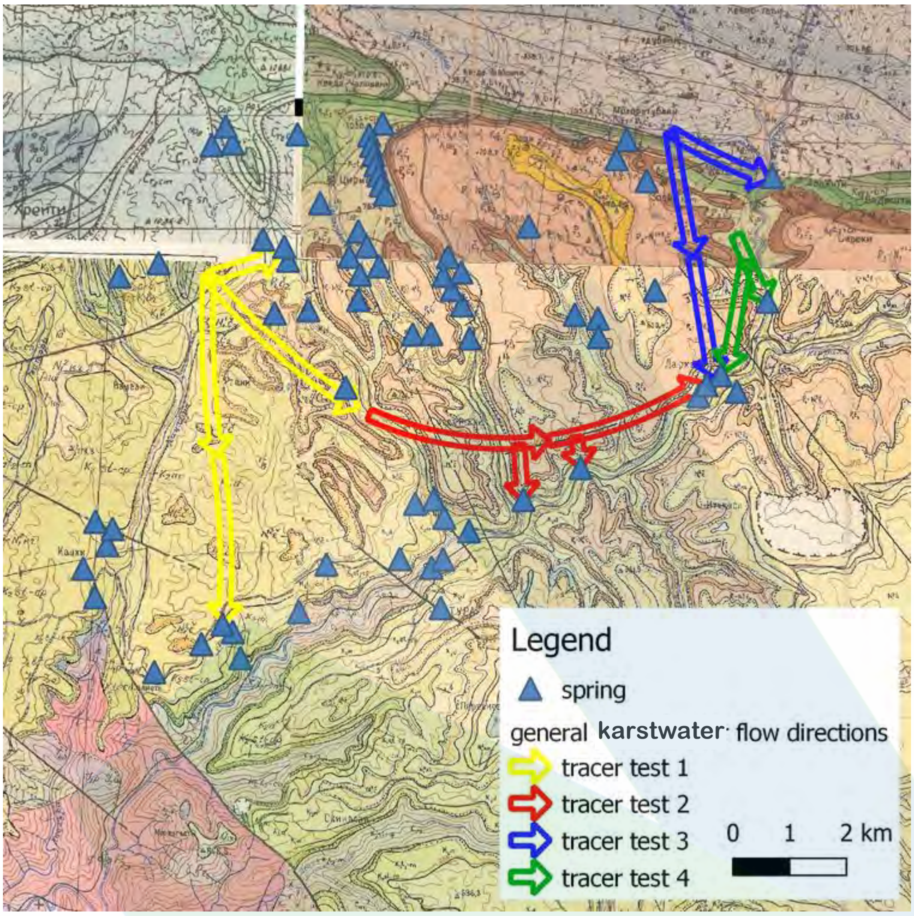

Figure 29: Significant groundwater flow in the area seem to be focused in the karst area (see yellowish colored limestones in the map) underlaying the Mn ore deposits (orange colors), some of the springs are undoubtedly of tectonic origin (groundwater flow data provided by Georgian Manganese, geological map provided by NEA)

Figure 30: A rainwater pond in the active open pit mining area.

3. Reference

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4. Field logbook - map of documentation points

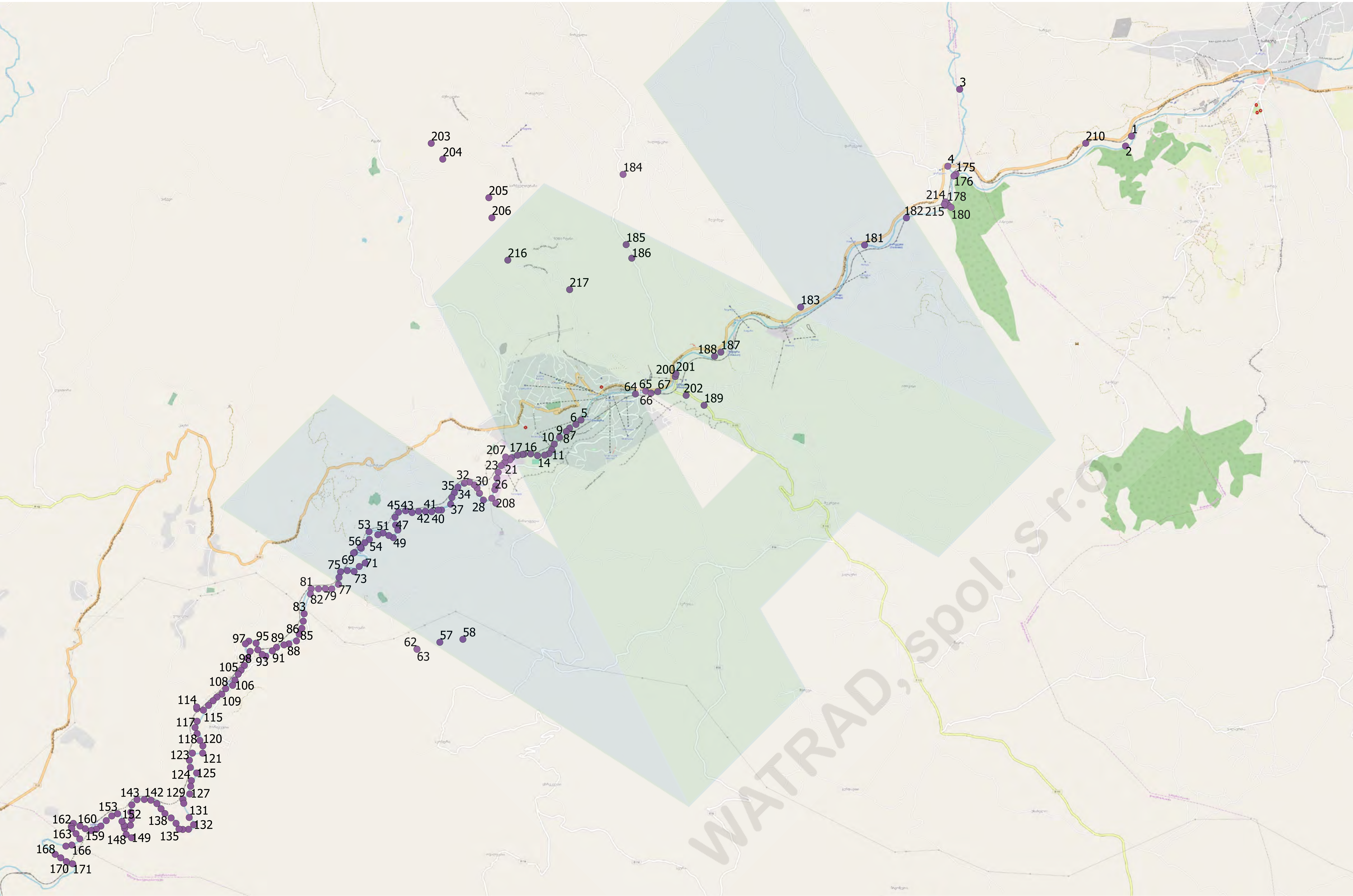
Field loggbook - map of documentation points

Project: Reducing the impact of mine water on drinking water sources in the Kvirila River basin
Type of object: Sediment sample
Logged by: Michal Vaněček & Petr Novák

Scale 1 : 50 000

0 1 2 3 4 km

WATRAD, spol. s r.o.
WATer dynamics Research And Determination



Field loggbook

WATRAD, spol. s r.o.
WATer dynamics Research And Determination

Project: Reducing the impact of mine water on drinking water sources in the Kvirila River basin
Type of object: Sediment sample
Logged by: Michal Vaněček & Petr Novák

Sample No.	Sampling date
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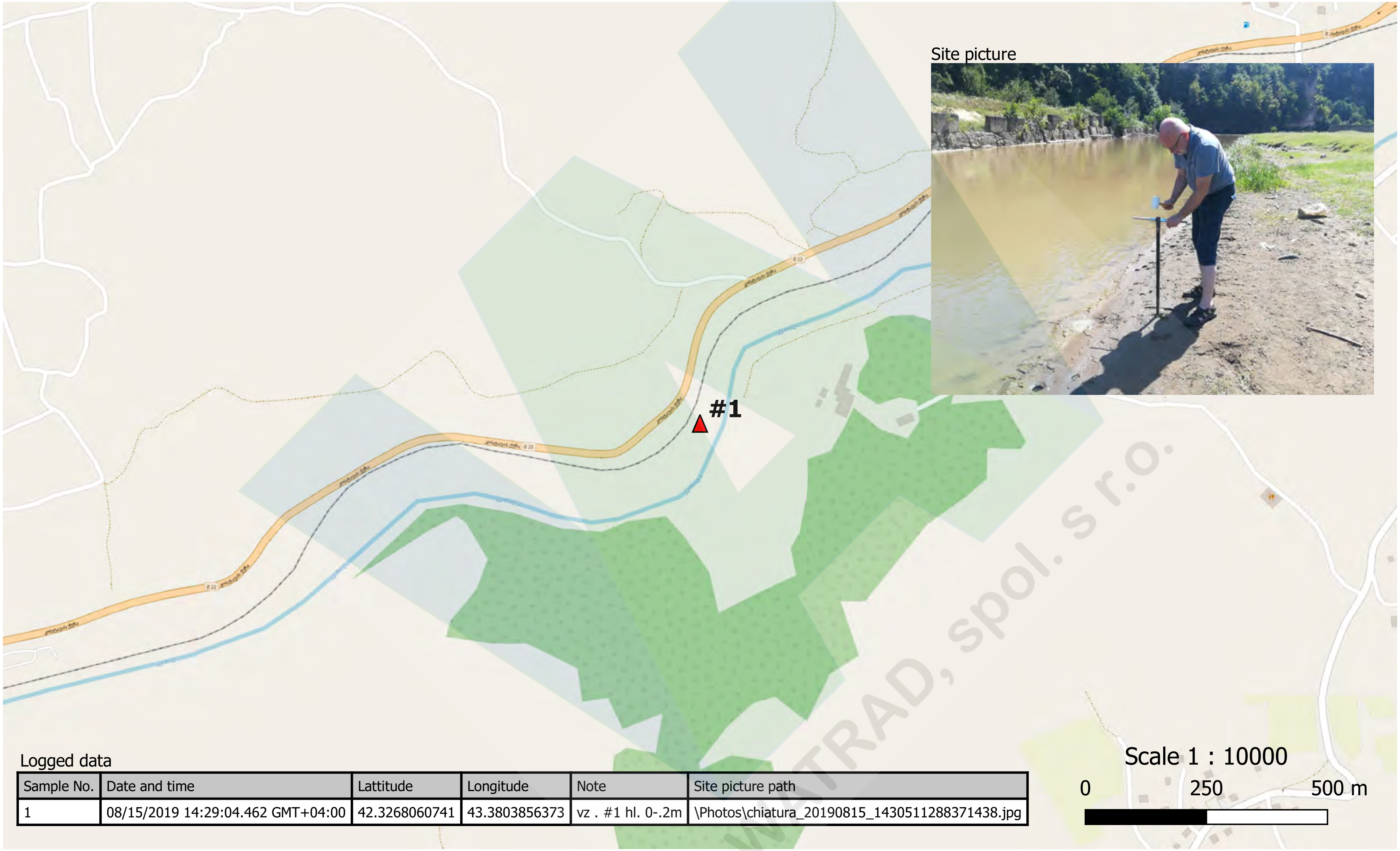

Site picture

Logged data

Sample No.	Date and time	Lattitude	Longitude	Note	Site picture path
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Field loggbook

WATRAD, spol. s r.o.
WATer dynamics Research And Determination

Project: Reducing the impact of mine water on drinking water sources in the Kvirila River basin
Type of object: Sediment sample
Logged by: Michal Vaněček & Petr Novák

Sample No.	Sampling date
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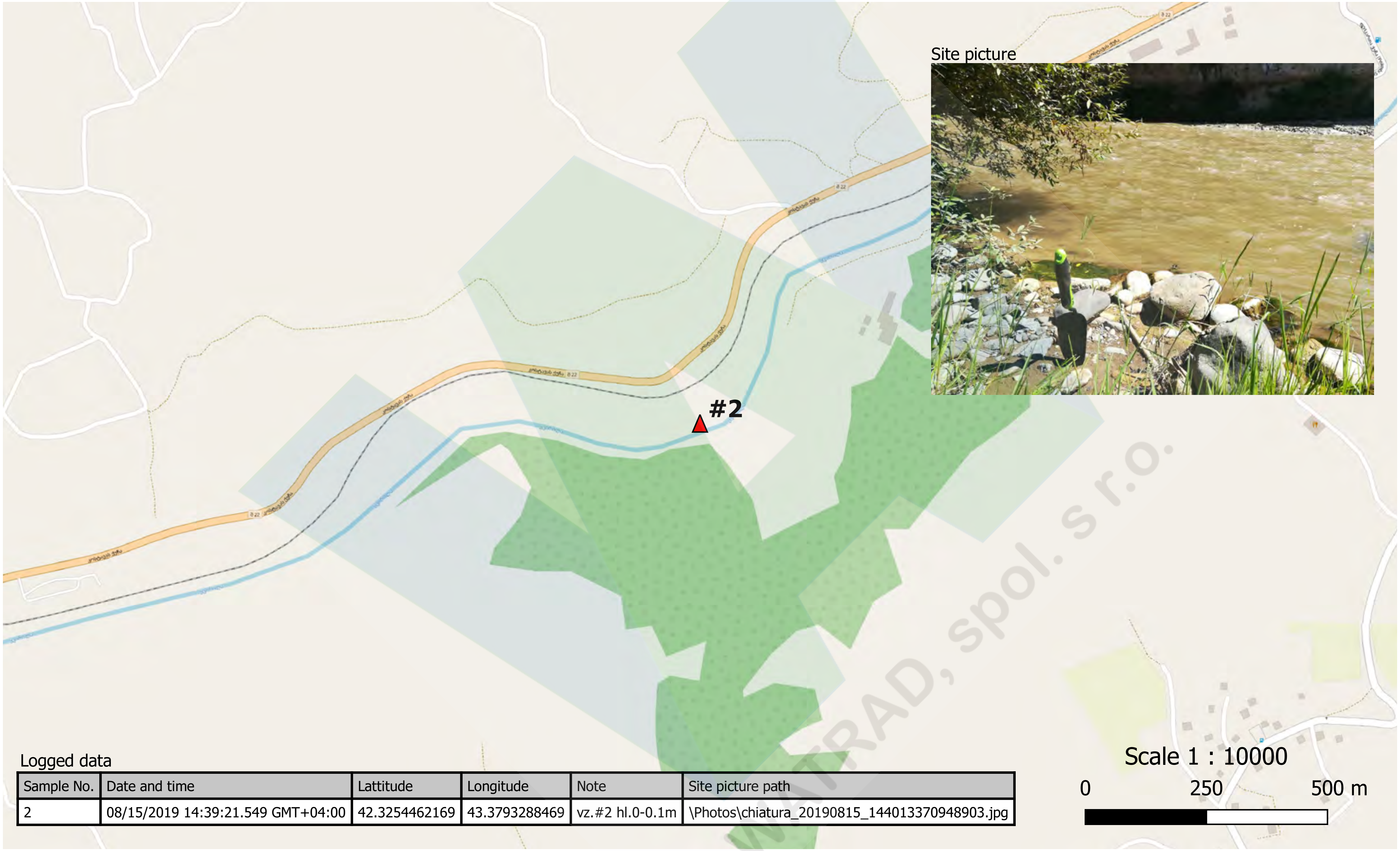

Site picture

Logged data

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Scale 1 : 10000

0 250 500 m

Field loggbook

Project: Reducing the impact of mine water on drinking water sources in the Kvirila River basin
Type of object: Sediment sample
Logged by: Michal Vaněček & Petr Novák

WATRAD, spol. s r.o.
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Sample No.	Sampling date
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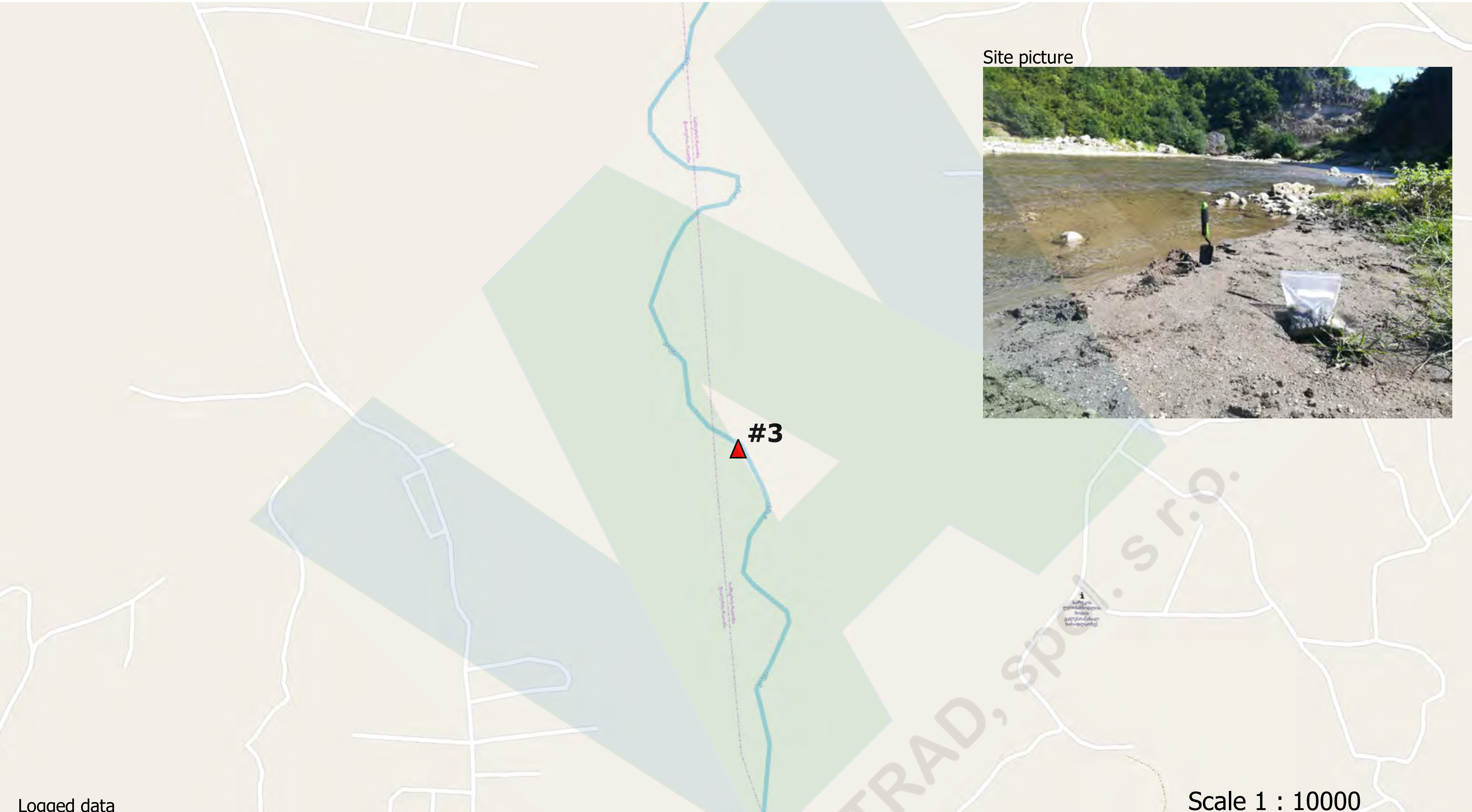

Site picture

Logged data

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Field loggbook

Project: Reducing the impact of mine water on drinking water sources in the Kvirila River basin
Type of object: Sediment sample
Logged by: Michal Vaněček & Petr Novák

Sample No.	Sampling date
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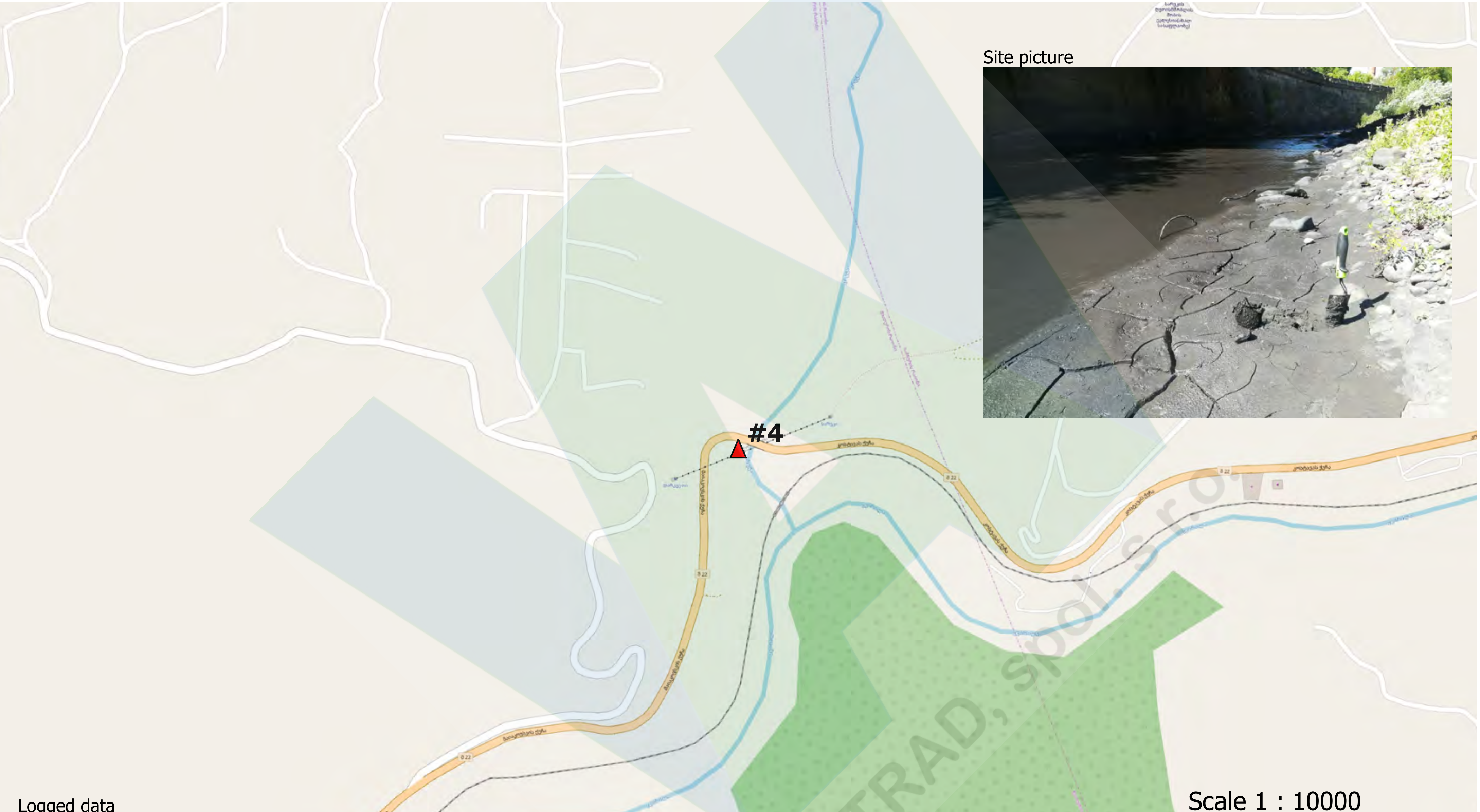

Site picture

Logged data

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Scale 1 : 10000

0 250 500 m

Field loggbook

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Project: Reducing the impact of mine water on drinking water sources in the Kvirila River basin
Type of object: Sediment sample
Logged by: Michal Vaněček & Petr Novák

Sample No.	Sampling date
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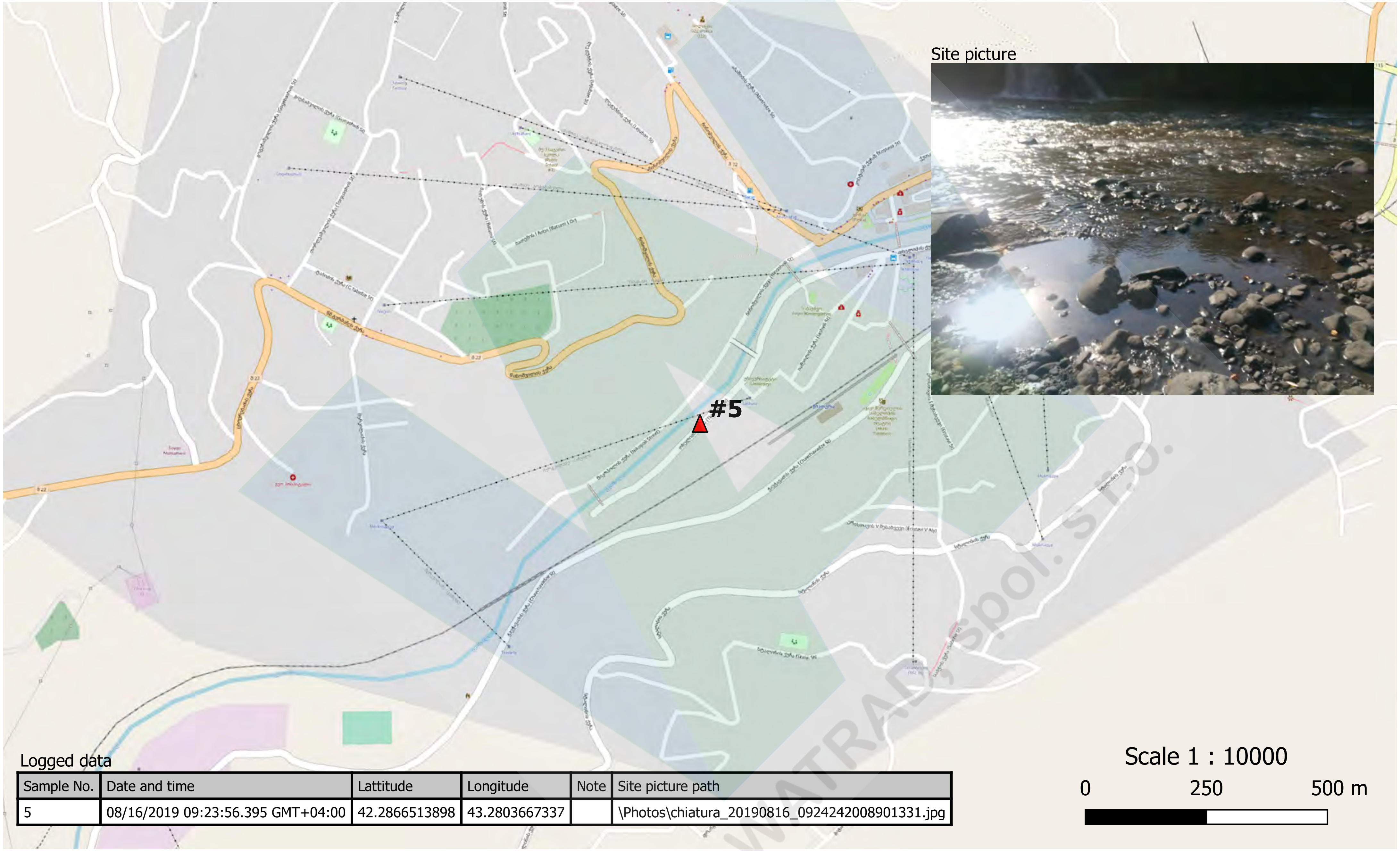

Logged data

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Scale 1 : 10000
0 250 500 m

Field loggbook

Project: Reducing the impact of mine water on drinking water sources in the Kvirila River basin
Type of object: Sediment sample
Logged by: Michal Vaněček & Petr Novák

Sample No.	Sampling date
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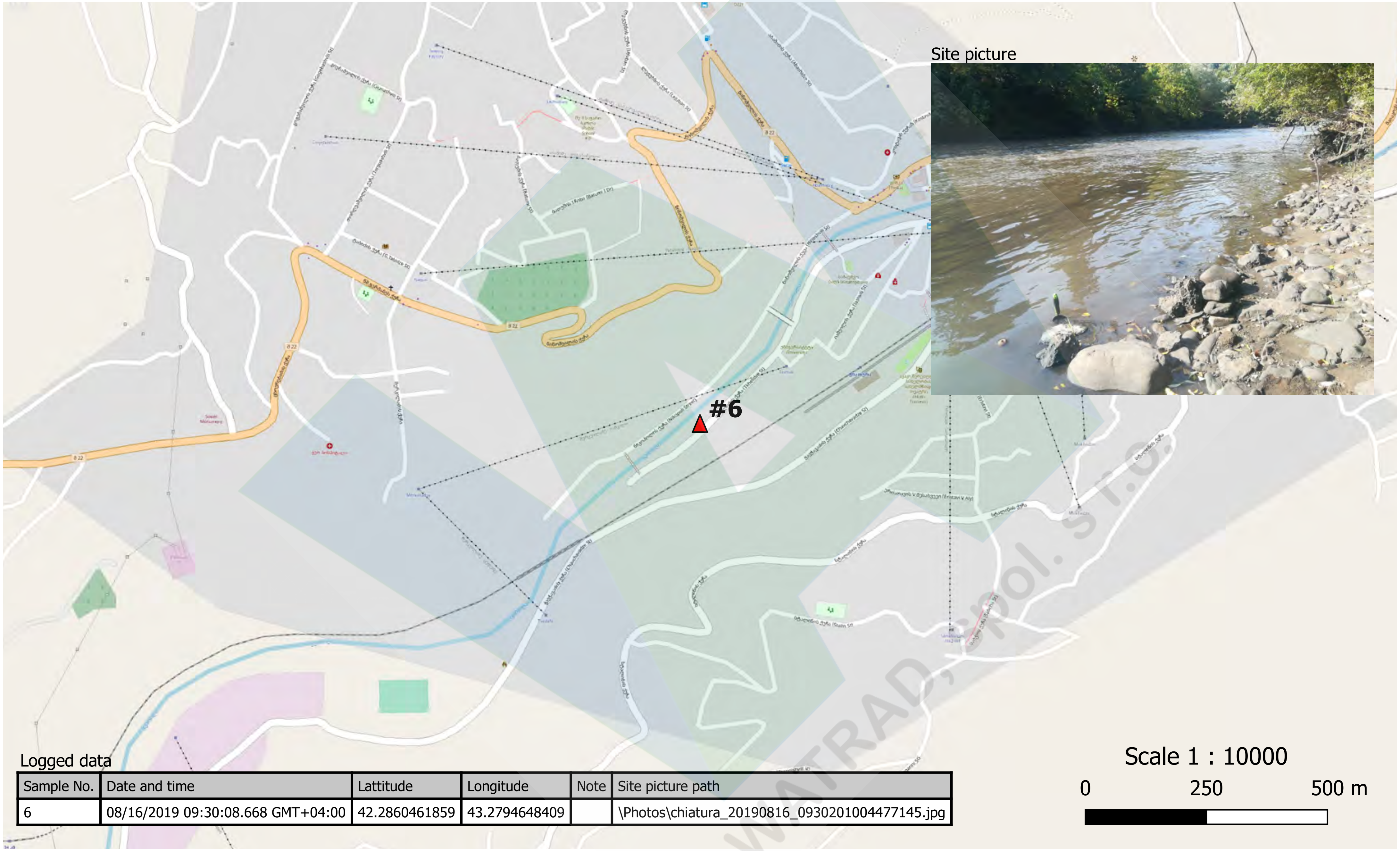

Site picture

Logged data

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Field loggbook

Project: Reducing the impact of mine water on drinking water sources in the Kvirila River basin
Type of object: Sediment sample
Logged by: Michal Vaněček & Petr Novák

Sample No.	Sampling date
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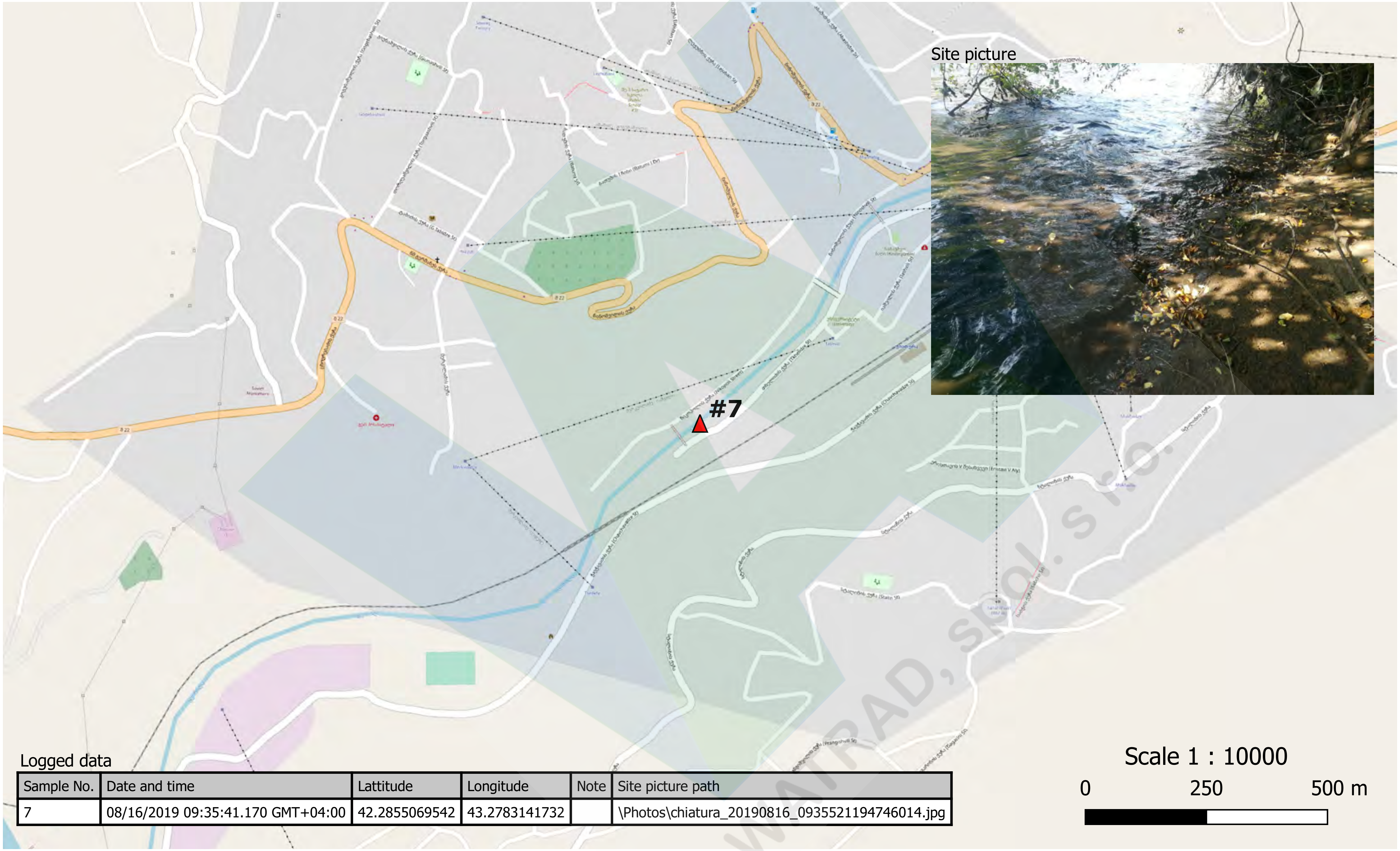

Site picture

Logged data

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Field loggbook

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Project: Reducing the impact of mine water on drinking water sources in the Kvirila River basin
Type of object: Sediment sample
Logged by: Michal Vaněček & Petr Novák

Sample No.	Sampling date
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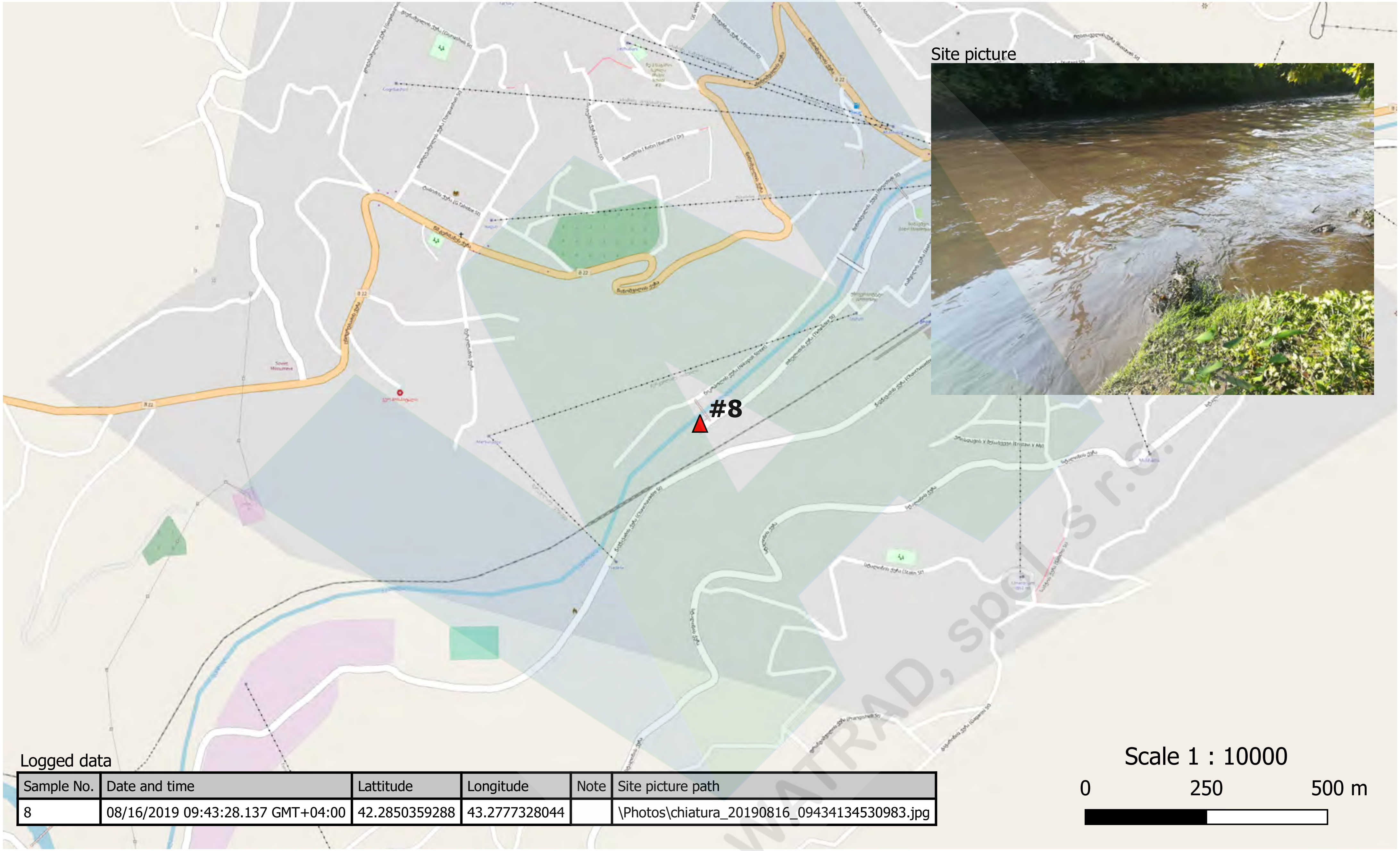

Site picture

Logged data

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Scale 1 : 10000

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Field loggbook

Project: Reducing the impact of mine water on drinking water sources in the Kvirila River basin
Type of object: Sediment sample
Logged by: Michal Vaněček & Petr Novák

Sample No.	Sampling date
9	08/16/2019 09:57:09.457 GMT+04:00

Site picture

Logged data

Sample No.	Date and time	Lattitude	Longitude	Note	Site picture path
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Field loggbook

WATRAD, spol. s r.o.
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Project: Reducing the impact of mine water on drinking water sources in the Kvirila River basin
Type of object: Wate sample
Logged by: Michal Vaněček & Petr Novák

Sample No.	Sampling date
218	08/24/2019 12:11:58.428 GMT+04:00

Site picture

Logged data

Sample No.	Sampling date	Lattitude	Longitude	River	Site picture path
218	08/24/2019 12:11:58.428 GMT+04:00	42.2871573755	43.2804753631	kvirili	\Photos\chiatura_20190824_1212401803594306.jpg

Scale 1 : 10000

0 250 500 m

Field loggbook - map of documentation points

Project: Reducing the impact of mine water on drinking water sources in the Kvirila River basin
Type of object: Object of interest
Logged by: Michal Vaněček & Petr Novák

Scale 1 : 50 000

0 1 2 3 4 km

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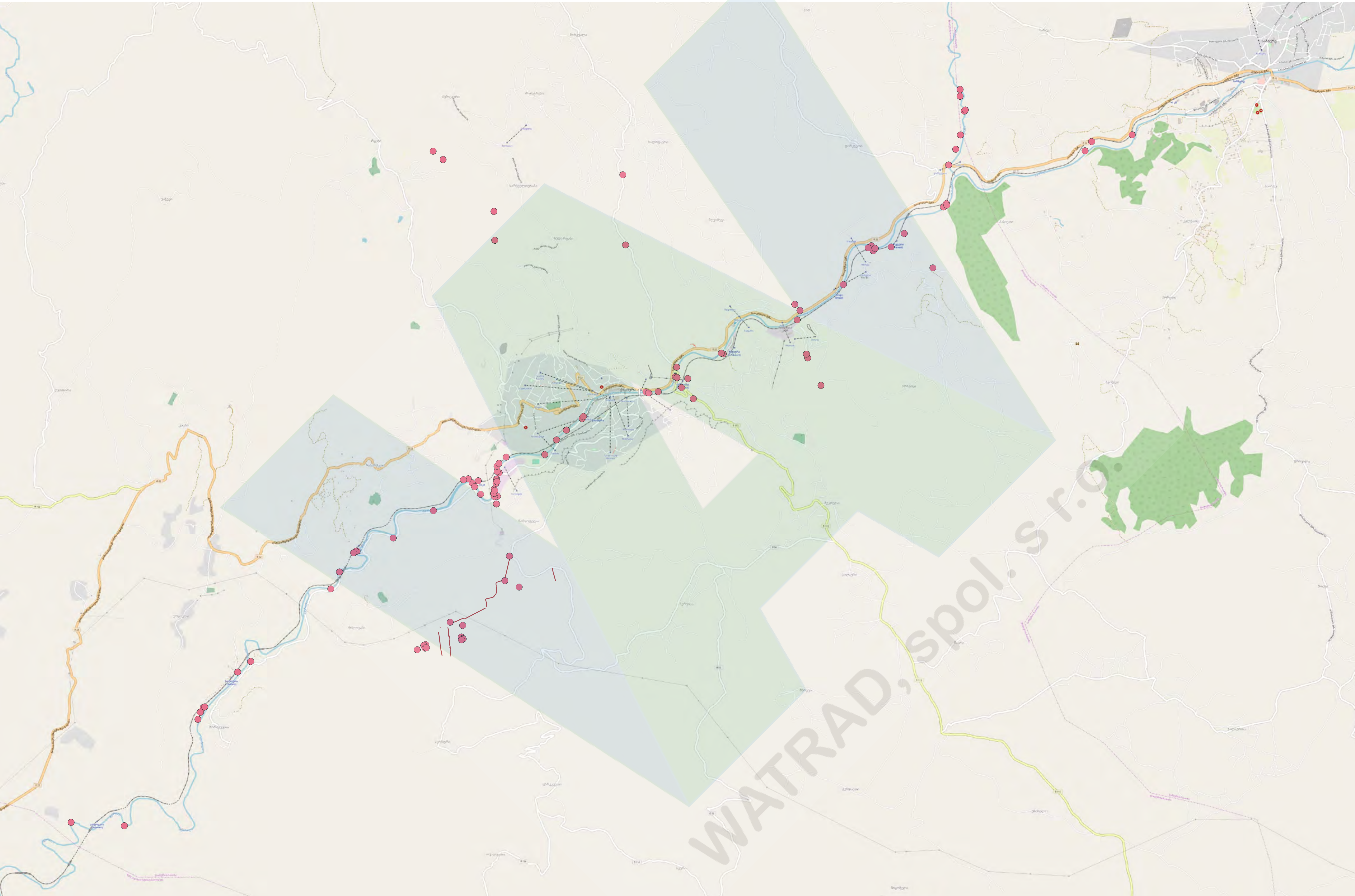
WATer dynamics Research And Determination



Field loggbook

Project: Reducing the impact of mine water on drinking water sources in the Kvirila River basin
Type of object: Object of interest
Logged by: Michal Vaněček & Petr Novák

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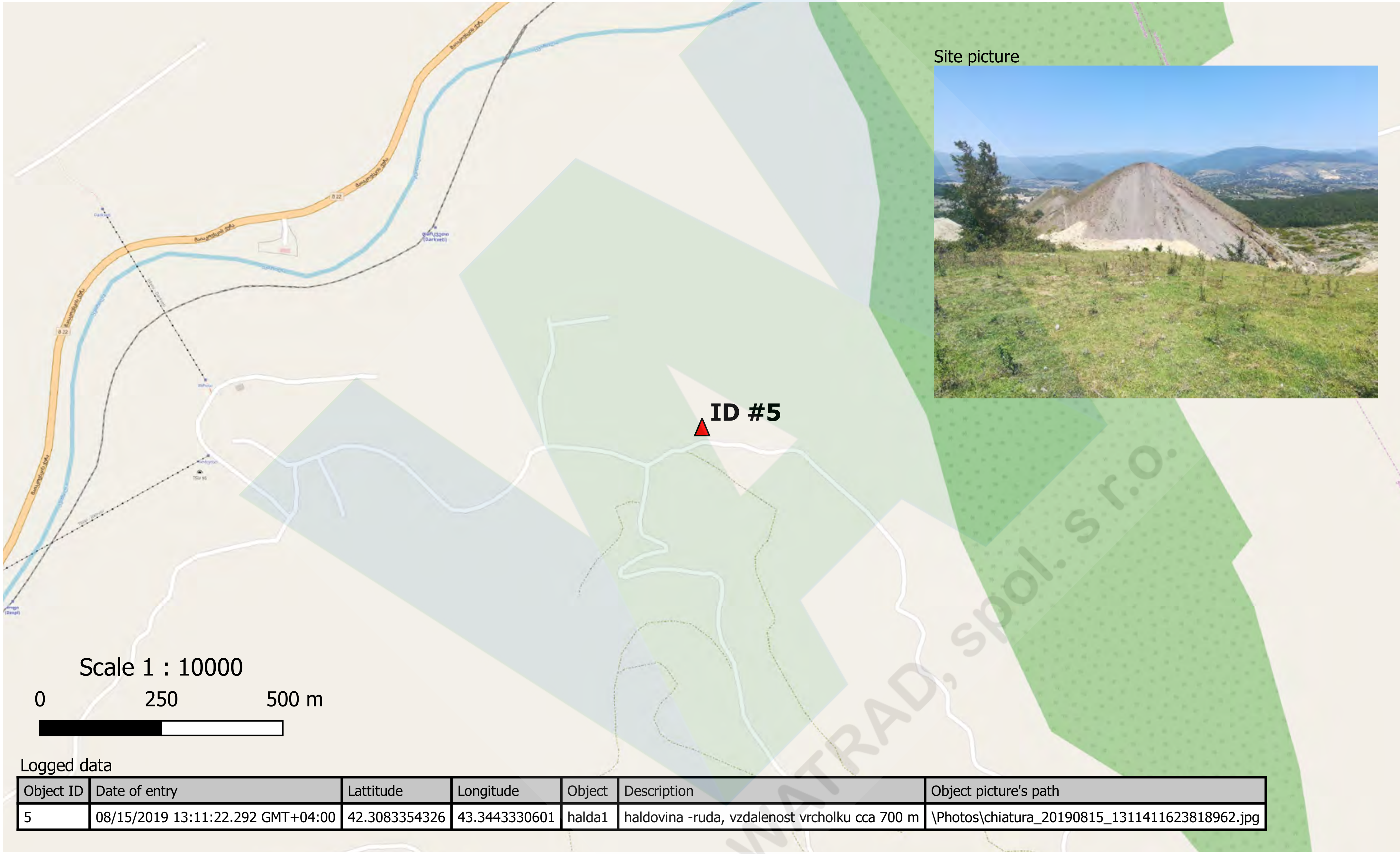

Logged data

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Field loggbook

Project: Reducing the impact of mine water on drinking water sources in the Kvirila River basin
Type of object: Object of interest
Logged by: Michal Vaněček & Petr Novák

Object ID	Date of entry
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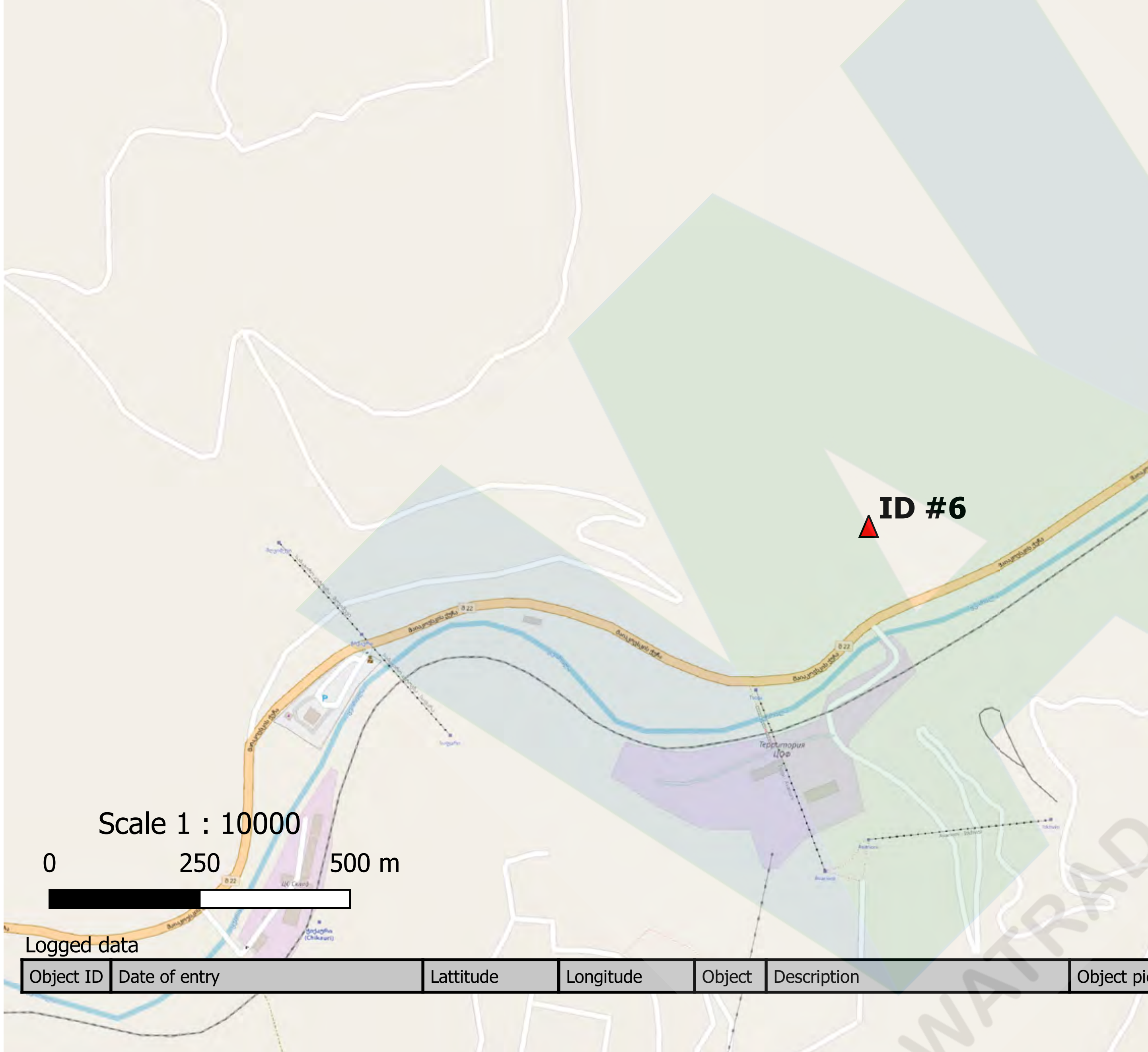
Site picture



Scale 1 : 10000

0 250 500 m

Logged data

Object ID	Date of entry	Lattitude	Longitude	Object	Description	Object picture's path

Field loggbook

Project: Reducing the impact of mine water on drinking water sources in the Kvirila River basin
Type of object: Object of interest
Logged by: Michal Vaněček & Petr Novák

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Object ID	Date of entry
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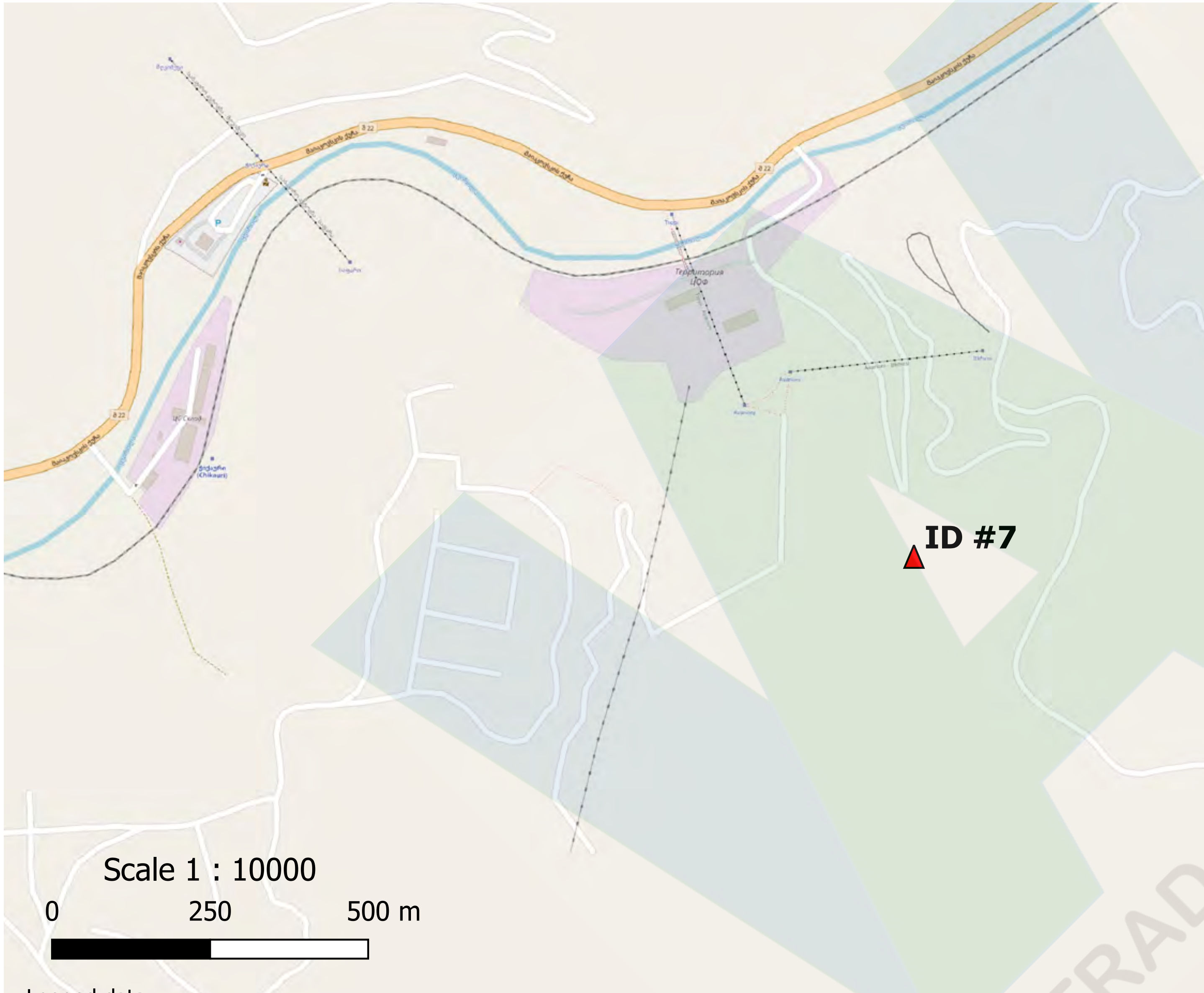

Site picture

Logged data

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Field loggbook - map of documentation points

Project: Reducing the impact of mine water on drinking water sources in the Kvirila River basin

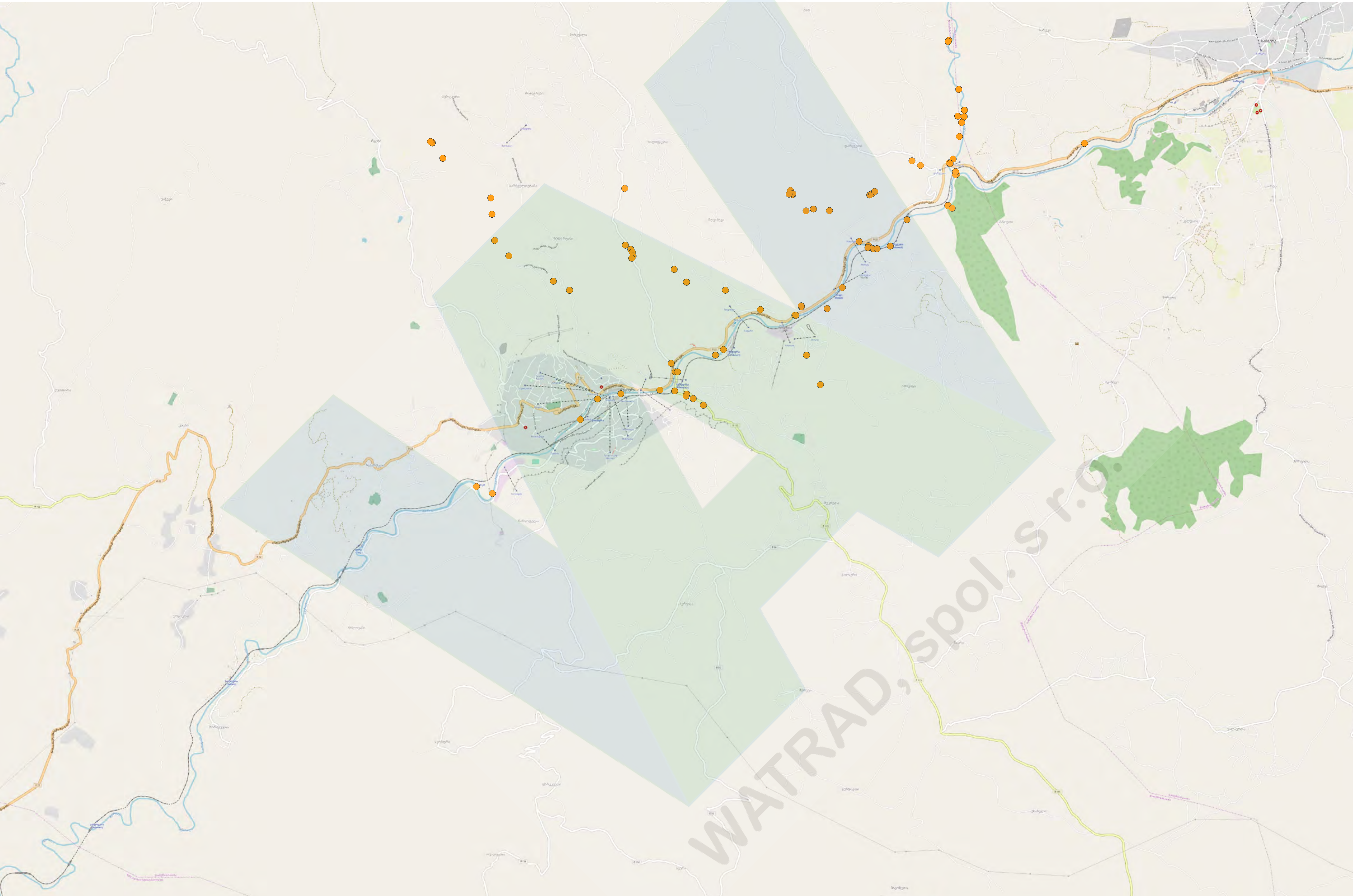
Type of object: General picture documentation

Logged by: Michal Vaněček & Petr Novák

Scale 1 : 50 000

0 1 2 3 4 km

WATRAD, spol. s r.o.
WATer dynamics Research And Determination



Field loggbook

Project: Reducing the impact of mine water on drinking water sources in the Kvirila River basin
Type of object: General picture documentation
Logged by: Michal Vaněček & Petr Novák

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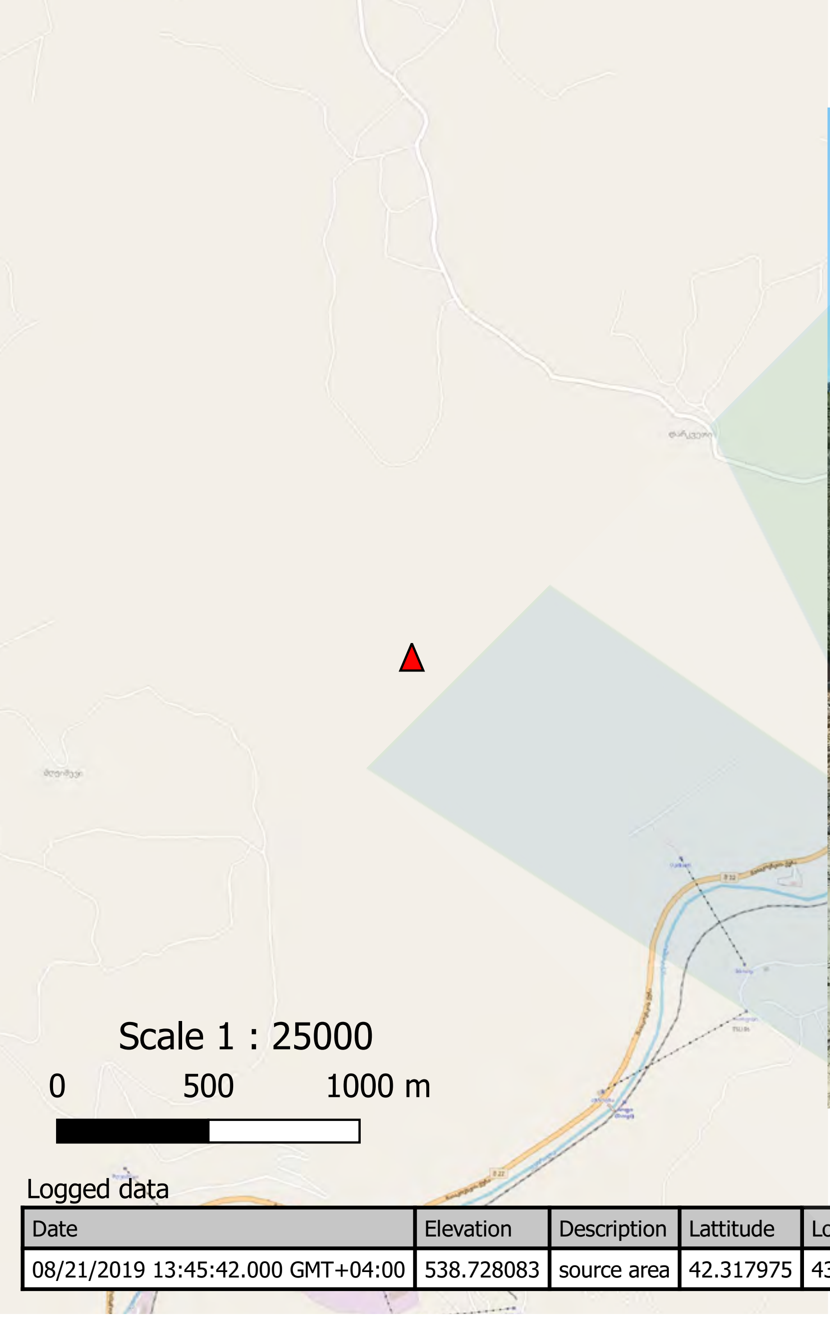

Site picture

Logged data

Date	Elevation	Description	Lattitude	Longitude	Picture's path
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Field loggbook

Project: Reducing the impact of mine water on drinking water sources in the Kvirila River basin
Type of object: General picture documentation
Logged by: Michal Vaněček & Petr Novák

Date
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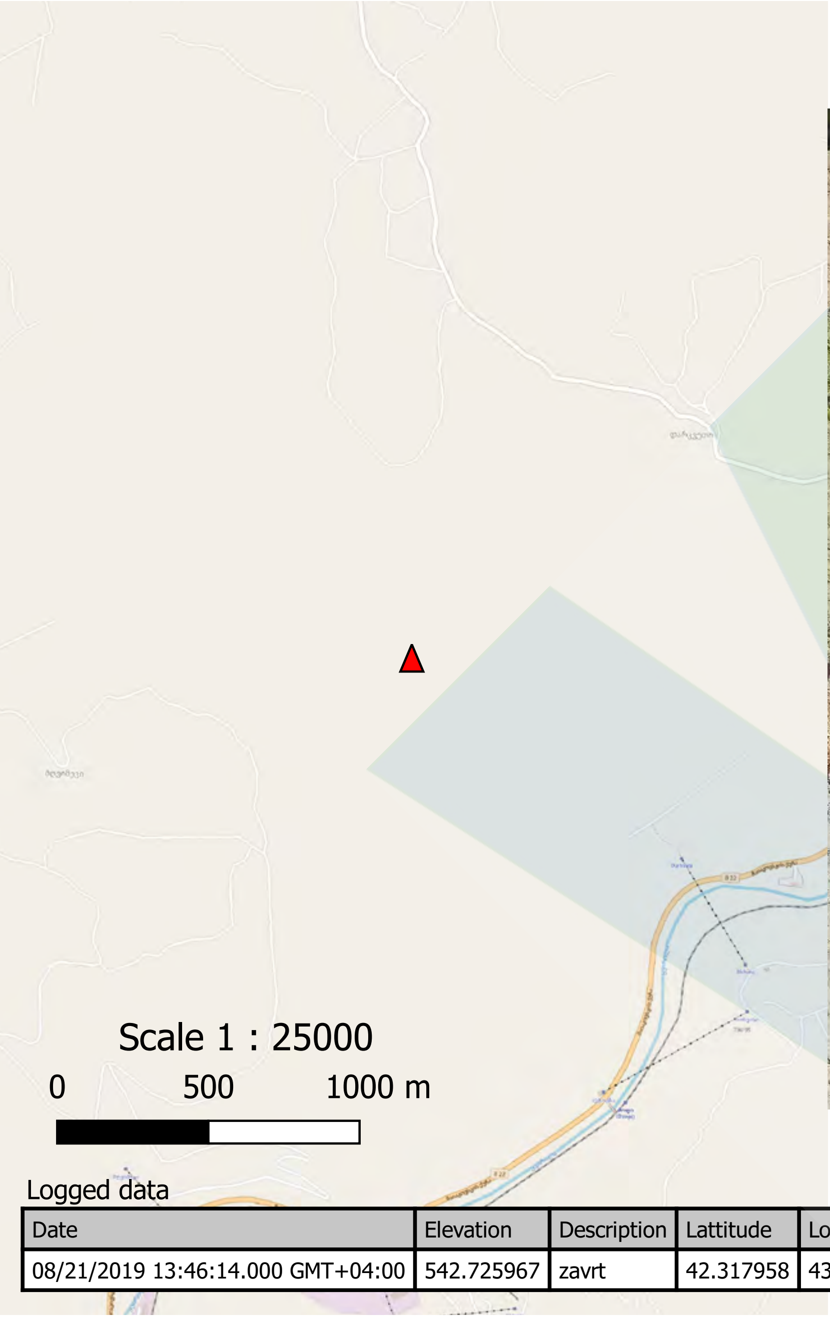
Site picture



Logged data

Date	Elevation	Description	Lattitude	Longitude	Picture's path
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Field loggbook

Project: Reducing the impact of mine water on drinking water sources in the Kvirila River basin
Type of object: General picture documentation
Logged by: Michal Vaněček & Petr Novák

Date
08/21/2019 13:47:37.000 GMT+04:00

Site picture

Logged data

Date	Elevation	Description	Lattitude	Longitude	Picture's path
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Field loggbook

Project: Reducing the impact of mine water on drinking water sources in the Kvirila River basin
Type of object: General picture documentation
Logged by: Michal Vaněček & Petr Novák

Date
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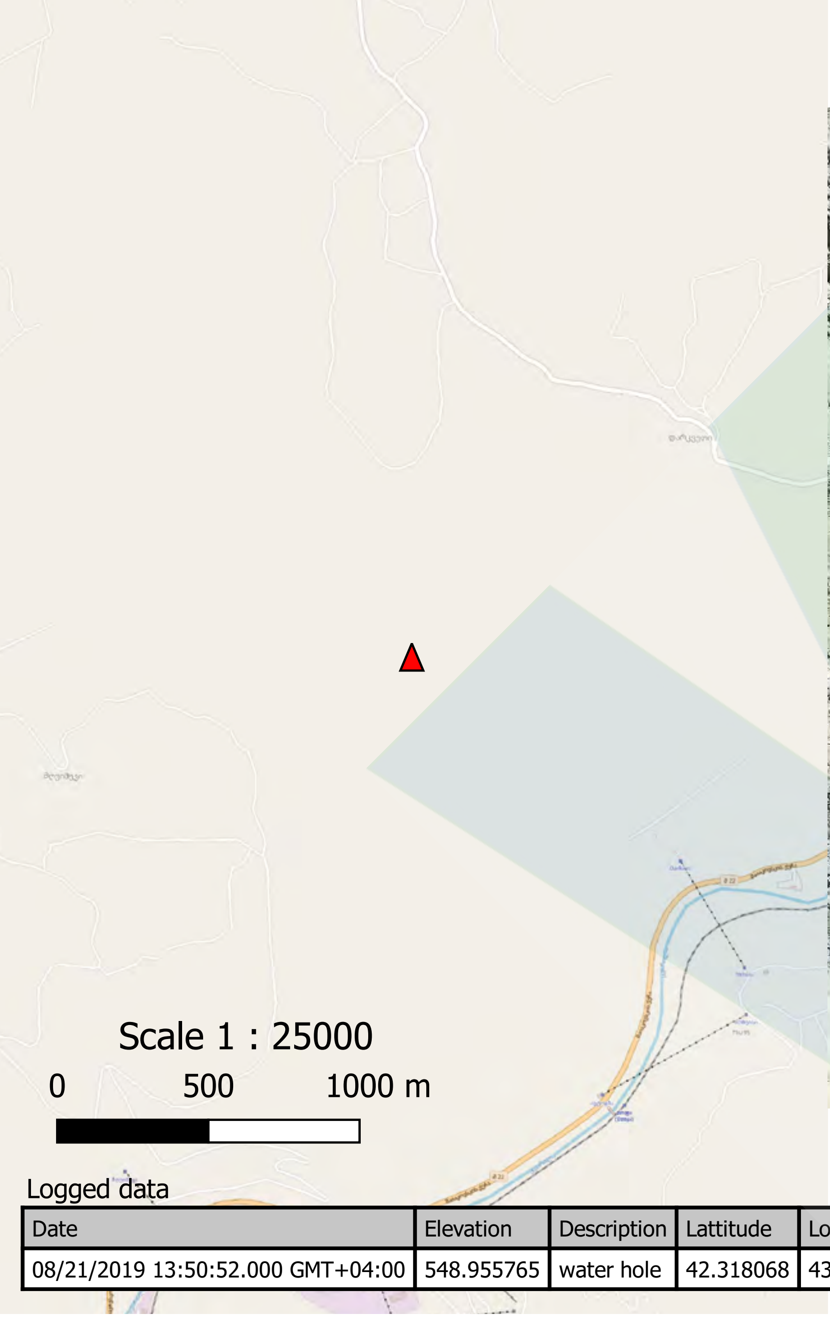

Site picture

Logged data

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Field loggbook

Project: Reducing the impact of mine water on drinking water sources in the Kvirila River basin
Type of object: General picture documentation
Logged by: Michal Vaněček & Petr Novák

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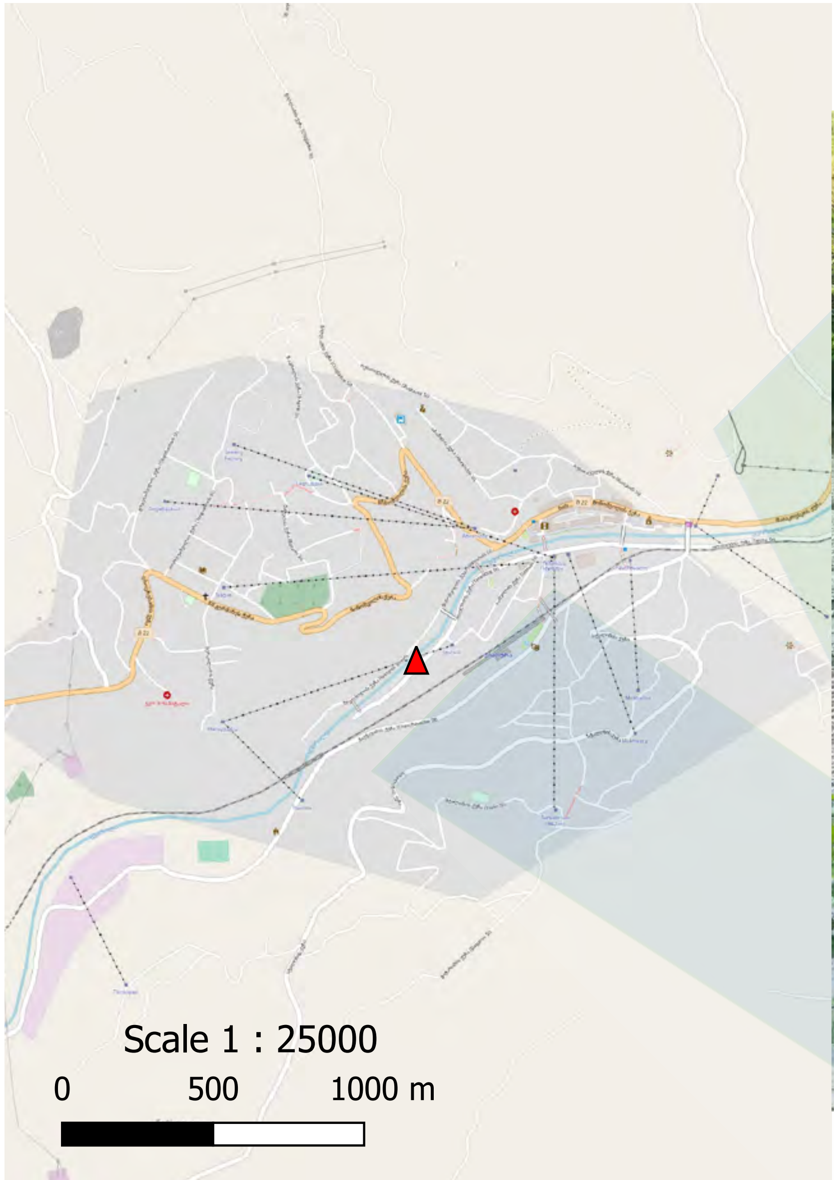

Site picture

Logged data

Date	Elevation	Description	Lattitude	Longitude	Picture's path
08/24/2019 12:30:25.000 GMT+04:00	361.120214	kvirila	42.286719	43.280259	\Photos\chiatura_20190824_122954916025022.jpg

Field loggbook

WATRAD, spol. s r.o.
WATer dynamics Research And Determination

Project: Reducing the impact of mine water on drinking water sources in the Kvirila River basin
Type of object: General picture documentation
Logged by: Michal Vaněček & Petr Novák

Date
08/24/2019 16:19:00.000 GMT+04:00

Site picture

Logged data

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Design proposal for cleaning the discharged technological water

Client:

Pardubice 2019, Czech Republic

Print No. **1**

Content

1. Introduction

This report describes main possible methods of treatment of the sludge arising from the manganese ore enrichment procedure. The main task is to propose a suitable, technically and economically viable model of process water management to prevent pollution of the Kvirila River, which serves as the main source of process water for enrichment plants.

The long-term pollution of the river is caused mainly by the discharge of untreated sludge after the ore enrichment process directly into the river Kvirila or into its tributaries. Most of the pollutants discharged in the sludge stream into the river are in undissolved form, but the concentration of dissolved compounds, including toxic barium, which has been documented on the basis of the samples taken, should also be considered.

To keep the recipient (Kvirila river) clean, it would mean running a large number of separate sludge treatment plants and ensuring sludge transport to the sludge landfill from each sub-treatment plant, which would be very demanding in terms of organization and difficult to control. The philosophy of selecting a suitable sludge management scenario is discussed in next document: *Chiatura: Reconstruction of Sludge Treatment Technology.*

Figure 1: Dalakhauri site with new ore treatment line

From a technical and economic reason it is for treatment and wastewater recycling process much more advantageous to centralize ore treatment plant to a few selected locations, so this solution is further elaborated in more details.

Establishment of these new central ore treatment plants means the creation of new suitable areas for storage of mined ore, storage of treated ore, the installation of new modern capacitive technology and controlled collection of polluted water for the subsequent purification process.

One of the selected central sites is existing Dalakhauri site with new ore treatment line (see photo), but so far without any water treatment technology. Process water is discharged into the Kvirila River.

2. River pollution characteristics

2.1 Sampling and analysis

The level of river sediments pollution is documented on the basis of the analysis of the samples taken in the period of field investigation. The results of this stage of work are described in another report. For the purposes of this document, water from the Kvirili River has been repeatedly taken from several locations. The results of chemical analyzes of river water are presented in this report.

Sample No.	209	209	212	212	213	213	218	218	General discharge standards for mining operations in the Czech Republic
Parameter	homogenised sample	filtered sample	homogenised sample	filtered sample	homogenised sample	filtered sample	homogenised sample	filtered sample	
pH (-)	7,38	-	7,97	-	7,75	-	7,75	-	6 - 9
TSS (105 °C)	33,00	-	442	< 5	8080	< 5	13500	-	40
TSS (550°C)	29,40	-	389	< 5	7130	< 5	12200	-	-
DIS (550°C)	109,00	-	166	149	206	159	234	-	-
Chloride (Cl^-)	1,97	-	10,7	11	3,59	4,78	4,87	-	-
Nitrate ($NO3^-$)	< 2	-	< 2	< 2	< 2	-	< 2	-	-
Sulphate (SO_4^{2-})	17,00	-	31,9	29,4	22,8	20,9	67,6	-	-
Carbonate (CO_3^{2-})	0,00	-	0	0	0	0	0	-	-
Bicarbonate (HCO_3^{2-})	139,00	-	172	170	169	170	198	-	-
Al	0,12	-	9,83	0,102	3440	0,412	89,7	-	-
As	< 0,01	-	< 0,01	< 0,01	1,14	< 0,01	< 0,01	-	0,5
B	0,028	-	0,081	0,108	1,56	0,103	0,131	-	-
Ba	**0,00646**	**-**	**2,66**	**0,3**	**477**	**0,553**	**16,6**	-	-
Be	< 0,00020	-	< 0,00020	< 0,00020	0,0822	< 0,00020	0,0025	-	-
Ca	36,90	-	56,9	46,3	1360	51,9	116	-	-
Cd	< 0,0020	-	< 0,0020	< 0,0020	0,0632	< 0,0020	< 0,0020	-	-
Co	< 0,0020	-	0,0138	< 0,0020	2,73	< 0,0020	0,110	-	-
Cr	< 0,0020	-	0,0125	0,0025	3,98	0,0051	0,111	-	-
Cu	0,0023	-	0,0218	0,0370	6,29	< 0,0020	0,307	-	1
Fe	0,114	-	12,3	0,0242	2520	0,175	94,0	-	3,0
Hg	< 0,010	-	< 0,010	< 0,010	< 0,010	< 0,01	< 0,010	-	-
K	0,91	-	3,49	0,674	381	0,875	15,8	-	-
Li	< 0,0020	-	0,018	< 0,0020	2,7	0,0136	0,122	-	-
Mg	4,68	-	12,8	8,84	734	5,01	42,8	-	-
Mn	**0,0045**	**0,00053**	**23,0**	**0,0209**	**9900**	**0,0962**	**476**	**0,00487**	**1,0**
Mo	< 0,0030	-	< 0,0030	< 0,0030	1,07	< 0,003	0,0429	-	-
Na	12,60	-	20,3	18,2	47,6	12,9	14,8	-	-
Ni	< 0,0050	-	0,127	< 0,0050	32	< 0,005	1,55	-	-
P	< 0,050	-	0,756	< 0,050	95	< 0,05	5,12	-	10
Pb	< 0,010	-	< 0,010	< 0,010	1,84	< 0,1	< 0,1	-	0,5
Sb	< 0,020	-	< 0,020	< 0,020	< 0,20	< 0,02	< 0,2	-	-
Se	< 0,030	-	< 0,030	< 0,030	4,61	< 0,03	< 0,3	-	-
V	< 0,0020	-	0,0765	< 0,0020	20,7	< 0,002	0,843	-	-
Zn	< 0,0030	-	0,0348	0,0468	8,78	0,0694	0,392	-	3

DIS - Dissolved Inorganic Substances
TSS - Total Suspended Solids

Sample description:
209 Kvirila - clean water upstream Chiatura
212 Polluted water downstream refinery plant (right side tributary)
213 Polluted process water ("schlam") on the output of rafinery plant
218 Kvirila in the town

Table 1: Analyzes of water samples taken in July 2019.

2.2 Negative influence of manganese generally

The importance of manganese removal from wastewater discharged into surface waters is given by its negative impact on the environment and also on human health.

Originally, the occurrence of manganese in surface water, which serves as a source of drinking or service water was considered only as an unpleasant circumstance burdensome process for water treatment and causing blockage of the water distribution pipelines due to manganese bacteria activity. Except that manganese causes dark brown spots on materials that come into contact with Manganic contaminated water, and negatively affects the organoleptic properties of water, the impact of this element on human health has also begun to be discussed.

"…… For example, Dr. Brad Racette of the University of Washington in St. Louis, Missouri, has studied welders who are routinely exposed to high levels of Mn and found a correlation with increased occurrence of manganese — a long-recognized syndrome that resembles Parkinson's Disease, with symptoms that range from slurred speech and loss of balance to an emotionless, mask-like set of the face. The inhalation of Mn appears to kill n€ons in a part of the brain called the striatum, which is also affected by Parkinson's Disease. …………….. n€al damage can occur in children exposed to well water with high manganese levels. A study of 362 students in Quebec noted that the average IQ of children who consumed well water that was in the top 20 percent for Mn content had IQs an average of 6 points lower than their peers whose water had lower levels of manganese."

Source: "The Hidden Dangers of Manganese In Drinking Water"; Water Online, May 21, 2018

2.3 Proposal of contaminants removing method

As described and justified below, the wastewater treatment method (sludge) will consists the separation of solids in the form of concentrated sludge, its dewatering and the supply of treated (purified) water back to the ore enrichment system.

So, in this case, the waste water treatment process can be defined as a sludge handling and water recycling system.

Based on analyzes of samples taken above and below the point of contamination, it can be stated that surface pollution by sediments and leaches from the surrounding terrain is minimal. The main source of pollution of the Kvirila stream is sludge originating from the wet manganese ore processing. After grinding, the ore is treated by a flotation process, where the sludge is discharged uncontrollably into the river.

Manganese, barium and aluminum can be identified as the main pollutants. Manganese occurs predominantly in undissolved form (as shown by analyzes from samples taken before and after filtration) and its elimination from the system will be relatively simple, similar to that of aluminum.

Barium could be a problem in case, if would be cleaned water discharged out of closed system into the river. In the first set of samples (25 July 2019) it occurs in the Kvirila stream in lower concentrations than in the second set (24 August 2019), but the environmental quality standard in this indicator in the flow, which is set according of €opean standards on 0.18 mg/L (for example, a sample taken from a right-side tributary - Ba concentration of 0.9 mg/L observed in a homogenized sample and 0.344 mg/L in a filtered sample. Other cations in this sample - Mn 21.5 mg/L, Al 8.42 mg/L. Unfortunately, there is no analysis of Ba from a sample taken from the river in the city.

In the second set of samples the concentration of Mn, Al and Ba is in the Kvirila stream higher in order, in the sample taken in the city it was found: Mn 476 mg /L, Al 89.7 mg /L, Ba 16.6 mg /L, in sample from right side inflow (sample from the same place as mentioned in the previous paragraph) was found: Mn 23 mg/L, Al 9.83 mg/L, Ba 2.66 mg/L, in the filtrate from this sample then Mn 0.02 mg/L, Al 0.102 mg/L, Ba 0.3 mg/L. Above the contamination site, Kvirila shows a minimum concentration of: Mn 0.0045 mg/L, Al 0.121 mg/L, Ba 0.00646 mg/L.

The above evaluation of the analysis results shows that it is sufficient to separate the suspended solids to allow water to be recycled back to the ore enrichment process. If the water after the separation of solid particles was also used for purposes other than the wet treatment of manganese ore or would be discharged into the river, it would also be necessary to address the removal of barium ions. These can be removed relatively easily but discharging water outside the ore enrichment system is not considered (on the contrary, water will have to be added to the system to cover losses), this report does not address the removal of Ba ions further.

An essential part of the sludge treatment technologies must also be equipment for dewatering of captured sludge to allow its transport to a landfill.

3. Sludge handling & process water recycling system

3.1 Technological part

In generally, there are two based options of the solution: Scenario No. 02 and Scenario No. 03.

Scenario No. 02 - It is based on pumping the collected sludge suspension into the central sludge accumulation (landfill) using a special piston pump. In this case, the purified process water will be withdrawn back into the system from a separate part of the central sludge accumulation – Ghurghumela Sludge TSF.

Scenario No. 03 – At each factory there will be a pumping technology that will pump the liquid suspension – tailing slurry – to the tailing slurry pipeline. Tailing slurry will flow to the central pumping station on the site of the factory marked 1 (see Figure Scenario No. 3) where will tailings be dewatered. Dry tailings will be transported by conveyor belt to the Ghurghumela Sludge TSF.

The landfill (reservoir) is in both cases the same place, main difference is in the way of feeding of the sludge into storage area.

3.1.1 Scenario No. 02

Process of sludge treatment will consist from coarse pretreatment (gravel removing equipment), accumulation and transport of sludge in form of suspension into storage area. Unlike the Scenario No. 03 sludge dewatering occurs only by gravitational sedimentation at the site of the deposit.

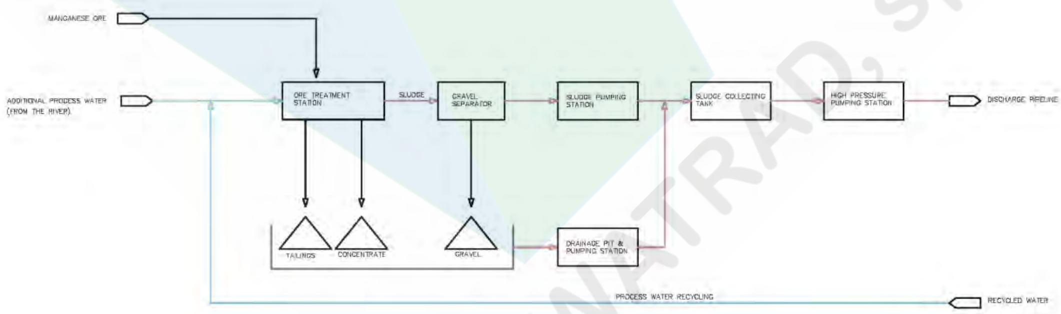


Figure 2: Sludge accumulation in central sludge handling system flow chart

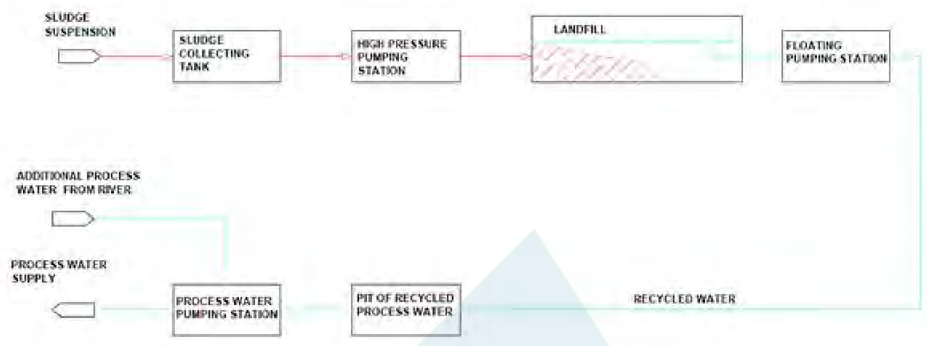


Figure 3: Flow chart of sludge accumulation in tailing pond

- Flowchart of returning clean water from the landfill

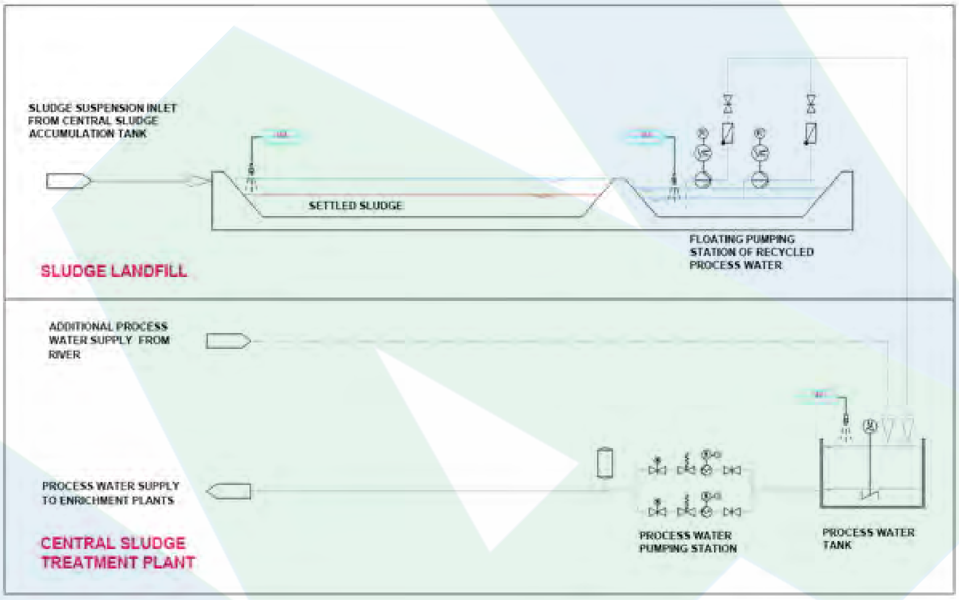


Figure 4: Accumulation and distribution system of treated water

The main technological parts will be as follows:

- Coarse mechanical pre-treatment and collection of sludge from the ore treatment process for each enrichment plant (four enrichment plants are assumed)
- Sludge accumulation in central sludge handling system
  Two tanks equipped by stirrers. Tanks will be placed in the central sludge treatment plant. Purpose of these tanks will be collection of sludge from all enrichment plants, compensation of sludge flow irregularity and ensuring of smooth operations of following parts of technology, i.e. high-pressure pumping station
- High pressure sludge pumping station
- Accumulation and distribution system of treated water
  Solids free water will be collected in concrete tank and through the pumping station will be supplied to reusing into enrichment plants.

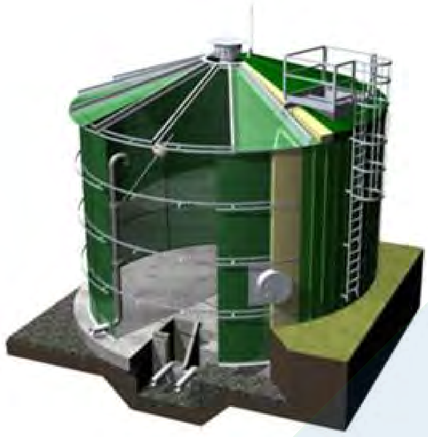


Figure 5: Sludge accumulation tank

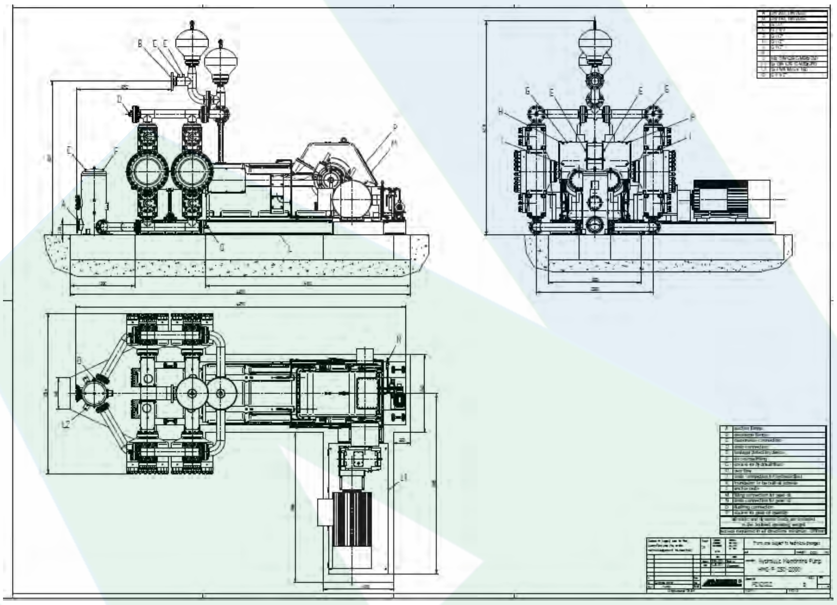


Figure 6: High pressure pump for sludge suspension transport to a landfill

3.1.2 Scenario No. 03

Process of sludge treatment will consists coarse pretreatment (gravel removing equipment), accumulation, settlement process to get thickened sludge, sludge dewatering process and transport of sludge to the storage area.

The main technological parts will be as follows:

- Coarse mechanical pre-treatment for each enrichment plant (four enrichment plant are assumed)
  The stream of sludge from after ore treatment process will be led by gravity into coarse gravel separator which will be constructed as concrete pit divided into two parts. First part will be equipped by system for the extraction of settled material. The purpose of this measure its protection of following parts of technological line (pumps) against damage. Second part of gravel separator will be served as a pit from which will be sludge pumped into collection tanks in central sludge treatment plant. For possible arrangement see picture below.

- Collection of sludge from the ore treatment process
  Two tanks equipped by stirrers. Tanks will be placed in the central sludge treatment plant. Purpose of these tanks will be collection of sludge from all enrichment plants, compensation of sludge flow irregularity and ensuring of smooth operations of following parts of technology, i.e. settlement tanks and filters presses. Based on available data we assume volume of each tank approx. 1400 m3.
- Mechanically scrapped settling tanks
- Homogenization tanks
  Filter press feed tank, to ensure equal solids concentration entering filter press.
- Sludge dewatering system
  Battery of filter presses of needed capacity to ensure dewatering of thickened sludge approx. up to 70% of dry material. Based on available data about sludge amount production we assume installation of 6 filter presses with capacity of approx. 22 m3 of dewatered sludge per each press for one cycle. Assumed time period of one cycle is 1 hour. Filter presses will be equipped for fully automatic operation.
- Transport of dewatered sludge to the storage area
  Pipe conveyor connecting central sludge treatment plant and sludge landfill – see to civil part of this report.
- Accumulation and distribution system of treated water
  Solids free water will be collected in concrete basin and through the pumping station will be supplied to reusing into enrichment plants.

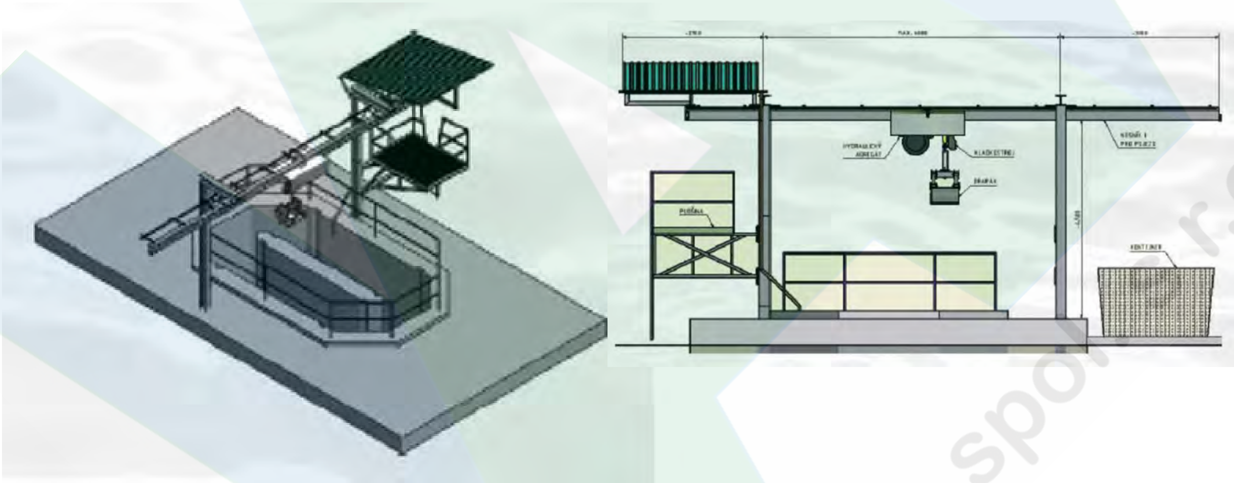


Figure 7: Coarse gravel separator

Figure 8: Tank equipped by stirrers

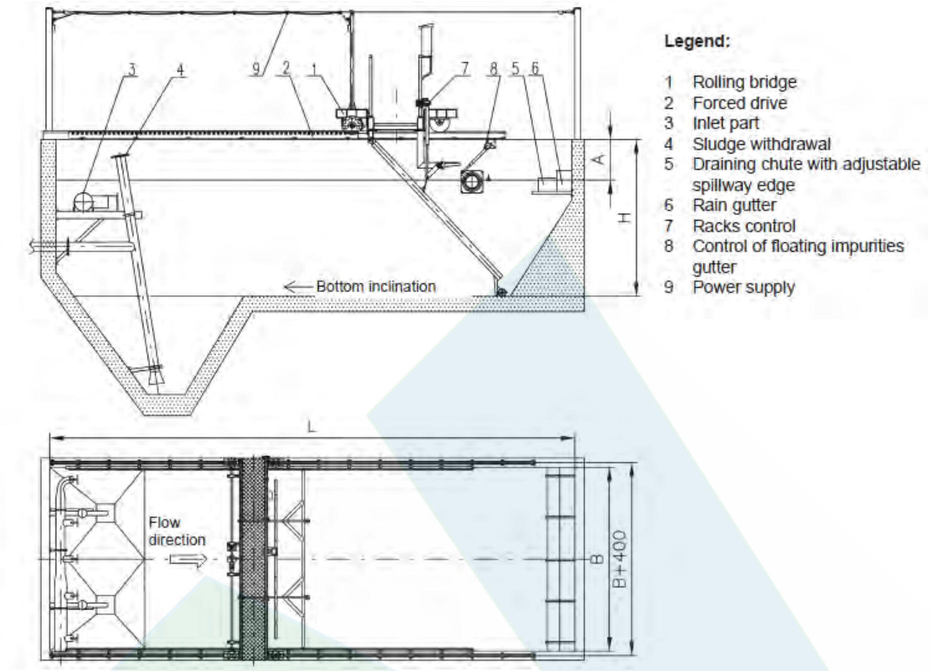


Figure 9: Mechanically scrapped settling tanks

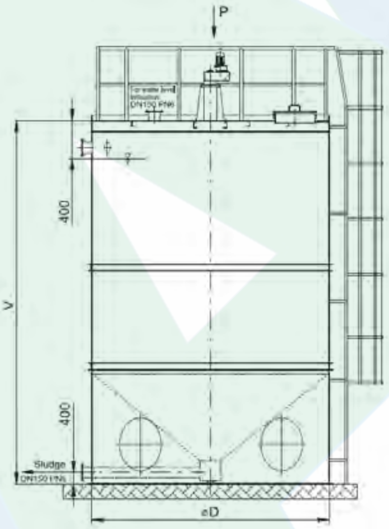


Figure 10: Homogenization tank

3.2 Civil part

On the base of sightseeing of Chiatura ore treatment sites, was proposed one of possible solution, selection of four places Factory No.1 to Factory No. 4 along the Kvirila river where new ore treatment plant with waste water/sludge suspension collection points are considered. Selected places are marked at attached schemes.

From this collection points will sludge suspension be transported (through gravel extraction facility) by pipes along the Kvirila river downstream to the site of Factory No.4, where will be collected and transported to the Ghurghumela sludge reservoir.

The waste water/sludge suspension from the individual new ore treatment Factory No. 1 to Factory No. 4 is collected through the pipeline to the accumulation tanks at the treatment plant Factory No. 4. Total length of the pipeleine between site No. 1 to No. 4 is approximately 9,5 km. It is considered that pipeline will be combination of plastic (HDPE) and steel material. Plastic pipes will be applied for underground part of pipes, steel material for aboveground pipes. The underground pipeline will prevail, each 100 m will be fitted by inspection shaft - for the inspection and cleaning of individual sections of the pipeline

The sludge transport to Ghurghumela sludge reservoir will be conditioned by renewal of banks of the dam, increasing the height of the existing dam body and establishment transport from site of Factory No.1. The reconstruction of the Ghurghumela sludge reservoir must be preceded by a proper and detailed geological survey of the dam body.

The concept of the project is based on the assumption that the tailing dam is stable. If the engineering-geological survey finds tailing dams unstable, it will be necessary to develop a different concept. Reconstruction of the Ghurghumela sludge reservoir is an integral part of the whole Chiatura water treatment process. Technical solution of this one is in detail described by other report.

As previously mentioned in case of siting the Dallakhauri sludge reservoir transport by new pipelines and special vehicles is not considered, due to fact that this place had not been reflected in the EIA report; nor had the assessment of the environmental and social impact of the sludge reservoir been presented.

3.2.1 New enrichment plants

Possible sites of the new enrichment plants / Factories No.1 to No. 4 on individual selected places and places in detail are presented by following schemes/photos:

Sludge transport from site No.4 to Ghurghumela sludge reservoir is proposed for two sludge treatment processes as Scenario No. 02 and Scenario No. 03.

3.2.2 Scenario No. 02 - pumping station

This technology point consists from Sludge accumulation tanks collected sludge suspension and pumping station transported sludge suspension to Ghurghumela sludge reservoir (see picture).

The fundamental difference is that the sludge dewatering process is realized only gravitationally (natural sedimentation process) in the sludge lagoon and the water for recycling is taken from a separate part of this lagoon. In this case there is no need for a pipe conveyor and a sludge dewatering system (filter presses and accessories).

Sludge accumulation tanks are the same type as tanks described for Option 1. The sludge accumulation tanks are connected into sludge pumping station.

Sludge pumping building is lightweight steel structure fixed to the strip foundations equipped by two pumps. Pumps are supported by RC foundation slab supported by compacted gravel bed. Around the pumps is sloped RC floor.

Discharge pipeline will be made of steel (main part), a final part that will no longer be loaded to much high pressure will be made of plastic (HDPE) allowing simply modification point of inlet into sludge lagoon, as it will progress process of its filling by sludge. Pipeline will be mostly situated on the ground, in case of crossing underground or aboveground, supported is by RC thresholds. Start of the sludge suspension deposit is assumed from the dam body towards end of the dam.

Figure 11:

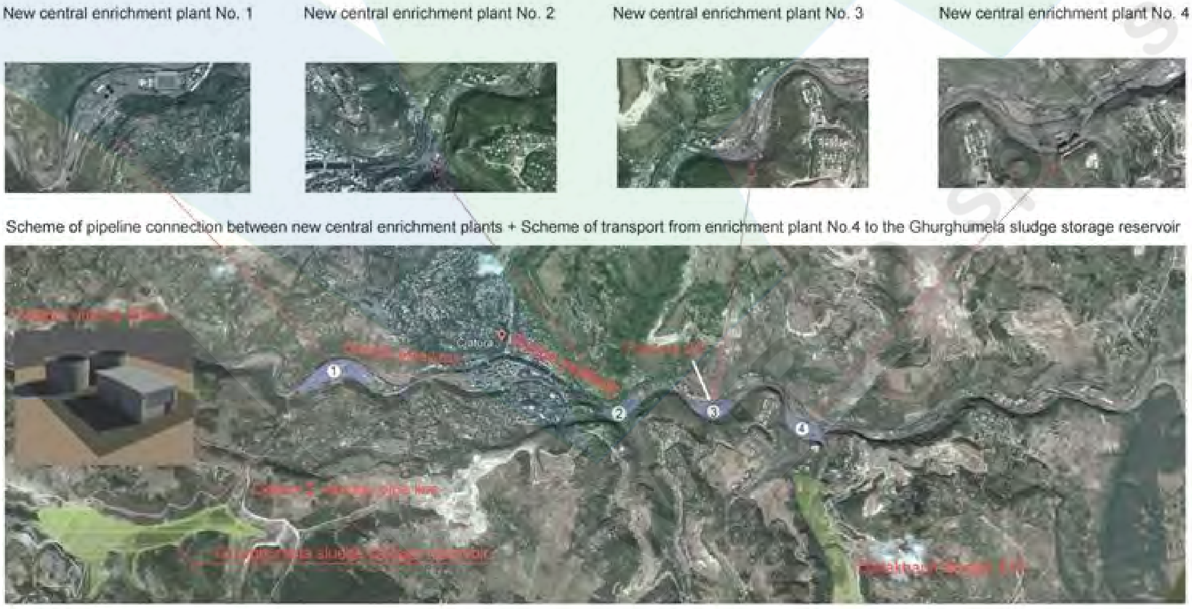


Figure 12: Scenario No. 02 – sludge pumps + discharge pipeline

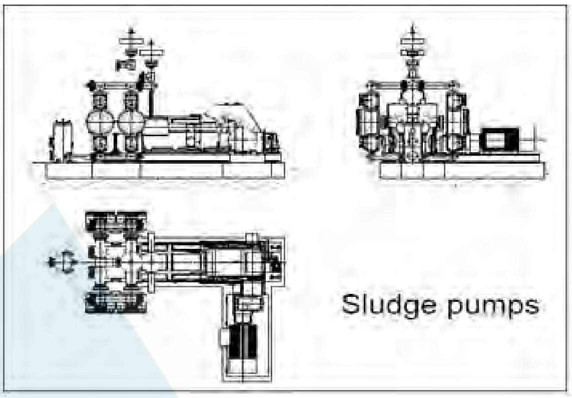


Figure 13

At the end of the dam the sludge landfill will be separated by spillway from separated reservoir of water almost free from solids. Water from this part of lagoon will be through pipeline returned to the ore treatment process. The pipeline will be made of the steel, underground part HDPE material.

3.2.3 Scenario No. 03 – conveyor belt

The sludge treatment line consist from Sludge accumulation tanks with sludge suspension, Mechanically scraped sludge settling tanks, Homogenization tanks and Press filters. Dewatered sludge is transported by pipe conveyor to Ghurghumela sludge reservoir (see picture).

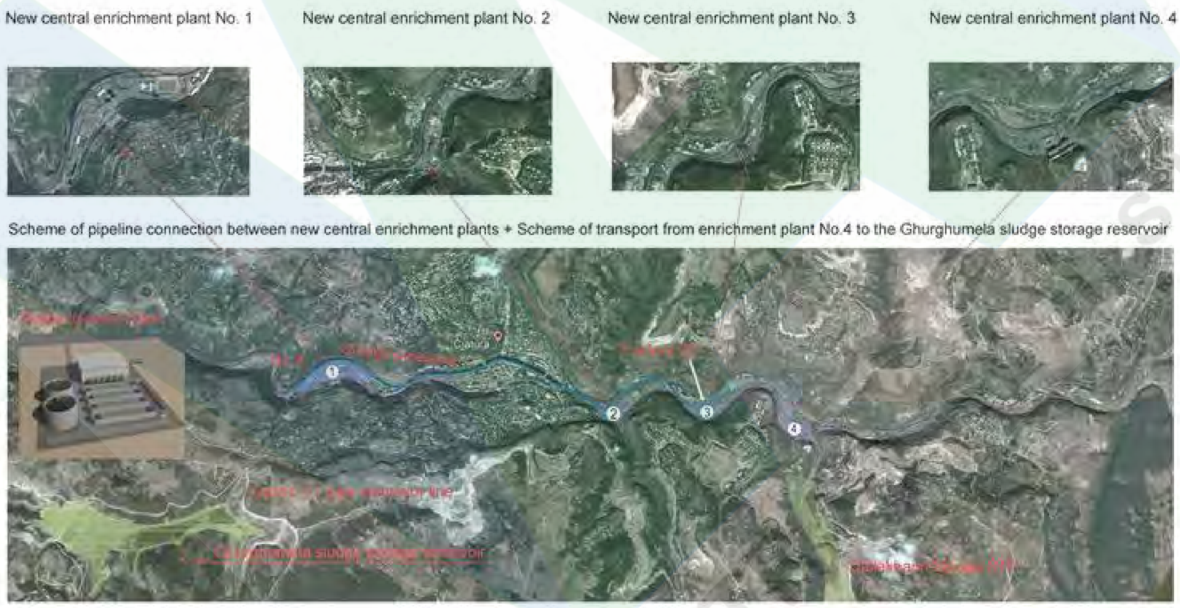


Figure 14: Scenario No. 3 – press filters + pipe conveyor

Sludge accumulation tanks are from steel material - prefabricated and enameled. Tanks are fixed to RC foundation slab supported by compacted gravel bed. Sludge accumulation tanks are connected to the clarifiers.

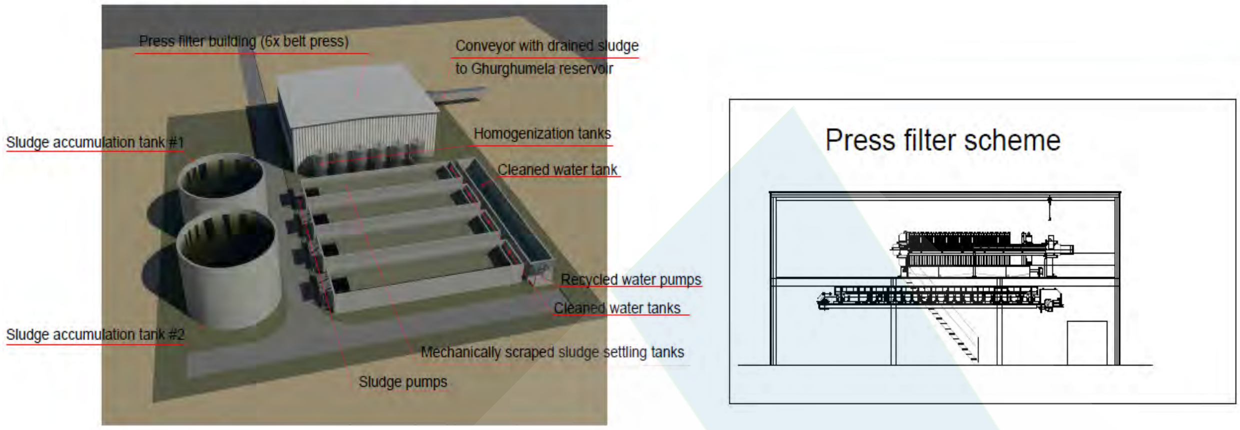


Figure 15:

Settlement tanks are aboveground monolithic RC structure fitted with sludge scraper and pumps transporting sludge suspension to homogenization tanks. Water after settlement process water flows gravitationally into cleaned water basin and following is reused in enrichment.

Sludge storage tanks are fixed to RC foundation slab supported by compacted gravel bed.

Sludge from the homogenization tanks goes into press filter building with filter presses. Press filter building is lightweight steel structure fixed to the strip foundations. Press filters are supported by RC foundation slab supported by compacted gravel bed. Around the press filters is sloped RC floor.

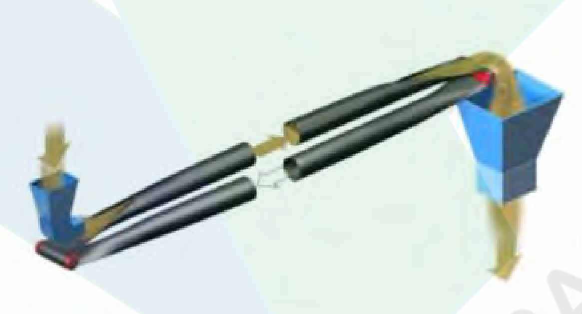


Figure 16:

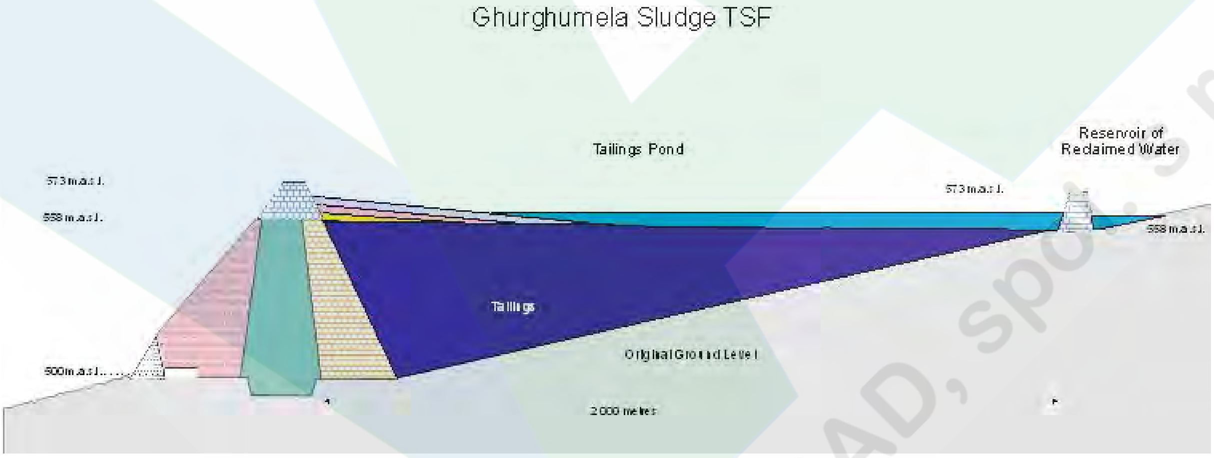
From press filters is drained dewatered sludge transported to Ghurghumela sludge reservoir by means of dust-free pipe conveyor. As shown on the attached picture, pipe conveyor line will be largely supported by aboveground steel "bridges". Supporting steel structure belongs from the pipe bridge supply, when civil structure contains concrete bridge foundations.

Figure 17:

Deposit of the sludge which comes from the conveyor into the dam area is assumed mechanically from the end of dam towards dam body.

4. Ghurghumela sludge tailing dam

The Ghurghumela Sludge (tailings pond) is located in a valley southwest of Chiatura. The valley is dammed by about 50 m high dam. The capacity of the tailing pond is at present not sufficient for more than three to five years of operation. The current dimensions of the tailings pond are approximately 2,000 m long, a maximum width of 800 m and an estimated maximum depth of 50 m. The body of the outer dam is approximately 320 m long and 408 m wide. The core of the dam is 135 m x 408 m. The body of the inner dam is 50 m x 408 m.



The sludge can be put into operation very quickly provided that the existing tailing dam is assessed as stable based on an engineering-geological survey. If the dam is assessed as stable, it will be appropriate to increase it by 15 m and increase the storage capacity of the valley. The tailing dam can be raised during the mud operation. From the safety point of view, this location is very suitable.

In order to mark this site as perspective for further use, it is necessary to assess the stability of the tailing dam.

5. Risk

It is necessary to define the risk associated with sludge storage. Risk can simply be defined as the effects of something on objectives; such effects might be positive or negative and may be multidimensional, incorporating aspects such as health and safety, environment, finances, and social elements. It could also define as the potential loss in health and safety, environment, economic associated with an event or activity. Potential risks associated with mine tailings are detailed in following table. The both geochemical and geotechnical risks are included in the potential risks associated with mine tailings.

Table 1: Potential risks associated with mine tailings

Phase	Potential risks
Operation	Leaking of tailings slurry pipeline
	Geotechnical failure
	TSF overflow
	Seepage through containment wall
	Seepage infiltration to ground water
	Particulate Matter (PM): dust or gas emissions
	Interaction of wildlife or livestock with tailings
	Mine acid pollution into the water: ground water and surface water
Closure	Erosion of containment wall
	Spillway failure
	Overtopping by rainfall run-off
	Failure of land cover system on tailings surface

These risks should be managed and monitored to prevent or eliminate the hazards that may occur. Managing and monitoring risks is one of the steps outlined in risk management principles. Risk management can be streamlined into seven stages: problem definition, data and information collection, risk identification, causes and controls, assessment and analysis, planning and action, and monitoring and review. This cycle is a continual improvement process where the monitoring and review stages act to produce further improvement initiatives.

Worldwide experts argue that the application of risk management will provide advantages for tailings management. These advantages are as follows:

1. Minimize tailings incidents associated with tailings transportation and storage,
2. Minimize the likelihood of environmental, health, safety, and business risks,
3. Minimize the risks associated from the initial mine tailings step, planning and design, through to the final step of post-closure,
4. Prioritization of having an action plan associated with hazards or risks in place.

Proposal

Ghurghumela: Stability Assessment of the Tailing Dam

Client:

Pardubice 2019, Czech Republic

Print No. **1**

Content

1. Introduction

A typical method of redeveloping an existing dam by expanding its reservoir capacity is raising the height of the dam body. Improving dam function in this way effectively lowers the costs and permits the use of the effective capacity obtained by raising the dam height. The aim of the work specified in this offer is to provide input data for the design of raising the height of the tailing dam body by 15 m.

To calculate the stability of the raised dam body and the subsequent elaboration of the design documentation to increase the dam body by 15 m will be necessary to determine for all dam body construction material geotechnical parameters. On site investigation and laboratory analysis will focus on the following data:

- soil material and classification,
- effective shear strength parameters
- effective angle of internal friction of soil in degrees
- effective cohesion (cohesiveness)
- natural soil gravity in kN / m3 above groundwater level,
- hydraulic conductivity of saturated zone.

In order to obtain the required quantities, we propose to carry out a geological survey in the range of:

- non-destructive geophysical investigation,
- engineering-geology survey,
- establishment of a monitoring network,
- hydrogeological investigation,
- geodetic survey.

2. Structure of works

The work will be carried out in 3 stages.

- 1st Stage: Geological site investigation
- 2nd Stage: Design
- 3rd Stage: Monitoring

2.1 1st Stage: Geological site investigation

2.1.1 Geophysical investigation

The aim of the geophysical measurements will be to carry out a basic description of the material composition of the dam and its homogeneity, a detailed survey of the surroundings of the possible problematic spots and drainage system. The survey will be conducted using a combination of the following geophysical methods:

- *SLINGRAM method = an electromagnetic method that measures the conductivity (resistance) of the rock environment. The result is isolines map or resistance graphs (conductivity / Q parameter) that show the homogeneity and basic material composition of the dike. Under favorable conditions, waterlogging / saturation of the dam / subsoil can be mapped.*

- *SP method = a measurement of the natural electrical potentials that occur at the site of water filtration through a porous environment. The aim will be interpreted to the map of potential leaks through the dike body or through the floor canal to a layer of fluvial sediments.*
- *ERT method = resistive tomography is a geoelectric DC method. The output is a resistance model - a cross-section of the rock environment. The results of the ERT method confirm the interpretation of the DEMP method and in addition show the distribution of resistances in the dam body and subsoil in depth. I.e. provide information on the internal structure / structure of the dike and its subsoil.*

The principle of SLINGRAM method (dipole electromagnetic profiling) is based on the measurement of induction of the primary electromagnetic field of the transmitting coil in the surrounding medium being investigated. The primary field induces a secondary field, whose intensity depends on the conductivity (resistivity) of the medium in the vicinity of the transmitting coil. In our case, sediments forming the body of the levee and rocks in its underlying layers are concerned. The depth to obtain the information on the conductivity of the medium depends on the frequency of the primary electromagnetic field. High frequencies have shallower depth penetration values than low frequencies.

In the measurements at the dam, the device GEM2 (GEOPHEX USA) operating as broadband digital multi-frequency electromagnetic device will be used. 4 operating frequencies will be used; these frequencies are selected as the most appropriate based on the analysis of electromagnetic noise at the site. The measurement will be conducted “continually” at a pace of walk. The resulting data density are approx. 3 to 4 scans per 1 m of profile. The device is connected to GPS navigation; this means that the measurement positions are recorded automatically.

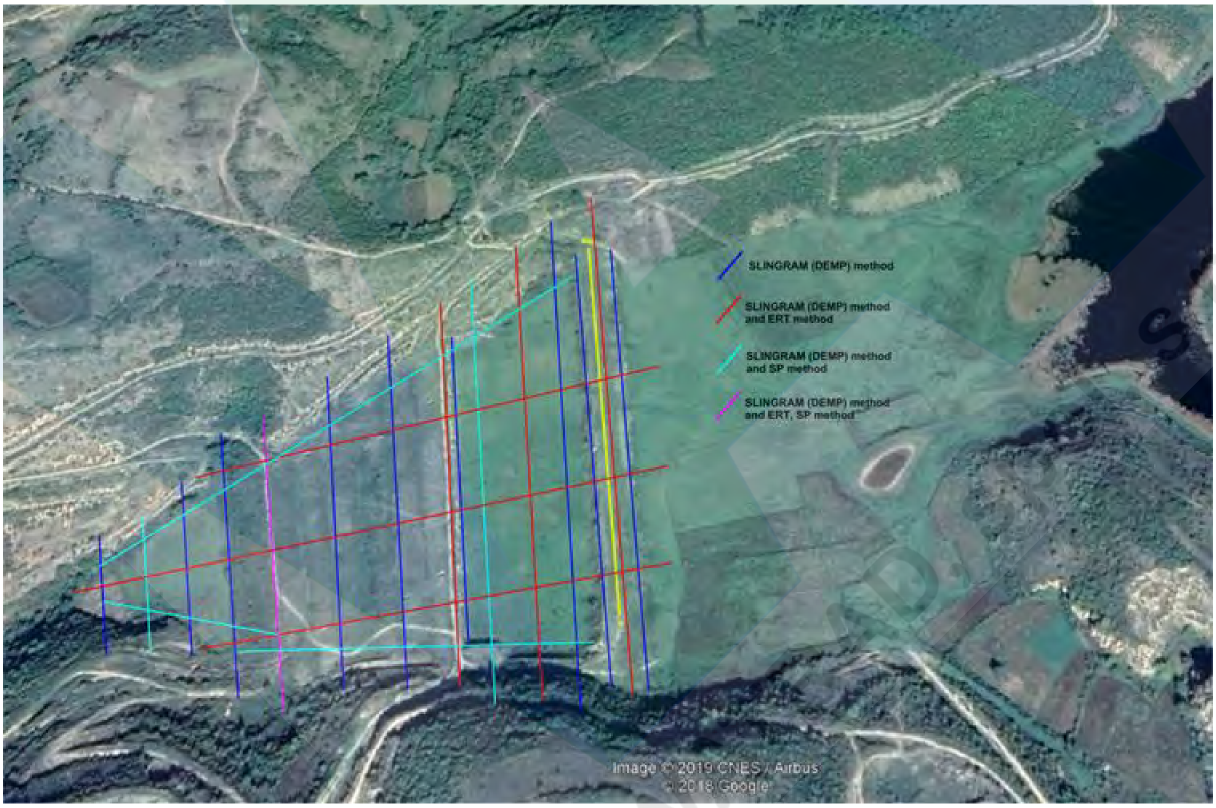


Figure 1: Network of geophysical measurements profiles

Self-potential (SP) method is used to measure the natural electrical potentials of soils and rocks. In surveying the earth dams, the filtration potential produced by water filtration through a porous medium can often be detected. The principle of this phenomenon consists in unequal mobility of anions and cations transferred by the liquid medium through porous materials. The outcomes of the measurement using the SP method are profile curves – graphs of electric potentials. Based on their analysis, the locations of potential seepage pathways through the levee/dam can be identified. The method is also suitable for repeated monitoring measurements aiming to monitor long-term changes in the seepage regime of the dam and its underlying layers.

Electrical resistivity tomography (ERT) belongs to direct-current geoelectrical resistivity methods. The principle of the method is based on the measurement of resistivity values of soils and rocks, using a large number of electrodes placed along the profile or in the vicinity. The electrodes are interconnected by a special cable that enables to connect the electrodes as current ones and potential ones step by step. This allows to perform the measurement for a great number of variants of a 4-electrode array with differing geometry and penetration depth

2.1.2 Engineering-geology survey

Within the framework of engineering geological survey, a maximum of 5 wells will be realized to the depth of 50 m. The boreholes will be drilled for the core. Two core samples will be taken from each well for laboratory analysis. The extent of laboratory analyzes is given by the requirements of the designer.

2.1.3 Monitoring network

On the air side of the dam will be drilled a larger number of small-profile wells equipped with casing and filters. The boreholes of the monitoring network are intended for long-term monitoring of the presence of groundwater in the dam body. The number of monitoring boreholes will be at least 8, in the optimum case it will be 19. All monitoring boreholes will be drilled into the foundation joint of the dam. Selected monitoring boreholes will be used for monitoring the hydrodynamic test.

2.1.4 Hydrogeological investigation

The aim of the proposed hydrogeological survey is to describe and evaluate existing hydrogeological condition in the defined area as follows:

- a description of the ground water level at the dam body,
- a hydraulic conductivity of saturated zone.

The siting of borehole will be based on the results of geophysical survey. For the needs of hydrogeological survey is assumed 1 hydrogeological exploration well (construction see Fig. 1), which will be used for as follow:

- evaluation of hydrogeological conditions inside the body dam,
- long-term monitoring of the groundwater regime.

2.1.5 Geodetic survey

During the drilling work, the central sludge dam will be focused. At the end of the field work will be carried out geodetic survey of all drilled boreholes.

2.1.6 Data processing

All information obtained during drilling will be processed. Furthermore, all data measured during hydrodynamic test and within laboratory test will be processed and evaluated as well. The result will be an expert assessment of the hydrogeological condition in the dam body and an assessment of geotechnical investigation for the needs of designer.

2.2 2nd Stage: Design stage

2.2.1 Data evaluation

Additional data will be submitted for dam rehabilitation and modification, including a report by a professional engineer describing the performance and maintenance history of the existing dam. In addition, all data regarding construction, such as existing subsurface explorations, construction materials used for the dam, and plans and specifications will be submitted. Designer will inspect and evaluate the structure as to its condition, performance, maintenance history and other information regarding foundation soils and existing conditions.

2.2.2 Design of dam modification

The designers of the specialized company will elaborate an implementation project for raising the dam. The project documentation will meet all requirements.

2.3 3rd Stage:Monitoring

The narrow-profile boreholes will be used to monitor the presence of ground water level in the dam body. Based on the hydrodynamic tests, a monitoring proposal will be developed. This stage is not further elaborated by this offer.

3. Subcontractors

This offer focuses on works designed primarily for the first stage. Not only at this stage, but also in the following stages, some works will be subcontracted:

1. The geophysical survey will be carried out by a Czech specialized company, which belongs to companies with a long tradition. The references of their orders include not only European countries, but also contracts realized in the territory of Georgia.
2. Drilling operations will be carried out by a Georgian drilling company. Supervision of any monitoring planned for the second stage is also agreed with the company representative.
3. Geomechanical laboratory tests on drilled cores will be conducted in the laboratories of the Georgian Technical University in Tbilisi. Data evaluation and mathematical modeling will be realized by Czech experts with many years of experience.
4. Design of dam modification will be developed by company VODNI DILA - TBD a.s. that is a Czech leading engineering and consulting company, which provides dam

safety supervision, special measurements and consulting services with 50 years of experience on over 300 waterworks.

5. All other activities, such as work sequence and management, geological surveillance, hydrodynamic testing, drilling core description and evaluation and exploration description will be carried out by the bidder.

4. Outcomes

The following outputs in English will be handed over to the client:

4.1 1st Stage:

1. Technical report
   - The course of the drilling operations and technical information on the wells will be described in the technical report.
2. Drilling and pump test documentation
   - The drill cores will be stored in the samplers. Drilling documentation will include photo documentation and description of the drilled core. Pumping and recovery test will be evaluated.
3. For the needs of designer following geotechnical parameters will be analyzed:
   - soil material and classification,
   - effective shear strength parameters
   - effective angle of internal friction of soil in degrees
   - effective cohesion (cohesiveness)
   - natural soil gravity in kN / m3 above groundwater level,
   - hydraulic conductivity of saturated zone.
4. Final Report
   - The completed work, the measured and achieved results from the hydrodynamic test and geotechnical investigation will be described in the final report of geological investigation.

4.2 2nd Stage

1. Design of dam modification
   - Evaluation of the stability of the existing sludge dam
   - Design documentation in the stage for building permit (PCB) to increase the tailings dam by 15 m

     Note: the works do not include engineering activities to obtain a building permit
   - Design of the technical-security surveillance (TSS) monitoring equipment for monitoring the safety and stability of the tailing reservoir.

5. Schedule

5.1 Schedule for optimal scope of work

The expected work schedule is shown in Table No.1.

- 1st stage
  - Geophysical investigation 27 days
  - Drilling 5 IG borehole 10 days
  - Drilling 19 monitoring boreholes 52 days
  - Drilling and equipment hg. well 4 days
  - Hydrodynamic test 4 days
  - Geotechnical laboratory testing 64 days
  - Data processing and evaluation 65 days
  - Geodetic survey 12 days
  - Final report 5 days
- 2nd stage
  - Evaluation of stability 20 days
  - PCB to increasing the dam by 15 m 60 days
  - TSS control equipment 20 days

For example, if work is started in in early December 2019, the work specified as:

- 1st stage will ends May 2020
- 2nd stage will ends August 2020

5.2 Schedule for minimal scope of work

The expected work schedule is shown in Table No.2.

- 1st stage
  - Geophysical investigation 27 days
  - Drilling 3 IG borehole 6 days
  - Drilling 8 monitoring boreholes 24 days
  - Drilling and equipment hg. well 4 days
  - Hydrodynamic test 4 days
  - Geotechnical laboratory testing 53 days
  - Data processing and evaluation 45 days
  - Geodetic survey 12 days
  - Final report 5 days
- 2nd stage
  - Evaluation of stability 20 days
  - PCB to increasing the dam by 15 m 60 days
  - TSS control equipment 20 days

For example, if work is started in in early December 2019, the work specified as:

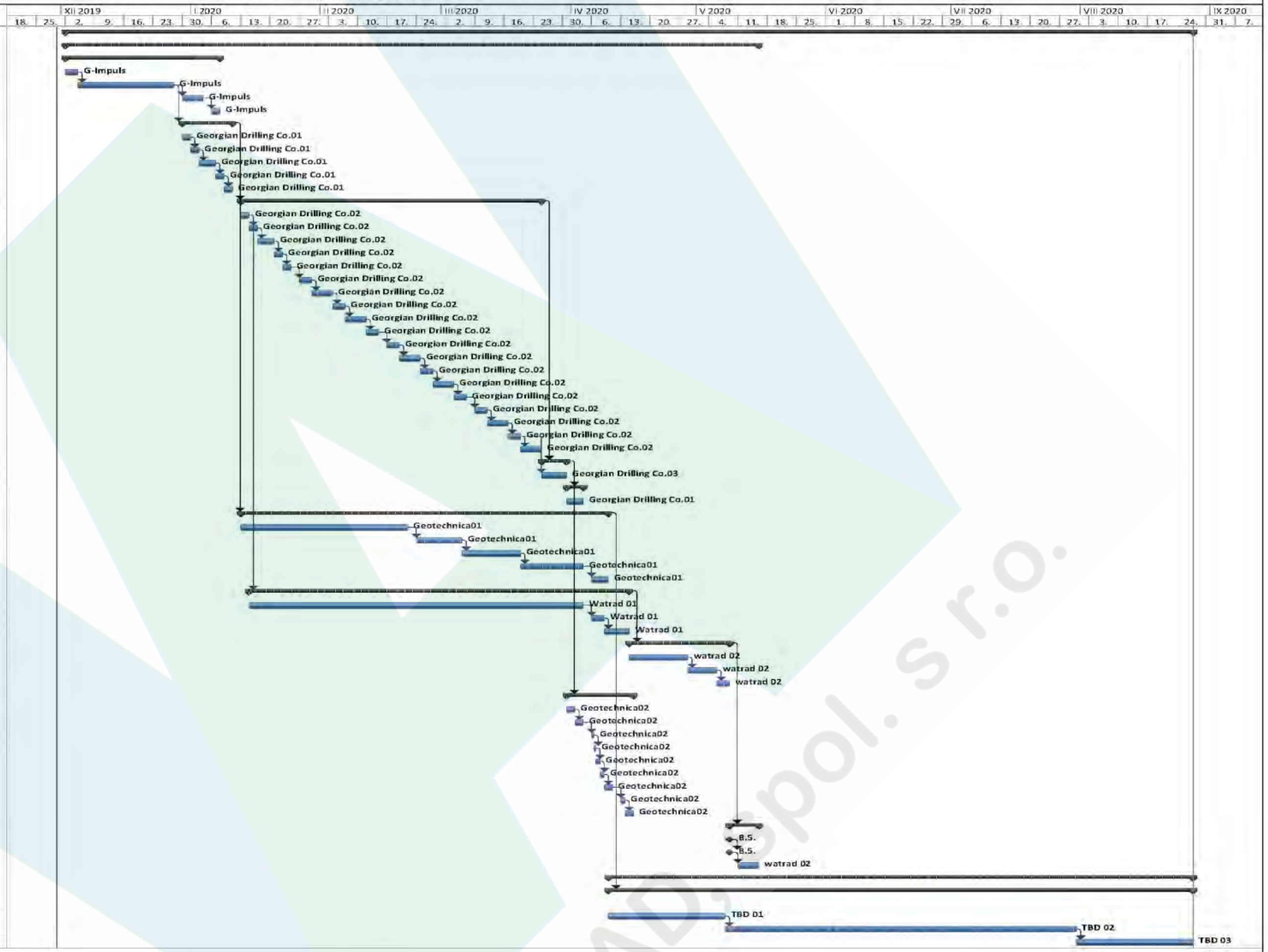
- 1st stage will ends April 2020
- 2nd stage will ends August 2020

Table No.1: Schedule of the works

A] Proposal for optimal scope of work

Evaluation the Stability of the Tailing Dam
Optimal Monitoring Network

ID	Název úkolu	Zahájení	Dokončení	Hodnota nákladů	Doba trvání
1	**Chiatura - Increase of Tailing Dam**	**2.12. 19**	**27.8. 20**	**$428 280,00**	**194 d**
2	**1st Stage: Geological Investigation**	**2.12. 19**	**15.5. 20**	**$382 680,00**	**120 d**
3	**Geophysical investigation**	**2.12. 19**	**7.1. 20**	**$60 480,00**	**27 d**
4	preparation of equipment	2.12. 19	4.12. 19	$6 720,00	3 d
5	site measurement	5.12. 19	27.12. 19	$38 080,00	17 d
6	data processing	30.12. 19	3.1. 20	$11 200,00	5 d
7	final report	6.1. 20	7.1. 20	$4 480,00	2 d
8	**IG Boreholes**	**30.12. 19**	**10.1. 20**	**$12 000,00**	**10 d**
9	IG-01 (50 m)	30.12. 19	31.12. 19	$2 400,00	2 d
10	IG-02 (50 m)	1.1. 20	2.1. 20	$2 400,00	2 d
11	IG-03 (50 m)	3.1. 20	6.1. 20	$2 400,00	2 d
12	IG-04 (50 m)	7.1. 20	8.1. 20	$2 400,00	2 d
13	IG-05 (50 m)	9.1. 20	10.1. 20	$2 400,00	2 d
14	**Monitorin Boreholes**	**13.1. 20**	**24.3. 20**	**$83 200,00**	**52 d**
15	MN-01 (10 m)	13.1. 20	14.1. 20	$3 200,00	2 d
16	MN-02 (10 m)	15.1. 20	16.1. 20	$3 200,00	2 d
17	MN-03 (20 m)	17.1. 20	20.1. 20	$3 200,00	2 d
18	MN-04 (20 m)	21.1. 20	22.1. 20	$3 200,00	2 d
19	MN-05 (20 m)	23.1. 20	24.1. 20	$3 200,00	2 d
20	MN-06 (30 m)	27.1. 20	29.1. 20	$4 800,00	3 d
21	MN-07 (30 m)	30.1. 20	3.2. 20	$4 800,00	3 d
22	MN-08 (30 m)	4.2. 20	6.2. 20	$4 800,00	3 d
23	MN-09 (30 m)	7.2. 20	11.2. 20	$4 800,00	3 d
24	MN-10 (40 m)	12.2. 20	14.2. 20	$4 800,00	3 d
25	MN-11 (40 m)	17.2. 20	19.2. 20	$4 800,00	3 d
26	MN-12 (40 m)	20.2. 20	24.2. 20	$4 800,00	3 d
27	MN-13 (40 m)	25.2. 20	27.2. 20	$4 800,00	3 d
28	MN-14 (50 m)	28.2. 20	3.3. 20	$4 800,00	3 d
29	MN-15 (50 m)	4.3. 20	6.3. 20	$4 800,00	3 d
30	MN-16 (50 m)	9.3. 20	11.3. 20	$4 800,00	3 d
31	MN-17 (50 m)	12.3. 20	16.3. 20	$4 800,00	3 d
32	MN-18 (50 m)	17.3. 20	19.3. 20	$4 800,00	3 d
33	MN-19 (50 m)	20.3. 20	24.3. 20	$4 800,00	3 d
34	**HG Boreholes**	**25.3. 20**	**30.3. 20**	**$8 000,00**	**4 d**
35	HG-01 (50 m)	25.3. 20	30.3. 20	$8 000,00	4 d
36	**Hydrodynamic test**	**31.3. 20**	**3.4. 20**	**$4 800,00**	**4 d**
37	HG-01	31.3. 20	3.4. 20	$4 800,00	4 d
38	**Geomechanical test**	**13.1. 20**	**9.4. 20**	**$35 840,00**	**64 d**
39	Lab core analysis (wells IG 01 - IG 05) - 12 pcs	13.1. 20	21.2. 20	$16 800,00	30 d
40	Back slope stability analysis	24.2. 20	5.3. 20	$5 040,00	9 d
41	Stress-strain and seepage analysis	6.3. 20	19.3. 20	$5 600,00	10 d
42	Evaluation of num modelling	20.3. 20	3.4. 20	$6 160,00	11 d
43	Final report	6.4. 20	9.4. 20	$2 240,00	4 d
44	**Data processing**	**15.1. 20**	**14.4. 20**	**$145 600,00**	**65 d**
45	Data collection	15.1. 20	3.4. 20	$129 920,00	58 d
46	Data evaluation	6.4. 20	8.4. 20	$6 720,00	3 d
47	Technical Report	9.4. 20	14.4. 20	$8 960,00	4 d
48	**Evaluation of investigation**	**15.4. 20**	**8.5. 20**	**$15 120,00**	**18 d**
49	Data collection	15.4. 20	28.4. 20	$8 400,00	10 d
50	Data processing	29.4. 20	5.5. 20	$4 200,00	5 d
51	Data evaluation	6.5. 20	8.5. 20	$2 520,00	3 d
52	**Geodetic survey**	**31.3. 20**	**15.4. 20**	**$13 440,00**	**12 d**
53	Flight + preparation	31.3. 20	1.4. 20	$2 240,00	2 d
54	Polygon preparation	2.4. 20	3.4. 20	$2 240,00	2 d
55	Surveying IG wells	6.4. 20	6.4. 20	$560,00	0,5 d
56	Surveying HG well	6.4. 20	6.4. 20	$560,00	0,5 d
57	Surveying MN wells	7.4. 20	7.4. 20	$1 120,00	1 d
58	Surveying Tailing Dam	8.4. 20	8.4. 20	$1 120,00	1 d
59	Surveying area of sludge impoundment	9.4. 20	10.4. 20	$2 240,00	2 d
60	Flight	13.4. 20	13.4. 20	$1 120,00	1 d
61	Technical report	14.4. 20	15.4. 20	$2 240,00	2 d
62	**Final report on geological investigation**	**8.5. 20**	**15.5. 20**	**$4 200,00**	**5 d**
63	Results of Geophysical Measurements	8.5. 20	8.5. 20	$0,00	0 d
64	Report on Geomechanical Properties	8.5. 20	8.5. 20	$0,00	0 d
65	Report on Hydrogeological Investigation	11.5. 20	15.5. 20	$4 200,00	5 d
66	**2nd Stage:**	**10.4. 20**	**27.8. 20**	**$45 600,00**	**100 d**
67	**Documentation for the stage the building permit (PCB)**	**10.4. 20**	**27.8. 20**	**$45 600,00**	**100 d**
68	Stability evaluation of existing dam	10.4. 20	7.5. 20	$8 800,00	20 d
69	PCB to increase the tailings dam by 15 m	8.5. 20	30.7. 20	$28 800,00	60 d
70	TBD control equipment project	31.7. 20	27.8. 20	$8 000,00	20 d



Stránka 1

Proposal:

Evaluation the Stability of the Tailing Dam

Optimal Monitoring Network

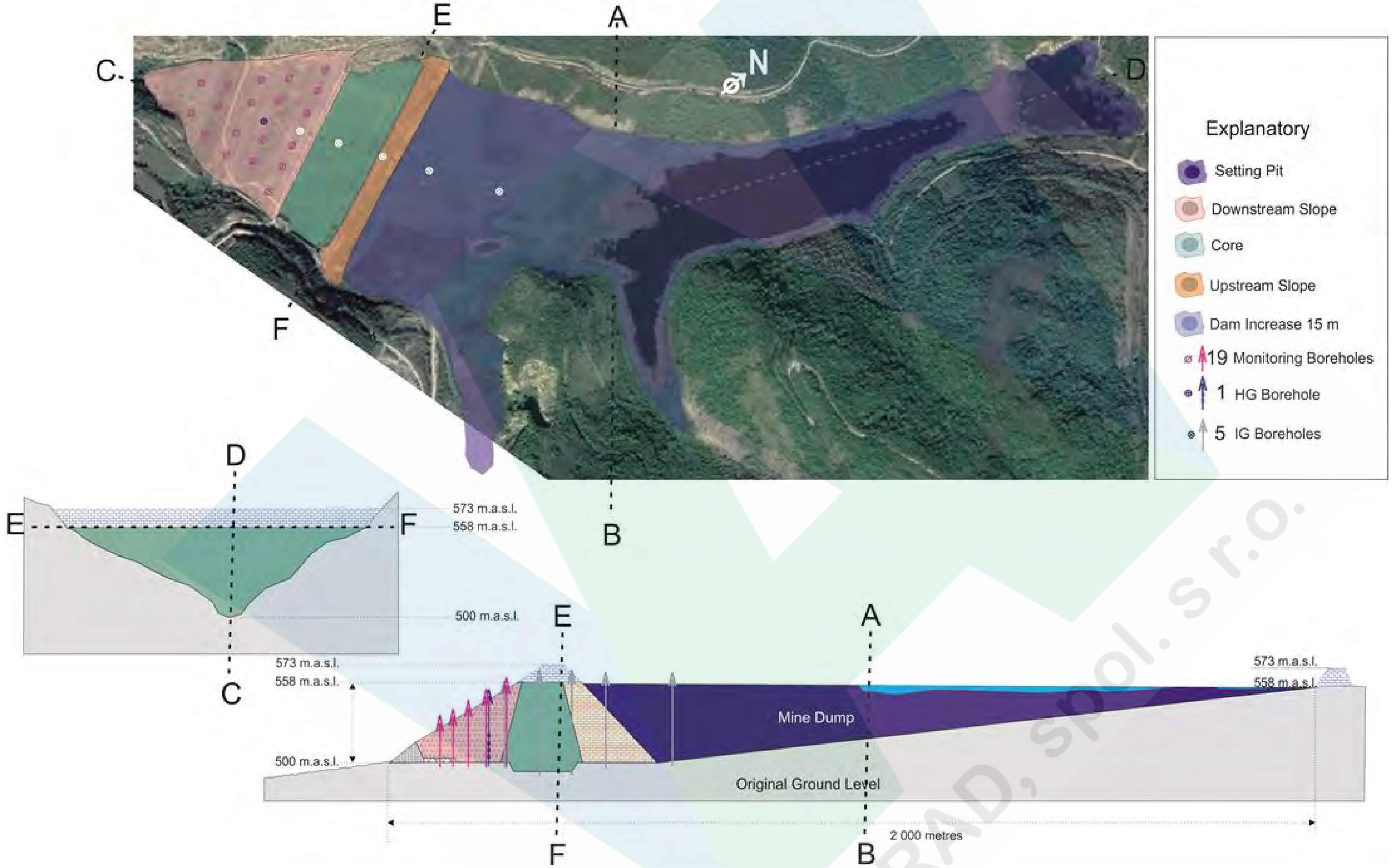
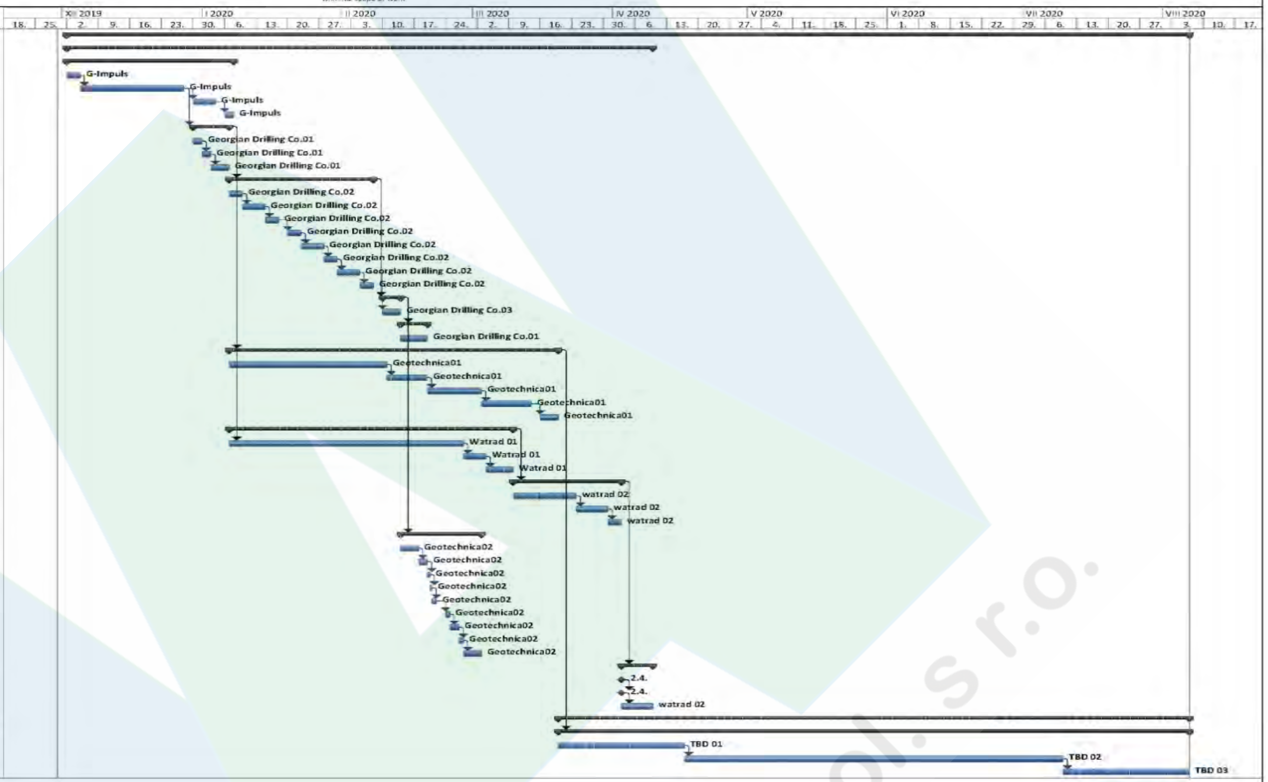


Table No.2: Schedule of the works

B] Proposal for minimal scope of work

Evaluation the Strability of the Tailing Dam
Minimal scope of work

ID	Název úkolu	Zahájení	Dokončení	Hodnota nakladů	Doba trvaní
1	**Chiatura - Increase of Tailing Dam**	**2.12. 19**	**6.8. 20**	**$327 720,00**	**179 d**
2	**1st Stage: Geological Investigation**	**2.12. 19**	**9.4. 20**	**$282 120,00**	**94 d**
3	**Geophysical investigation**	**2.12. 19**	**7.1. 20**	**$60 480,00**	**27 d**
4	preparation of equipment	2.12. 19	4.12. 19	$6 720,00	3 d
5	site measurement	5.12. 19	27.12. 19	$38 080,00	17 d
6	data processing	30.12. 19	3.1. 20	$11 200,00	5 d
7	final report	6.1. 20	7.1. 20	$4 480,00	2 d
8	**IG Boreholes**	**30.12. 19**	**6.1. 20**	**$7 200,00**	**6 d**
9	IG-01 (50 m)	30.12. 19	31.12. 19	$2 400,00	2 d
10	IG-02 (50 m)	1.1. 20	2.1. 20	$2 400,00	2 d
11	IG-03 (50 m)	3.1. 20	6.1. 20	$2 400,00	2 d
12	**Monitorin Boreholes**	**7.1. 20**	**7.2. 20**	**$38 400,00**	**24 d**
13	MN-01 (40 m)	7.1. 20	9.1. 20	$4 800,00	3 d
14	MN-02 (40 m)	10.1. 20	14.1. 20	$4 800,00	3 d
15	MN-03 (50 m)	15.1. 20	17.1. 20	$4 800,00	3 d
16	MN-04 (50 m)	20.1. 20	22.1. 20	$4 800,00	3 d
17	MN-05 (50 m)	23.1. 20	27.1. 20	$4 800,00	3 d
18	MN-06 (50 m)	28.1. 20	30.1. 20	$4 800,00	3 d
19	MN-07 (50 m)	31.1. 20	4.2. 20	$4 800,00	3 d
20	MN-08 (50 m)	5.2. 20	7.2. 20	$4 800,00	3 d
21	**HG Boreholes**	**10.2. 20**	**13.2. 20**	**$8 000,00**	**4 d**
22	HG-01 (50 m)	10.2. 20	13.2. 20	$8 000,00	4 d
23	**Hydrodynamic test**	**14.2. 20**	**19.2. 20**	**$4 800,00**	**4 d**
24	HG-01	14.2. 20	19.2. 20	$4 800,00	4 d
25	**Geomechanical test**	**7.1. 20**	**19.3. 20**	**$29 680,00**	**53 d**
26	Lab core analysis (wells IG 01 - IG 03) - 7 pcs	7.1. 20	10.2. 20	$14 000,00	25 d
27	Back slope stability analysis	11.2. 20	19.2. 20	$3 920,00	7 d
28	Stress-strain and seepage analysis	20.2. 20	2.3. 20	$4 480,00	8 d
29	Evaluation of num modelling	3.3. 20	13.3. 20	$5 040,00	9 d
30	Final report	16.3. 20	19.3. 20	$2 240,00	4 d
31	**Data processing**	**7.1. 20**	**9.3. 20**	**$100 800,00**	**45 d**
32	Data collection	7.1. 20	27.2. 20	$85 120,00	38 d
33	Data evaluation	28.2. 20	3.3. 20	$6 720,00	3 d
34	Technical Report	4.3. 20	9.3. 20	$8 960,00	4 d
35	**Evaluation of investigation**	**10.3. 20**	**2.4. 20**	**$15 120,00**	**18 d**
36	Data collection	10.3. 20	23.3. 20	$8 400,00	10 d
37	Data processing	24.3. 20	30.3. 20	$4 200,00	5 d
38	Data evaluation	31.3. 20	2.4. 20	$2 520,00	3 d
39	**Geodetic survey**	**14.2. 20**	**2.3. 20**	**$13 440,00**	**12 d**
40	Flight + preparation	14.2. 20	17.2. 20	$2 240,00	2 d
41	Polygon preparation	18.2. 20	19.2. 20	$2 240,00	2 d
42	Surveying IG wells	20.2. 20	20.2. 20	$560,00	0,5 d
43	Surveying HG well	20.2. 20	20.2. 20	$560,00	0,5 d
44	Surveying MN wells	21.2. 20	21.2. 20	$1 120,00	1 d
45	Surveying Tailing Dam	24.2. 20	24.2. 20	$1 120,00	1 d
46	Surveying area of sludge impoundment	25.2. 20	26.2. 20	$2 240,00	2 d
47	Flight	27.2. 20	27.2. 20	$1 120,00	1 d
48	Technical report	28.2. 20	2.3. 20	$2 240,00	2 d
49	**Final report on geological investigation**	**2.4. 20**	**9.4. 20**	**$4 200,00**	**5 d**
50	Results of Geophysical Measurements	2.4. 20	2.4. 20	$0,00	0 d
51	Report on Geomechanical Properties	2.4. 20	2.4. 20	$0,00	0 d
52	Report on Hydrogeological Investigation	3.4. 20	9.4. 20	$4 200,00	5 d
53	**2nd Stage:**	**20.3. 20**	**6.8. 20**	**$45 600,00**	**100 d**
54	**Documentation for the building permit (PCB)**	**20.3. 20**	**6.8. 20**	**$45 600,00**	**100 d**
55	Stability evaluation of existing dam	20.3. 20	16.4. 20	$8 800,00	20 d
56	PCB to increase the tailings dam by 15 m	17.4. 20	9.7. 20	$28 800,00	60 d
57	TBD control equipment project	10.7. 20	6.8. 20	$8 000,00	20 d

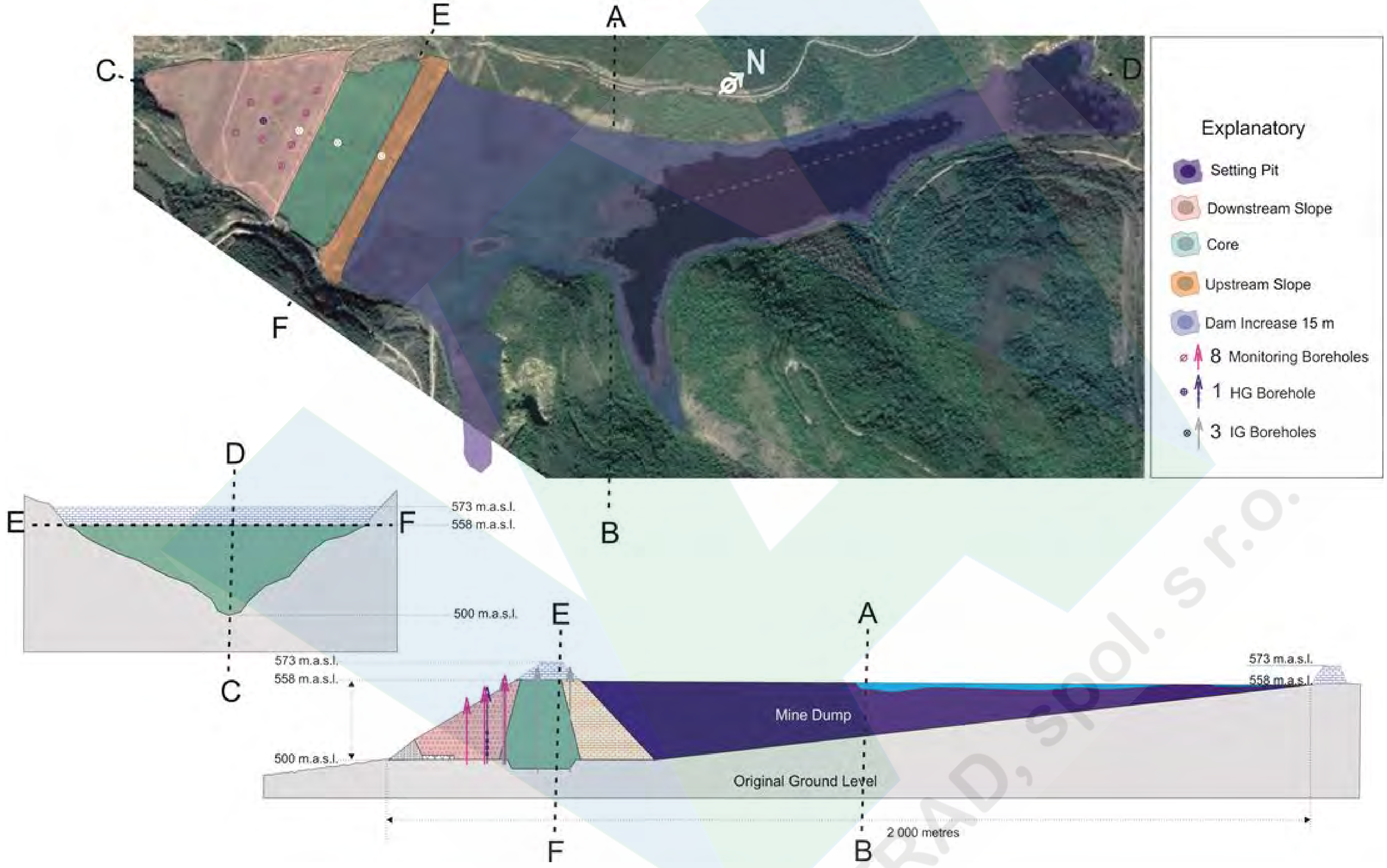


Stránka 1

Proposal:

Evaluation the Stability of the Tailing Dam

Minimal Monitoring Network



6. Price

The price of works is based on the Watrad ltd. pricelist valid for 2019 and the bids obtained from subcontractors. The price covers all of the above mentioned work, overtime work, Saturday and Sunday work, employee diets and insurance, transport etc., i.e. the price is final.

6.1 Price for optimal scope of work

The expected work schedule is shown in Table No.1.

- 1st stage
  - Geophysical investigation 60 480 $US
  - Drilling 5 IG borehole 12 000 $US GE supplier
  - Drilling 19 monitoring boreholes 83 200 $US GE supplier
  - Drilling and equipment hg. well 8 000 $US GE supplier
  - Hydrodynamic test 4 800 $US GE supplier
  - Geotechnical laboratory testing 35 840 $US
  - Data processing and evaluation 145 600 $US
  - Evaluation of investigation 15 120 $US
  - Geodetic survey 13 440 $US GE supplier
  - Final report 4 200 $US
- 2nd stage
  - Evaluation of stability 8 800 $US
  - PCB to increasing the dam by 15 m 28 800 $US
  - TSS control equipment 8 000 $US

The price of each stage is as follow:

- 1st stage USS 382 680
- 2nd stage USS 45 600

Total price of the optimal scope of work

428 280 US $ excluding VAT

The amount of VAT will be charged in accordance with the rules for work performed abroad on the day of invoicing. The offeror assumes that the invoiced amount will not be subject to VAT.

6.2 Price for minimal scope of work

The expected work schedule is shown in Table No.1.

- 1st stage
  - Geophysical investigation 60 480 $US
  - Drilling 5 IG borehole 7 200 $US GE supplier
  - Drilling 19 monitoring boreholes 38 400 $US GE supplier
  - Drilling and equipment hg. well 8 000 $US GE supplier
  - Hydrodynamic test 4 800 $US GE supplier

◦ Geotechnical laboratory testing	29 680 $US	
◦ Data processing and evaluation	100 800 $US	
◦ Evaluation of investigation	15 120 $US	
◦ Geodetic survey	13 440 $US	GE supplier
◦ Final report	4 200 $US	
– 2nd stage		
◦ Evaluation of stability	8 800 $US	
◦ PCB to increasing the dam by 15 m	28 800 $US	
◦ TSS control equipment	8 000 $US	

The price of each stage is as follow:

- 1st stage USS 282 120
- 2nd stage USS 45 600

Total price of the optimal scope of work

327 720 US $ excluding VAT

The amount of VAT will be charged in accordance with the rules for work performed abroad on the day of invoicing. The offeror assumes that the invoiced amount will not be subject to VAT.

7. Conclusion

The presented work schedule reflects the transport conditions between Georgia and the Czech Republic and the upcoming season. The project submitter notes that it will not be possible to consider the work as defective or unfinished if it is not fully completed within the given deadline and that it will be necessary for its subsequent completion at another deadline.

Watrad ltd. holds the appropriate professional qualifications necessary to carry out the work specified in the proposal.

An integral part of this offer is Terms and Conditions of Watrad ltd.

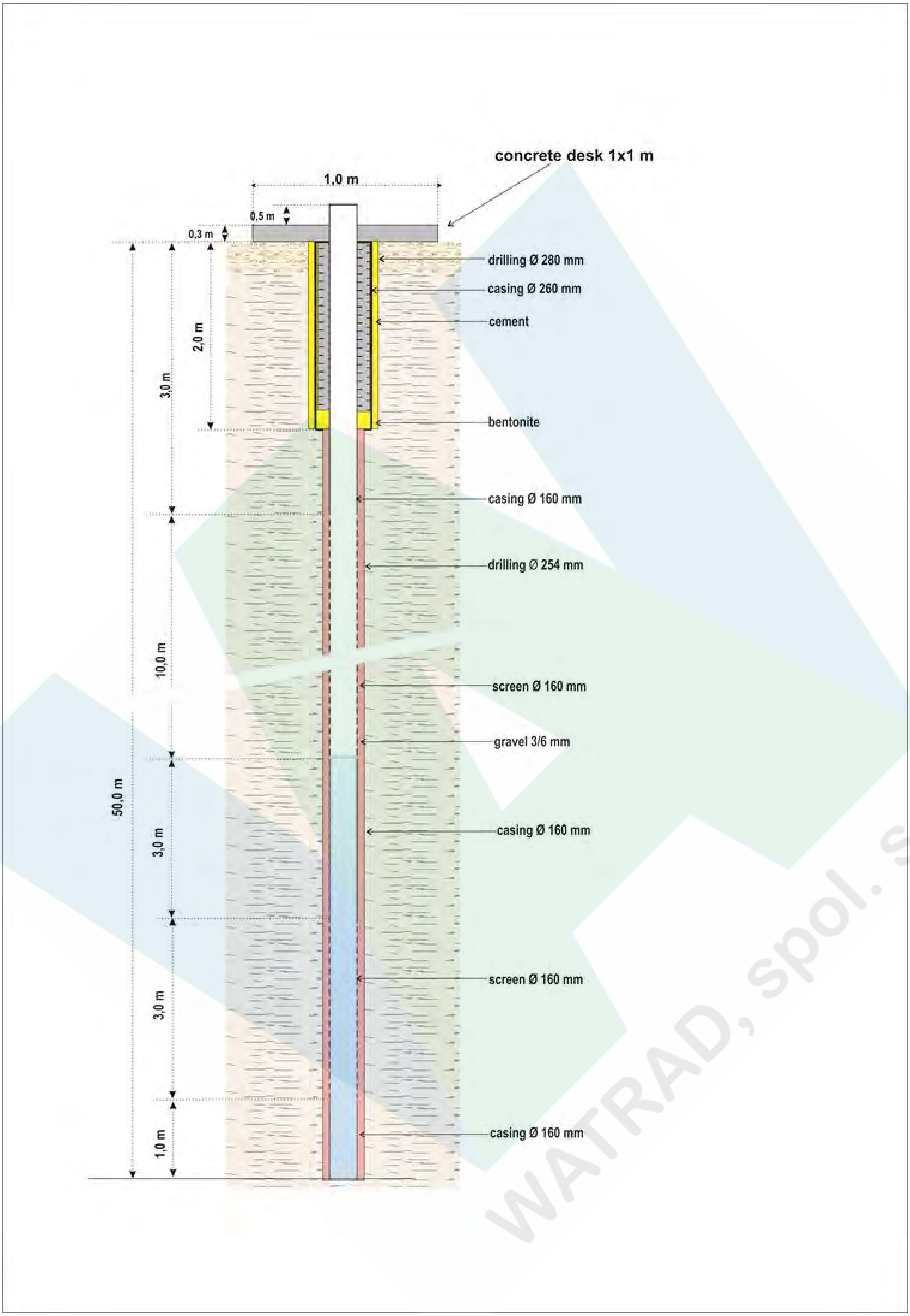
The offer is valid until the end of 2019.

We believe that you will find our offer interesting and we will proceed further in our negotiations.

10.12.2019

MSc. Michal Vanecek

Fig. No. 1: Schema of borehole



8. List of selected references

WATRAD, spol. s r.o.

Established:	16.2.1992
Business partners:	Mgr. J. Michálková, Mgr. M. Vaněček
Registered Office:	S.K.Neumanna 1316, 532 07 Pardubice, Czech Republic
Headquarter:	Osadní 26, 170 00 Praha 7, Czech Republic
Phone:	+420 220 878 920
web:	www.watrad.cz
E-mail:	watrad@watrad.cz
Head Manager:	RNDr. L. Kelnar (Industrial Safety) MSc. P. Novak, EurGeol (Geology)
Number of employees:	max. 15

Company activities

1. Geology survey, i.e. economic geology survey, hydrogeology survey, engineering geology survey. The company is accredited in compliance the Czech Republic legal framework in the following fields
   - Design, implementation and evaluation of geological works in the field of hydrogeology.
   - Design, implementation and evaluation of geological works in the field of engineering geology.
   - Identification and verification of geological conditions for the construction, operation and disposal facilities for the storage of gases, liquids and waste in natural rock structures and underground spaces.
   - Design, implementation and evaluation of geological works in the field of economic geology.

   Three company experts are Eurogeologist Title holders. The EurGeol is a professional title awarded by European Federation of Geologists. EurGeol is world-wide recognized allowing its holder work not only in EU but also in Canada, Australia, USA or South Africa.
2. Safety of chemical and petrochemical industry operations, so-called industrial safety according to EU directive called SEVESO III. Three company experts are accredited for professional competence in the field.

Within the period 2014 - 2016, the company's experts participated in a project aimed at evaluating a large landslide in the Bazaleti area near the municipality of Duscheti. Several monitoring stations have been built in the area as part of the early warning system. The task of the system is to warn residents in case of landslide.

Knowledge and technical equipment

A) Extensive experience in localisation of new groundwater sources for individuals, municipalities and larger agglomerations. Expert knowledge of the company specialists guarantees the correct evaluation of groundwater resources. The hydrogeologist also provides recommendations on source utilisation to ensure maximal lifespan of the well.

B) Complete technical equipment for pumping and recovery tests in wells. The progress of the pumping and recovery test is recorded automatically using sensors with the possibility of remote data reading.

C) The company's technical equipment includes waterproof borehole inspection cameras that are capable provide colour images and videos of the inspected well up to 700 m deep. The camera dualhead system provides frontal as well as side view.

D) The company has drones that are used for aerial surveys and inspections. Utilisation of the drones is advantageous in terrain reconnaissance, evaluation of landslides, etc.

E) An essential part of the company's technical equipment are technologies and software for monitoring qualitative and quantitative changes in groundwater in boreholes. This equipment allows identify and evaluate hydraulic connection between individual wells or connection between a pollution source and a water source.

F) Within the framework of research and development, the company specialists constructed a technology enabling intensification of the crack network in wells. Application of this technology increases the inflow of groundwater into a well and thus increases the amount of pumped water.

References to geophysical methods:
A similar described geophysical methodology has been successfully used in the past to investigate the flood dams around the TRENT and HUMBER rivers in the UK. In total, approximately of 200 km of dikes were measured between the yeas of 2014 and 2018. The client was Environmental Agency of UK.

Overview of selected projects

Geological team of Watrad ltd. realizes about 20 medium and large geological orders every year. This means that more than 300 major geological projects have been realized since 1992. The following table shows only a small number of representative projects.

No.	Name of the report	Investor	Year
1.	Research of Intergranular Porosity Influence on Deep Geological Disposal into Geological Formations and Methodology and Measuring Apparatus - Phase 2010	Ministry of Industry and Trade of the Czech Republic	2014
2.	Research of Use of Energetic Potential of the Mine Water in the Areas of Previous Mining Activities in the Czech Republic – Phase 2010: Atlas of Mine Water Geothermal Potential in the Czech Republic	Ministry of Industry and Trade of the Czech Republic	2014
3.	Minimization of the Impact of Mining Water on the Environment and Drinking Water Resources	Czech Development Agency	2015
4.	Geoparcs – the new direction for sustainable regional development	Czech Development Agency	2015
5.	Evaluation of Landslide Susceptibility in the Mountainous Parts of Georgia on the Example of Endangered Settlements, International Roads and Energy Conduits in Dusheti Municipality	Czech Development Agency	2016
6.	Revitalisation of deep spa wells – hydrodynamic tests of teh NP-740, NP-742, NP-744 a NP-747 boreholes	Patronus, Investment Fund Darkov	2016
7.	Database of hydrogeology survey in the Czech republic	KINDRA, EFG Brussel	2017
8.	Dairy groundwater source	Lacrum – Velké Meziříčí	2017
9.	Skrýšov – farm groundwater source	Mr. Karel Roden	2018
10.	Žloukovice – municipal groundwater source	Municipality of Nizbor	2018

9. Business Terms and Conditions

Preamble:

The Business Terms and Conditions of WATRAD spol. s r.o. are an integral part of the offer sent to the Client. By sending the order, the Client agreed with the wording and content of the Business Terms and Conditions of WATRAD, spol. s r.o.

The Contractor shall mean WATRAD, spol. s r.o., the Client shall mean the entity whose authorized representative issued the order.

Specialists of WATRAD spol. s r.o. hold the appropriate professional qualifications required to carry out the work specified in the offer, i.e. for the fields of bearing geology, engineering geology and hydrogeology, as well as the European Geologist Certification No. 1490, no. 1491 and No. 1491, and No. 1489.

1. Subject of Performance

1. The job description of the subject of performance is sufficiently described in the offer, which is an integral part of the order.
2. The subject of performance will be in accordance with the offer and will be described and evaluated in the final report.

2. Price of the Subject of Performance

1. The price of the works is stated in the offer and in case the Client so requests, it will be supported by a structured calculation of the proposed works.
2. The price of the agreed subject of performance is determined according to the price list of the company and the subcontractors for the year 2019.
3. The price of the agreed subject of performance expresses the financial requirements of the calculated works.
4. Any additional work will be agreed and approved in advance with the Client.
5. The amount of VAT will be charged according to valid regulations at the time of invoicing.

3. Deadlines, Work Schedule

1. Work will start on the date specified in the order.
2. The subject of performance - Final Report - shall be handed over to the Client within the deadline specified in the order, unless otherwise specified in writing.
3. Completion of works shall be deemed to be a protocol on handover and takeover of the agreed subject of performance.
4. The protocol on handover and takeover shall mean a record of handover and/or takeover of the subject of performance, which is agreed and signed by the responsible persons of the Contractor and the Client. The record is made in two copies, one for each party.
5. If the Contractor duly prepares the subject of performance or its agreed part before the agreed date, the Client undertakes to take over the subject of performance or its part and pay the Contractor the price of the subject of performance.

6. The Contractor shall not be liable for delays in performed work caused by the Client, the investor, unpreparedness of the work place, or for delays caused by other investor's/Client's suppliers of works.
7. It is not possible to consider a work to be defective or incomplete if it is not fully completed within the deadline specified in the order and is completed on an alternative date.

4. Place of Performance

1. The place of performance shall be the registered office and premises of the Client, the location affected by technical work, or the registered office and premises of the Contractor.

5. Payment Terms

1. Payment shall be made in three instalments.
2. For the first instalment, upon receipt of the order/signing of the contract for work, an invoice amounting to 35 % including VAT of the agreed amount will be issued.
3. After completion of the drilling work, equipping the well and adjusting the surroundings of the well, the second invoice amounting to 35 % including VAT of the agreed amount will be issued.
4. After submitting the final report from the survey, i.e. project carried out, the third final invoice of 30 % including VAT of the agreed amount will be issued.
5. The Client undertakes to pay the price of the subject of performance on the basis of invoices issued by the Contractor with a maturity of up to 14 calendar days from the day of its delivery to the Client, unless agreed otherwise in writing.
6. The invoice shall contain all the particulars of a tax document.

6. Coordination

1. The Contractor undertakes to
    a) proceed with the implementation of the subject of performance with professional care,
    b) comply with generally binding regulations,
    c) comply with technical standards,
    d) comply with the Client's regulations and rules.
2. The Client shall, to the extent necessary, ensure the co-operation of their employees and the Contractor's employees on the basis of the specific requirements of the Contractor stated in the offer or later upon agreement in writing.
3. The Client undertakes to provide information as specified by the Contractor, unless such information is of a secret or top secret nature. In case of confidentiality regime, the Contractor shall only be provided with the data format of the required information.
4. The Client shall ensure the participation and cooperation of the necessary workers within the shortest possible period of time, however, no later than 2 working days from the submission of a written request by the Contractor.

7. Inspection Days

1. The inspection day shall be held as required by either Contracting Party.
2. The inspection day shall be convened by the responsible person of the Client.

3. The program of the inspection day shall be prepared by the responsible persons of the Contractor and the Client by mutual agreement.
4. The minutes agreed and signed by the responsible persons of the Contractor and the Client shall be made from each inspection day.
5. The inspection day minutes shall be made in two copies, one for each party.
6. In no case shall the inspection day minutes or any other minutes from meetings between the two parties replace the provisions of the Business Terms and Conditions, which may only be changed in writing by means of a contract.

8. Defective Work

1. Defect of the subject of performance is a deviation in the quality, scope and parameters of the subject of performance stipulated in the offer, technological processes, generally binding technical standards, and laws or other legislative regulations.
2. The Contractor shall be liable for defects that the subject of performance has at the time of implementation up to the time of its protocol handover and for defects that occur within the warranty period, which is 6 months within the scope of the quality guarantee hereby provided by the Contractor to the Client for the subject of performance.
3. The Client undertakes to make any complaint to the Contractor about the defect of the subject of performance immediately after its discovery in writing.

9. Fines for Non-Compliance with this Business Terms

1. In the event of a Client's delay in payment, the interest on late payment shall be 0.05 % of the invoiced amount for each day of delay, but no more than 10 % of the agreed price plus VAT. The payment of the fine shall not affect the Contractor's right to full compensation for damages.
2. If the Contractor submits the subject of performance after the stipulated deadline, the Contractor shall pay the Client a fine of 0.05 % of the price plus VAT for each commenced day of delay, but no more than 10 % of the agreed price including VAT. The payment of the fine shall not affect the Client's right to full compensation of damages.

10. Final Provisions

1. The parties undertake not to give any third parties access to commercial and technical information entrusted to them by the other Party without written consent. In addition, the parties undertake to protect this information as part of a trade secret, and not to use it for any purpose other than for the performance of the agreed works.
2. When implementing the subject of performance, the Contractor shall always give priority to the Client's interests over their own interests with the aim of fulfilling the agreed subject of performance in a timely and high-quality manner.
3. In the event that the Client requires the implementation of the subject of performance in an open/un-boarded well, they assume full responsibility for the loss of the Contractor's instrumentation. If the well is buried with subsequent loss of instrumentation, the Client shall pay the cost of the buried equipment.
4. In the event of withdrawal from the agreed performance by one of the involved parties, the parties are obliged to mutually settle all debts and obligations incurred up to the effective date of the agreed performance.

5. In the event of withdrawal from the agreed performance by one of the involved parties, the Contractor's entitlement to the payment of the part of the price corresponding to the scope of the partially performed subject of performance shall not expire.
6. The terms and conditions of the unexpressed expressis verbis in the text are governed by the Civil Code and other generally binding legal regulations, as amended, applicable to the agreed business relations.
7. The Contractor shall confirm the validity of the order in writing to the Client's address. The Business Terms and Conditions become effective upon receipt of a written order confirmation by the Client.
8. The rights and obligations arising from the Business Terms and Conditions shall pass to the Client's legal successors.
9. The Client declares that they fully understand the provisions of the Business Terms and Conditions of Watrad spol. s r.o. and agree with them at their own free will.
10. The Order contains basic information about the Client, and the basic information about the Contractor is given in the Annex to the Business Terms and Conditions.

Mgr. Michal Vaněček
Company Director
Watrad, spol. s r.o.

11. Contractor‘s Coordinates

Contractor:	**WATRAD, spol. s r.o.**
Represented by	**Mgr. Michal Vaněček** Executive Director
Person authorized to act in contractual and commercial matters:	**Mgr. Jana Michálková** Sales Director
technical:	**Mgr. Petr Novák** Qualified person
Company registered office:	S.K.Neumanna 1316 532 07 Pardubice Registered in the Commercial Register kept by the Regional Court in Hradec Králové, Section C, File 24868
Correspondence address:	**Osadní 26** **170 00 Prague 7**
ID No.:	47541253
VAT No.:	CZ47541253
Bank:	ČSOB, a.s., Kamenická, 170 00 Prague 7
Bank account No.:	191927924/0300
IBAN	CZ89 0300 0000 0001 9192 7924
BIC/SWIFT	CEKOCZPP

Czech and Georgian legislative instruments for controlling mine water discharges

Client:

Pardubice 2019, Czech Republic

Print No. **1**

Content

1. Mining sector regulation framework analysis

1.1 European mining industry legislation

At present, EU legislation largely leaves the area of mining and processing of minerals the responsibility of individual states. The cause of this situation is not only the recent popular marginalization of the mining industry within the European Union, but undoubtedly also considerable differences in the concept and implementation of mining legislation in individual states. Today, the Czech Republic belongs to a group of few European Union countries with comprehensive mining law. The cause of the different position of the upper legislation in the individual states of the European Union is undoubtedly mainly the different historical importance of mining and quarrying. Despite the considerable fragmentation of national approaches, a number of regulations have been incorporated into European Union legislation that affect the mining and treatment of mineral resources to a greater or lesser extent.

When assessing the legal status of the extractive industries within the European Union, it is necessary to distinguish two fundamental categories by which the European Union affects the extraction and treatment of mineral resources. Community law applicable to the extraction and treatment of mineral resources at several levels provides, in principle, the regulatory tools needed to assess the significance and impact of mineral extraction on other public interests such as life and health, the state of the environment, private and public property, etc. these interests during the mining process, as well as control mechanisms to enforce the omitted requirements. Given the strong focus of the European Union in particular on environmental protection, a paradoxical situation arises at first glance when, although the actual mining and treatment of mineral resources remains de-jure within national competence, the mining industry is relatively heavily regulated by the European legislation in the area of environmental protection and human rights protection.

The second, very complex category is the European Union's mineral and non-mineral policies. These EU countries' policies are fairly ambivalent in the case of extractive industries. Life and health protection policies on the one hand, as a source of constraints, of course, although necessarily with a delay, are reflected in the regulatory framework; within the European Union. Balancing the requirements of EU policies in individual areas in relation to the extraction and treatment of minerals, possibly with the subsequent adequate transposition of relevant policies into Community law, is currently one of the key tasks of the European executive and legislation.

Communication from the European Commission of 4 November 2008 entitled "Raw materials initiative - meeting the critical needs for growth and jobs in Europe" (COM (2008) 0699) and Communication of 2 February 2011 entitled "Addressing the challenges of commodity issues, markets and raw materials" (COM (2011) 0025; 2011 Communication) The Commission acknowledged that ensuring reliable and undisturbed access to raw materials is an important factor for the EU's competitiveness. The Communications launched and at the same time strengthened the Raw Materials Initiative, an integrated strategy to tackle the various challenges of access to non-energy and non-agricultural raw materials. The raw materials initiative is based on three pillars:

– ensuring a level playing field in access to resources in third countries;
– promoting a sustainable supply of raw materials from European sources;
– increasing resource efficiency and recycling.

The Council supported the enhanced raw materials initiative in its conclusions of 10 March 2011 on addressing the challenges of raw materials and commodity markets. The European Parliament also endorsed the strategy in its resolution of 13 September 2011. In its report on "An effective European strategy for the Raw materials "(2011/2056 (INI)) The European Parliament asked to be kept regularly informed in the Raw Materials Initiative on the development of non-energy raw materials and the achievement of its objectives through annual progress reports, which will also focus on policy coherence in the field of raw materials. trade, development and environment, and on social impacts, as well as data on critical raw materials.

1.2 Critical raw materials in the EU

The EU Working Group [1],[2] which prepared the list of critical raw materials for the next ten years, found that the amount of registered resources and stocks or stocks was not decisive for classification as critical raw materials. other geological assumptions, but changing geopolitical-economic conditions affecting supply and demand for individual minerals. In emerging economies of source countries, administrative measures (taxes, export quotas and tariffs, subsidies, etc.) are increasingly being applied to preserve strategic resources for own use. In addition, for many minerals, the concentration of resources in a few countries (eg rare earths) is increasing.

The EU working group analyzed the position of 41 minerals and metals in terms of their critical deficit for the EU (Annex V to the Report on Ad-hpc WG on defining critical raw materials). It was based on the concept of critical deficit, mainly due to the risk that supply disruptions of the raw material will significantly affect the economy. Two types of risk were considered:

(a) the risk of supply disruption resulting from the political and economic stability of the producing countries, the degree of concentration of production, the possibility of substitution and the degree of recycling;

(b) the environmental risk of the source country concerned, with an assessment of the measures necessary to preserve the environment, the implementation of which could jeopardize the supply of raw materials for EU needs.

The position of individual mineral commodities and metals is shown in the chart assessing supply risk versus economic significance.

A total of 14 raw materials were evaluated by the Working Group as critical. In fact, there are 35 minerals and elements, as the platinum group contains, in addition to platinum, palladium, iridium, rhodium, ruthenium and osmium. In addition to yttrium and scandium, 15 so-called lanthanides (La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb must be added to the rare earth elements listed here and Lu).

The high supply risk of the listed minerals and metals for the EU is mainly due to the prevailing concentration of world production in China (Sb, fluorite, Ga, Ge, graphite, In, Mg, REE (rare earth elements), W), Russia (Pt metals group)), The Democratic Republic of Congo (Co, Ta) and Brazil (Nb, Ta).

Minerals and metals on the lower right-hand side of the diagram may very easily move up to the critical area in the future. Without counting the risk and deficit according to the formulas used by the Working Group, we can say with certainty that from the Czech Republic's point of view, this group also includes aluminum, chromium, manganese, molybdenum, nickel, rhenium, tellurium, vanadium and iron ore. . Similarly, in the lower left region there are also critical raw materials for the Czech Republic, such as copper, lithium and titanium.

1.3 Mining Law of the Czech Republic

In the legal order of the Czech Republic, Act 44/1988 Coll., On the protection and use of mineral resources, together with Act 61/1988 Coll. on mining activities, explosives and the State Mining Administration, Act No. 157/2009 Coll., on Mining Waste Management, Act No. 62/1988 Coll., on Geological Work and the Czech Geological Survey and related implementing regulations form a separate area of law called Mining Law.

Mining law is not autonomous. Most of the proceedings under the Mining Law are conducted according to the Code of Administrative Procedure (Act 500/2004 Coll.). Legislation in the area of the environment (Czech and European), health and safety at work also has a significant impact on mining law.

1.3.1 Mineral resources in the legal order of the Czech Republic

The position of mineral resources and the possibilities of their exploitation (mining) are primarily regulated in the Czech legal order by Act No. 44/1988 Coll., On the protection and use of mineral resources (Mining Act). The Mining Act lays down principles for the protection and economic exploitation of mineral resources and activities related to the exploitation of mineral resources, from prospecting and exploration to mining and treatment, as well as the principles of operational safety and environmental protection in these activities.

The scope of the Mining Act is defined by the definition of minerals that are considered to be solid, liquid and gaseous parts of the Earth's crust, with the exception of most groundwater (plain and mineral), peat, most mud, sand, gravel and cobbles in watercourses and cultural soil. The Mining Act also distinguishes two categories of minerals – reserved and non-reserved minerals, which differ considerably in the ownership and protection regime.

According to the Mining Act, deposits of reserved minerals in the Czech Republic are mineral resources owned by the Czech Republic. In principle, the state, through a license, allows private entities to extract the deposits they own. A mining organization that has a designated mining area is also obliged to pay for the extracted minerals and is entitled to dispose of the extracted minerals to the extent and under the conditions stipulated in the decision on the determination of the mining area (Act No. 44/1988 Coll., Section 24 (10)). However, the Mining Act does not explicitly address the transfer of reserved minerals to a mining organization. While the current practice is that, by paying remuneration, the extracted minerals are de facto in the ownership of the mining organization, but given the attitude of a considerable part of the public, there is a possibility that the policy will be revised and especially the remuneration for extracted minerals.

1.3.2 Protection of raw materials

The need to protect mineral resources by means of the Mining Act is based on the fact that deposits of mineral resources are not transferable and mineral resources can only be mined where they are located. The protection of the deposit against being prevented or hindered by its extraction takes place through a protected deposit area, which is established above and in the vicinity of the deposit. Protected deposit area includes an area in which structures and equipment that are not related to the extraction of an exclusive deposit could make it impossible or more difficult to extract an exclusive deposit (Act No. 44/1988 Coll., Section 16). In order to protect mineral resources, buildings and facilities that are not related to the extraction of an exclusive deposit can only be set up in a protected deposit area on the basis of a binding opinion of the relevant authority (Act 44/1988 Coll. issued after consultation with the District Mining Authority, which will propose conditions for the location or implementation of construction or equipment (Act No. 44/1988 Coll. § 19).

The protection of reserved mineral deposits is also reflected in spatial planning. Spatial planning authorities and processors of land-use planning activities should rely on evidence of reserved and anticipated reserved deposits. On the practical level, however, the requirement to find the best solution from the point of view of two often conflicting general interests is difficult to meet. Therefore, spatial planning authorities often decide which of the interests prevails and will therefore be given priority [25]. However, it should be noted here that spatial planning authorities at all levels (municipal authorities, regional authorities, Ministry for Regional Development, Ministry of Defense - see Act 183/2006 Coll., On spatial planning and building code, § 5) are at least subject to political guidance and their activities, including decision-making, can in this case depend on the current position of the ruling political representation. At the same time, the Mining Act protects mineral resources also through the requirement for economic exploitation of the deposit (Act No. 44/1988 Coll., Section 30).

1.3.3 Royalties

The Mining Act provides for two types of reimbursement to a mining organization. Payments from the mining area for exclusive deposits amount to CZK 1,000 per ha per year.

The remuneration of the extracted minerals shall not exceed 10% of their market price. The starting point for the determination is the average market price in the year in which the minerals were extracted. However, for many minerals, the percentage set is lower and for some minerals it is only 0.5%. The amount of the reimbursement is determined by the Government Decree of 16 March 2016 on reimbursement rates.

At the same time, it is necessary to mention that according to the Mining Act payments have a fixed budget allocation. The payment for the mining area is an income of the municipal budget in which the mining area is located (Act No. 44/1988 Coll., Section 33g). The reimbursement of the extracted minerals is 38% of the budget of the municipality in whose territory the mining of other minerals was carried out and 62% of the budget of the state budget Act 44/1988 Coll. § 33n). Thus, the municipalities in whose territory mining takes place directly participate in profit.

1.3.4 Land ownership rights in the context of mining

The Charter of Fundamental Rights and Freedoms (Act No. 2/1993 Coll., Article 11) stipulates that only the law may determine which property necessary to meet the needs of the whole society, development of the national economy and public interest may be owned only by the state or other designated legal entities. At the same time, ownership obliges. It must not be abused to the detriment of the rights of others or contrary to the legally protected general interests. Its performance must not harm human health, nature and the environment beyond the limits set by law. At the same time, the Constitution of the Czech Republic (1/1993 Coll., Article 7) obliges the state to ensure the careful use of natural resources and the protection of natural resources.

Ownership of minerals is essential for the owner of the land on or under which mining is or will be carried out. In the case of land as an object of ownership, the Land Register Act (Act 256/2013 Coll., Section 2) defines land as a part of the land surface separated from neighboring parts by the boundary of the territorial unit or boundary of the cadastral territory. , the boundary of another law, the boundary of the scope of the lien, the boundary of the scope of the right of construction, the boundary of land types, or the interface of the way of land use. Ownership of such a landowner area entitles the landowner to exercise title not only on the land itself, but also in the space above and below it. The landowner may exercise his property in the space above and below the land as high and as deep as he wishes, unless otherwise prohibited by other regulations.

Reserved minerals, among which, among others, minerals from which it is possible to industrially produce metals, are state-owned. Reserved minerals and their accumulation (deposit of reserved minerals) are not part of the land. Possible use (extraction) of reserved minerals is carried out under the mining license regime. The second group consists of non-reserved minerals such as aggregates, which are part of the land and are owned by the landowner.

Ownership of land under which the deposit of reserved minerals is located does not confer any rights on the landowner to exploit those minerals. On the other hand, if the deposit of reserved resources is used, some rights of the landowner may be restricted. On the other hand, it should be pointed out that ownership of suitably located plots of land can be a great advantage, especially in the exploration phase.

At the same time, however, mining organizations can, if their project reaches the mining stage, gain priority on land (Act No. 44/1988 Coll. § 20). The entity to which a mining area is located on a land owned by the State shall have the right to have it entered into by the administrative authority, legal entity or its organizational unit managing or managing such land on period of anticipated exploitation of the deposit or purchase agreement for the sale of land An entity that has been granted a mining license has priority over other persons interested in renting or selling land owned by the state, which is located in a designated protected deposit area. In both cases, however, the application must be accompanied by a favorable opinion of the municipality in whose cadastral territory the land is located.

1.3.5 Depreciation of mineral reserves

Along with the definition of mineral resources (deposits of reserved minerals) as state property, it also provides for the possibility of depreciation of mineral reserves (Act No. 44/1988 Coll., Section 14a). At first sight, this logical institute intuitively aimed at extracted or marginal deposits has a much broader application. The deposit of exclusive raw materials can be depreciated because of the particularly complex mining, technical, safety or geological conditions related to natural conditions or caused by unforeseen events) but also because of the threat to other legally protected general interest, especially environmental protection, of these stocks. These factors may be of a very temporary nature and, in particular, the second option allows the depreciation of stocks for political reasons.

Based on the write-off of reserves, it is possible to completely remove the protection of an exclusive deposit as a general interest for possible future use. In case of abolition of a protected deposit area, restrictions on land use, including construction activities, will result, which may result in targeted placement of development or municipal infrastructure precisely in order to make possible future use of the deposit.

1.4 Raw material policy of the Czech Republic

On 22 June 2017, the Government of the Czech Republic adopted a document entitled “Raw Material Policy of the Czech Republic”. In the section devoted to ore resources (minerals from which metals can be obtained), the current state of ore mining and the outlook for the future is described in the following paragraph:

“With regard to the many years of ore mining in the Czech lands, the ore potential of the Czech Republic is limited and, with some exceptions, these are small deposits with local significance. Therefore, the massive use of traditional ore raw materials from domestic sources cannot be expected. However, some specific ore deposits in our territory may be promising in the future. After a change in the world market for mineral raw materials, in case of long-term favorable development of world prices, the possibility of reassessing the profitability of possible use of some metal deposits under new technical and economic conditions opens up to maximum utilization of technological progress achieved in the last 30 years. The limiting factor for their possible use is the economic profitability and use of such mining and treatment technology that would not have a devastating impact on the environment. In the future, the discovery of new or yet unknown ore deposits of local importance cannot be ruled out. The aim in this area is primarily to support exploration activities, especially aimed at new prospective commodities and involvement in the European project of geological exploration of deeper parts of the Earth's crust. In assessing the possible use of some of the known ore deposits, it must be assumed that any mineral deposit can be subject to an assessment as to whether or not it is economically viable under strict environmental protection requirements. '

At present, efforts are being made to supplement the Czech Republic's raw materials policy. In accordance with the Government Resolution, the state administration endeavors to limit the possibility of private capital entering the exploration and thus the extraction of reserved resources in particular by means of non-legislative procedures. The survey should primarily be carried out by the Czech Geological Survey and the state enterprise DIAMO. The private sector defends itself against such efforts through the Mining Union.

1.5 Other general interests and their protection

The protection of mineral resources in general is not superior to other public interests such as the protection of the environment, life and health or the development of municipalities and their infrastructure. On the contrary, the protection of these interests is explicitly enshrined in the Mining Act (see Act No. 44/1988 Coll., Section 15 and Section 33).

Spatial planning authorities and processors of land-use planning documentation should propose a solution that is most advantageous in terms of protection and use of mineral resources and other legally protected general interests. It should be noted here that spatial planning authorities at local and regional level are at least subject to political guidance and that the elected self-government approves the land-use planning documentation.

The Ministry of the Environment, the Ministry of Industry and Trade and the Czech Mining Authority make opinions on spatial development policy and on spatial development principles in terms of the protection and use of mineral resources. Again, despite continuity at the level of officials, ministries are politically guided and it is difficult to imagine the long-term disproportion between the ministry's attitude at expert level and that of its superior political representation.

The consequence of this situation is that the attitude of a part of the public, the visible pressure of interest groups or political ambitions can change the conditions for the realization of the mining project, significantly slow down or even stop it quite quickly.

1.6 Licensing process in the Czech Republic

1.6.1 Geological Survey

Geological exploration is a prerequisite for efficient mining of minerals. Generally speaking, it provides information on the type, content and distribution of the material of interest, as well as the surrounding rock environment. Geological survey in the Czech Republic is governed by Act 62/1988 Coll., On geological works. This Act applies to the whole spectrum of geological surveys. Act was originally created primarily for the field geological survey and describes in detail its particulars. The geological exploration organization imposes obligations, but it also gives it considerable rights related to the importance of mineral resources.

The key element of the geological exploration is the exploration area. The Geological Act explicitly stipulates that prospecting and exploration of mineral resources may only be carried out in the designated exploration area. However, only the person to whom the exploration area has been granted the right to carry out exploration has the exclusive right to prospecting and exploring the reserved deposit in accordance with the determination of the exploration area. At the same time, only one exploration area can be established for a single reserved deposit.

Conducting a geological survey outside the specified exploration area is an offense for which a fine of up to CZK 1 million can be imposed.

The application for the designation of the exploration area is submitted to the Ministry of the Environment. At the same time, the applicant must have a license for mining activities pursuant to Section 5 of Act 61/1988 Coll., On mining activities, explosives and the State Mining Administration, and must fulfill the condition of integrity. The parties are:

- the applicant,
- the municipality in whose territory the exploration area proposal or part thereof is situated
- or persons to whom the status of a party to the proceedings is granted special laws (in particular, this may be, for example, pursuant to Act 114/1992 Coll., on nature and landscape protection, civil associations or associations focused on nature protection § 70).

The Ministry of the Environment shall reject the application for the designation of the exploration area if:

- the proposed exploration area overlaps in whole or in part with an area already established for the same mineral by another contracting entity or with a designated mining area
- prior consent to the application for the determination of the mining area to a person other than the applicant has been given to the deposit
- the applicant fails to prove the required good repute or mining license
- in the last ten years, the applicant has been dismantled in accordance with Section 21 of the Geological Act
- the survey is contrary to the state's raw materials policy
- the survey is contrary to state environmental policy
- the survey is contrary to national defense interests
- the survey is contrary to the state's foreign obligations
- if the other public interest exceeds the interest in further exploration and subsequent exploitation of the reserved deposit The municipality and the interested public have at the stage of exploration area not only access to management but practically as a result of possible and often practiced politicization of the problem

The reconnaissance territory to which it was granted pays a fee derived from its area. In the first calendar year, this fee is CZK 2,000 / km2 (including the started year and started km2) of the designated survey area.

The fee is increased every year by CZK 1,000 for each km2 (Act 62/1988 Coll. Section 4b). The exploration area fee is the income of the municipality in which the exploration area is located. If the survey area is located in the territory of several municipalities, the fee shall be divided according to the proportion of areas of the survey area located in the territory of each municipality. The use of the fee as an initiative for the municipality has repeatedly proved to be ineffective in the past (most recently see, for example, the search for space for a deep radioactive waste repository, the planned exploration of shale gas deposits in the Broumov promontory). The municipality, if opposed to the mining project, usually prefers the fee rather than allowing exploration.

1.6.2 Exclusive deposit certificate

If the reserved mineral is found in quantity and quality that can reasonably expect its accumulation, the Ministry of the Environment will issue a certificate of exclusive deposit.

The Ministry of the Environment shall send the Certificate of Exclusive Deposit to the Ministry of Industry and Trade, the Regional Authority, the District Mining Authority, the Planning Authority, the Building Authority and the organization for which the Exclusive Deposit was searched or explored.

1.6.3 Proposal for designation of protected deposit area

The proposal contains the main information on the deposit and proposers, which is evaluated by the Ministry of the Environment. It is mainly the described character of the bearing, type of mineral, extent of the bearing and its geometric shape with vertices marked in the coordinate system and proposal of conditions of protection of the bearing against preventing or making its mining more difficult. After the allocation of a protected deposit area, the petitioner has a preferential right for the possible allocation of the mining area of the deposit.

1.6.4 Proposal for determination of mining area

The organization submits a proposal to determine the mining area to the District Mining Office. The design shall include, inter alia, the name of the mining area, its areal content, the designation and coordinates of the vertices of the geometric figure, its height limits, where appropriate, and the justification of the boundaries of the mining area; the coordinates of the peaks are ascertained by displacement from the map or measurement methods, the mineral or group of minerals of the reserved deposit, the extent, location, shape and thickness of the deposit, its tectonic failure and quantity and its impact on the surface, the assessed stock calculation with the geological map of the deposit, the map of the stock with any transverse and longitudinal cross-sections of the deposit, the exclusive deposit certificate and the decision on the designated protected deposit area, if any.

Plans for opening, preparation and quarrying of reserved deposits and plans for securing and liquidation of major mine workings and quarries

The organization authorized to extract exclusive deposits is obliged to draw up plans for the opening, preparation and extraction of such deposits. Plans must be prepared well in advance of mining. The opening, preparation and quarrying plans shall include a quantification of the anticipated costs of settling the mining damage incurred in connection with the planned activity and for the remediation and reclamation of the land concerned, including a proposal for the amount and method of establishing the necessary financial reserve.

1.6.5 EIA

Mining in the new mining area is subject to the Environmental Impact Assessment (EIA) pursuant to Act No. 100/2001 Coll., On environmental impact assessment. The competent authority (regional authority, MoE) shall issue a binding opinion on the environmental impact assessment within 30 days from the expiry of the deadline for the opinion on the basis of documentation or notification, opinion and public hearing pursuant to Section 17 testimonial. The particulars of the opinion are set out in Annex No. 6 to Act No. 39/2015 Coll. The competent authority shall forward the opinion to the notifier, the administrative authorities concerned and the local and regional authorities concerned and ensure that it is published. The opinion is the basis for a decision pursuant to special legal regulations. The notifier submits the opinion in the application as one of the documents for the follow-up proceedings under these regulations (zoning proceedings, building permit). The opinion is valid for 5 years from the date of its issue. The validity of the opinion may be extended by 5 years at the request of the notifier, even repeatedly if the notifier proves in writing that there have been no substantial changes in the implementation of the project, conditions in the territory concerned, new knowledge related to the material content of the documentation and the development of new technologies usable in the project. [26].

Mining is currently relatively environmentally friendly. The EIA process gives scope for participation in permitting procedures. This institute can be successfully used for obstruction. The public is meant by one or more persons. Recent developments in the issue should limit public participation towards an effective (positive or negative) assessment.

1.6.6 Mining activities permit

Authorization for mining activities can be issued on the basis of Decree of the Czech Mining Authority No. 15/1995 Coll., Only to a legal or natural person who proves that it is professionally qualified by itself or through professionally qualified employees (racing, racing mine, racing quarry, a mining designer or a major mining meter) to ensure activities within the scope of the required authorization. The license is issued by the relevant Mining District Office in whose jurisdiction the legal or natural person has its registered office or place of business or domicile. If such a place is not in the territory of the Czech Republic, jurisdiction depends on the place of the intended activity for which the license is required.

Table 2: Licensing process in the Czech Republic

Main progress steps	**Partial step**
Geological Survey	Establishment of the exploration area
	Geological exploration project
	Geological survey - prospecting stage and exploration stage
	Geological documentation of mining activities
Protection of mineral resources	Exclusive deposit certificate
	Protected deposit area
Permitting mining activities	Determination of mining area
	Plan for opening, preparation and quarrying of reserved deposits and plans for securing and liquidation of main mine workings
	Environmental Impact Assessment - EIA
	Mining activities permit
By permitting mining activities, the State Mining Administration continues to supervise mining activities until the liquidation of the mine workings (boreholes, etc.), including subsequent remediation, reclamation and possible mining damages.	

1.7 Regulation framework in Georgia

1.7.1 Overview of the relevant laws

The following is an overview of the relevant laws related to the project:

1.7.1.1 Framework Legislation
- No. 786 Constitution of Georgia (1995, as amended)
- No. 2181 General Administrative Code of Georgia (1999, as amended)
- No. 4113 Labor Code of Georgia (2010, as amended)
- No. 2608 On Public Safety (2018, as amended)
- No. 5069 On Public Health (2007, as amended)
- No. 519 Environmental Protection (1996, as amended)
- No. 4708: On Cultural Heritage (2007, as amended)
- No. 2937 On License and Permit Fees (2003, as amended)
- No. 1860 On Regulatory Fees (2005, as amended)

1.7.1.2 Permitting Legislation
- No. 1775 License and Permits (2005, as amended)
- No. 890 Environmental Assessment Code (2017, as amended)

1.7.1.3 Specific Environmental Laws
- No. 242 On subsoil (1996, as amended)
- No. 136 On the System of Protected Areas (1996, as amended)
- No. 936 On Water (1997, as amended)
- No. 2994 Waste Management Code (2014, as amended)
- No. 631 On Import, Export and Transit of Waste (1995, as amended)
- No. 2124 The Forest Code of Georgia (1999, as amended)
- No. 946 On Fees for the Use of Natural Resources (2004, as amended)
- No. 1438 On Vine and Wine (1998, as amended)

1.7.1.4 Specific Building Laws
- No. 3213: On Spatial Planning and Urban Development (2018)
- No. 577 On Construction Activities (2000, as amended)
- No. 1335 On Architectural Activities (1998, as amended)
- No. 6157 Product Safety and Free Movement Code (2012, as amended).

1.7.2 Regulation framework in Georgia – preliminary summary

Recently, the European Bank for Reconstruction and Development has produced a comprehensive review on the Georgian mining sector regulatory framework [3]. The report clearly points out critical issues in the Georgian regulatory framework of the mining sector
- Soviet-industrial-era legacies including narrow legislative scope and neglected mining-related environmental impacts continue.
- Stringent reserves reporting and calculation of fees fails to capture true benefits of mineral developments.

- Investor eligibility is not legally prescribed; gaps in how investments are introduced, managed and enforced as well as performance obligations and safeguards for environmental and social impacts are insufficiently addressed.
- Little to no legislative provision is given to ensuring best investment, due diligence, technical quality and other benchmarks for legitimate and sound mining investment.
- Despite years of improved fiscal regimes, with respect to minerals, modernization and improvement of revenue management should be legislated.
- Mine safety and mine worker health are minimally regulated and modern regulatory capacity for inspectors, miners and policy-makers is not in place.
- Social and labor aspects are treated as part of broader legal frameworks that do not sufficiently capture the dynamic and temporary nature of mining as a business or of mining impacts in the near and long-term.
- No guidance on post-mining livelihoods – e.g., when a mineral deposit is depleted, mine communities are left without employment, adequate environmental rehabilitation, and important revenues that, while the mine was operating, had been directly paid to the Municipality.

The mining regulatory framework is based on two main acts – The Subsoil Law and The License and Permit Law.

The Subsoil29 Law (1996, amended later) regulates the exploration and extraction of minerals from land and water by domestic and foreign investors with the objective of ensuring rationale use in consideration of environment and sustainable development. It is important to note that the "Subsoil" legislation includes not only minerals but underground natural emissions, water, oil and gas, storage, underground construction – so in effect, it is not only a mining and minerals" law but is more broadly applied. Some critical nuances and details specifically relevant to minerals are sorely missed; the most obvious example is that a license includes a variety of uses from assessment to exploration to extraction to processing without clear process for conversion of these license aspects and requirements for each investment phase. The law also provides for state oversight, much of it emphasizing technical aspects and reporting aspects.

The Licenses and Permits Law (2005) – regulates a variety of licenses and permits and under Article 7, includes licensing and permit information specifically relevant to mining

- Mineral exploration and exploitation or exploitation license
- License to use underground space
- General license for forest use

The primary minerals legislation relies on antiquated terminology (or English translation of same), approaches and ways of implementing mineral investments that do not reflect modern best practices. Most striking is that the legislation does not set out investment criteria, licensing rights and obligations or distinguish amongst the various types of minerals or investment phases of mining investments, likely leaving Government to miss useful revenues and economic development opportunities. Further, this legislation lightly addresses some very critical mining-relevant issues, if at all, specifically health and safety and environmental aspects. More regulatory detail and supporting legislation would be useful.

General law framework is applies to

- Labor safety

- Public rights and safety
- Environment protection
- Waste management
- Tax and royalties
- Land use
- Forestry
- Water use
- Reporting and statistics
- Mine projection and construction

In theory, all mineral resources are state property and all mining activity connected is subject to licensing. A special license on the exploitation of mineral resources should be obtained at the state auction. The license validity should depend on the mineral type and on the actual demand for it. Together with the obtained license the licensee obtains also the temporary right on land use necessary for processing operations After finalizing its activities, the company is obliged to conduct rehabilitation of the territory concerned and return it recovered to the state. During the whole period of exploitation of mineral resources the licensed companies should meet the appropriate environmental requirements and rules, adopted for the time being only in the field of ambient air protection.

2. BREF documents and BAT

Environmental protection in industry in EU is ensured, among other things, by the application of BREF documents, which provide so-called best available techniques (BAT). BATs lead to a high level of environmental protection and are part of Integrated Pollution Prevention and Control (IPPC).

Georgia has not yet introduced IPPC permits for large industrial installations. There is still no guidance on how to assess BAT, record information on high-risk industrial installations and report on major industrial accidents. Environmental self-monitoring and self-reporting by industry are not mandatory and, therefore, not enforced. Georgia wants to join the EU and will also have to implement this directive into national legislation and meet its requirements.

The following BREFs apply to the project:

- Best Available Techniques (BAT) Reference Document for the Management of Waste from Extractive Industries in accordance with Directive 2006/21/EC, European Commission; 2018 (a review of the Reference Document on Best Available Techniques for Management of Tailing and Waste-Rock in Mining Activities; European Commission; 2009).
  Document, Best Available Techniques Reference Document for the Management of Waste from Extractive Industries, in accordance with Directive 2006/21/EC, abbreviated as MWEI BREF, is a review of the Reference Document for Management of Tailings and Waste-Rock in Mining Activities (MTWR BREF). This document presents data and information on the following:- General information and key figures on extractive industries in Europe, extractive waste generation, extractive waste facilities and key environmental issues (Chapter 1).- Applied processes and techniques for the management of extractive waste (Chapter 2).- Emission and consumption levels resulting from the management of extractive waste (Chapter 3).- Techniques to consider in the determination of Best Available Techniques (Chapter 4). This includes generic management and waste hierarchy techniques, risk-specific techniques to ensure safety, techniques for the prevention or minimization of water status deterioration, techniques for the prevention or minimization of air and soil pollution and other risk-specific techniques.- Best available techniques conclusions (Chapter 5).- Emerging techniques (Chapter 6). This includes techniques that were reported at different levels of technology readiness.- Remarks and recommendations for future work (Chapter 7).

- Reference Document on Best Available Techniques in the Ceramic Manufacturing Industry; European Commission; 2007.
  This document addresses the industrial activities specified in Section 3.5 of Annex I to Directive 96/61/EC, namely: 3.5. Installations for the manufacture of ceramic products by firing, in particular roofing tiles, bricks, refractory bricks, tiles, stoneware or porcelain, with a production capacity exceeding 75 tons per day, and/or with a kiln capacity exceeding 4 m³ and with a setting density per kiln exceeding 300 kg/m³'. For the purposes of this document the industrial activities falling within this description will be referred to as the 'ceramic

industry'. The major sectors which are based on the ceramic products (ceramics) manufactured are as follows:

- wall and floor tiles
- bricks and roof tiles
- table- and ornamental ware (household ceramics)
- refractory products
- sanitary ware
- technical ceramics
- vitrified clay pipes
- expanded clay aggregates
- inorganic bonded abrasives.

– Best Available Techniques (BAT) Reference Document for the Production of Cement, Lime and Magnesium Oxide, Industrial Emissions Directive 2010/75/EU; European Commission; 2013.
In particular, this document covers the following processes and activities: production of cement, lime and magnesium oxide (dry process route), raw materials–storage and preparation, fuels–storage and preparation, use of waste as raw materials and/or fuels, quality requirements, control and preparation, products–storage and preparation, packaging and dispatch.

– JRC Reference Report on Monitoring of Emissions to Air and Water from IED Installations, Industrial Emissions Directive 2010/75/EU; European Commission; 2018.
The monitoring of emissions to air and water represents an important element in preventing and reducing pollution from industrial installations and in ensuring a high level of protection of the environment taken as a whole. Therefore, the Industrial Emissions Directive 2010/75/EU (IED) address the monitoring of emissions in a number of instances. This JRC Reference Report on Monitoring summarizes information on the monitoring of emissions to air and water from IED installations, thereby providing practical guidance for the application of the Best Available Techniques (BAT) conclusions on monitoring in order to help competent authorities to define monitoring requirements in the permits of IED installations.

10.12.2019

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Watrad, spol. s r.o.

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Chiatura: Feasibility Study Reconstruction of Sludge Treatment Technology

Pardubice 2019, Czech Republic

Print No. **1**

Content

1. Introduction

This report describes main possible methods of treatment of the sludge arising from the technology of manganese ore concentration. The main task is to propose a suitable, technically and economically viable model of process water management to prevent pollution of the Kvirila River, which serves as the main source of process water for enrichment plants.

The long-term pollution of the river is caused mainly by the discharge of untreated sludge after the ore enrichment process directly into the river Kvirila or into its tributaries. Most of the pollutants discharged in the sludge stream into the river are in undissolved form, but the concentration of dissolved compounds, including toxic barium, which has been documented on the basis of the samples taken, should also be considered.

The level of river pollution is documented on the basis of the analysis of the samples taken in the next part of this report.

2. Present Situation

The license for use of manganese ore owned by Georgian Manganese was issued in 2006 for 40 years. According to the terms of the license, 16 430 hectares has been allocated for the company for entrepreneurial activities, including 13 068 hectares in Chiatura district (24% of the total area of the district) and 3 362 hectares in Sachkhere district.

At the internet is available lot of literature that describes past and present conditions on the site as follow:

- Generally wastewater produced in ore washing technological process contains large amounts of weighted particles, manganese compounds and a small number of other microelements. For treatment of the wastewater, the enrichment plants are equipped with sedimentation tanks and tunnels where the weighted particles (sludge) were deposited, and then water was returned to the enrichment plants for recycling. In order to remove sludge from the plants, a sludge line (two parallel pipelines) was constructed through which the sludge was supplied to the central flotation plants where manganese concentrate was separated from sludge. In the past the remaining sludge was pumped out to the so-called Ghurghumela reservoir. The sludge was deposited in the Ghurghumela reservoir after which the water was returned for recycling.
- Currently, none of the enrichment plants of Chiatura mining and enriching complex has an operative treatment facility. The previously existing sludge lines are out of operation. Thus, the Ghurghumela sludge reservoir is inactive at present. In fact, most of the sedimentation tanks and tunnels are not functional, the pipeline no longer exists and the wastewater of the enrichment plant flows without the prior treatment into the river Kvirila that causes pollution of the river water with solids incl. residues and manganese compounds. An additional source for Kvirila pollution is the mine dump of the agglomerate, where the agglomerate after processing of intermediate products of various

factories by the enrichment plant (central floatation plant) is deposited. This is an intermediate waste, which contains an average 15 % manganese, and in case of improvement of enrichment technologies, it is possible to obtain a manganese concentration from it. The dump is located on the left bank of the river Kvirila.

- In November 2014, Georgian Manganese released the Environmental Impact Assessment report for the construction a new enrichment plant and exploitation of manganese ore in Chiatura. The main drawback of the new project was the unresolved problem related to disposal of production waste – sludge.
- The Company discussed two alternatives for waste disposal for the new enterprise: 1. Ghurghumela sludge reservoir - which has long been out of order, and 2. Dalakhauri sludge reservoir – the construction of which was opposed by the local Gamgeoba and the population of Itkhvisi and Shukruti villages - mainly due to the threat of adverse impacts and the proximity to the villages.

Following picture shows that manganese ore is being treated at 23 sites in surrounding area of Chiatura town by companies that are suppliers of or owned by Georgian Manganese. There are as well other for let say factories that are large treatment objects belonging to GM.

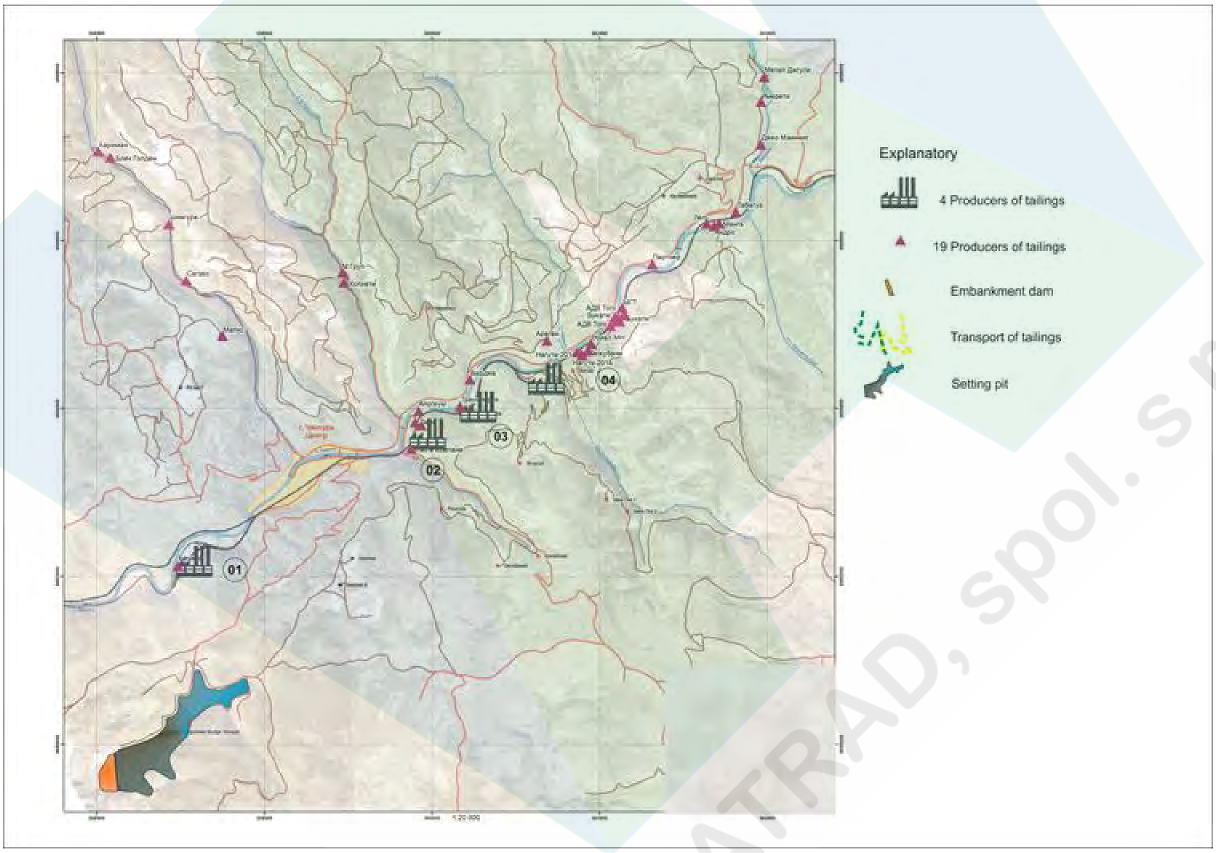


Figure 1: Location of treatment facilities in Chiatura site

In order to ascertain the current state of the manganese ore treatment process, most of these ore treatment plants were visited by us.

Manganese ore is treated in these places in a very simple way by obsolete facility (see enclosed photo). Ore treatment process is using water from the nearby watercourse. Used water is returned back to the watercourse largely without cleaning process.

Figure 2: Typical treatment technology

The issue of pollution of surface watercourses by treatment of manganese ore in the Chiatura area is discussed in the document "Investigation focused on the content of manganese in sediments of surface watercourses in the Chiatura area".

3. Tailings management

3.1 Tailings disposal strategies

The mapping of the sources of water pollution in the Kvirila River has the unequivocal conclusion that the originators are manganese ore processing plants. Operators do not comply with the basic rules applicable to ore treatment if using surface water. After getting to know the current situation and assessing the impact of technology operation on the quality of watercourses in the Chiatura area, three possible versions of the solution were developed.

There are only three possible scenarios. All scenarios work with the fact that the sludge will need to be concentrated in a suitable place. For this reason, two sites are considered. These two sites are called Ghurghumela Sludge and Dallakhauri Sludge.

A tailings storage facility (TSF) is a structure made up of (one or more dams) built for the purposes of storing the uneconomical ore (ground up rock, sand and silt) and water from the milling process.

3.2 Tailing pond area selection

At the Georgian Manganese management level, two sites that are eligible for tailing storage are discussed. It is a site known as Dallaghauri (Dalaghauri) Sludge, located very close to Chiatura, and Ghurghumela Sludge, which is more distant from Chiatura.

Figure 3: Position of Dallakhauri sludge and Ghurghumela sludge

Dallakhauri Sludge is located in a valley on the left bank of the Kvirila River. The valley is located in the northern suburbs of Chiatura. The valley is already loaded with mining waste, but for the valley to be fully usable, it will be necessary to cross the valley with a new dam. From the safety point of view, however, this location is less suitable, as the valley faces the inhabited area and the body of dam will be in close proximity to the Kvirila River.

Ghurghumela Sludge is a site where the mud is already disposed of. It is a sludge which was established and operated in the last century. At present, the sludge is not operated and construction work is necessary for its further use. The sludge can be put into operation very quickly provided that the existing tailing dam is assessed as stable based on an engineering-geological survey. If the dam is assessed as stable, it will be appropriate to increase it by 15 m and increase the storage capacity of the valley. The tailing dam can be raised during the mud operation. From the safety point of view is this location very suitable.

3.3 Ghurghumela sludge tailing dam

The Ghurghumela Sludge (tailings pond) is located in a valley southwest of Chiatura. The valley is dammed by about 50 m high dam. The capacity of the tailing pond is at present not sufficient for more than three to five years of operation. The current dimensions of the tailings pond are approximately 2,000 m long, a maximum width of 800 m and an estimated maximum depth of 50 m. The body of the outer dam is approximately 320 m long and 408 m wide. The core of the dam is 135 m x 408 m. The body of the inner dam is 50 m x 408 m.

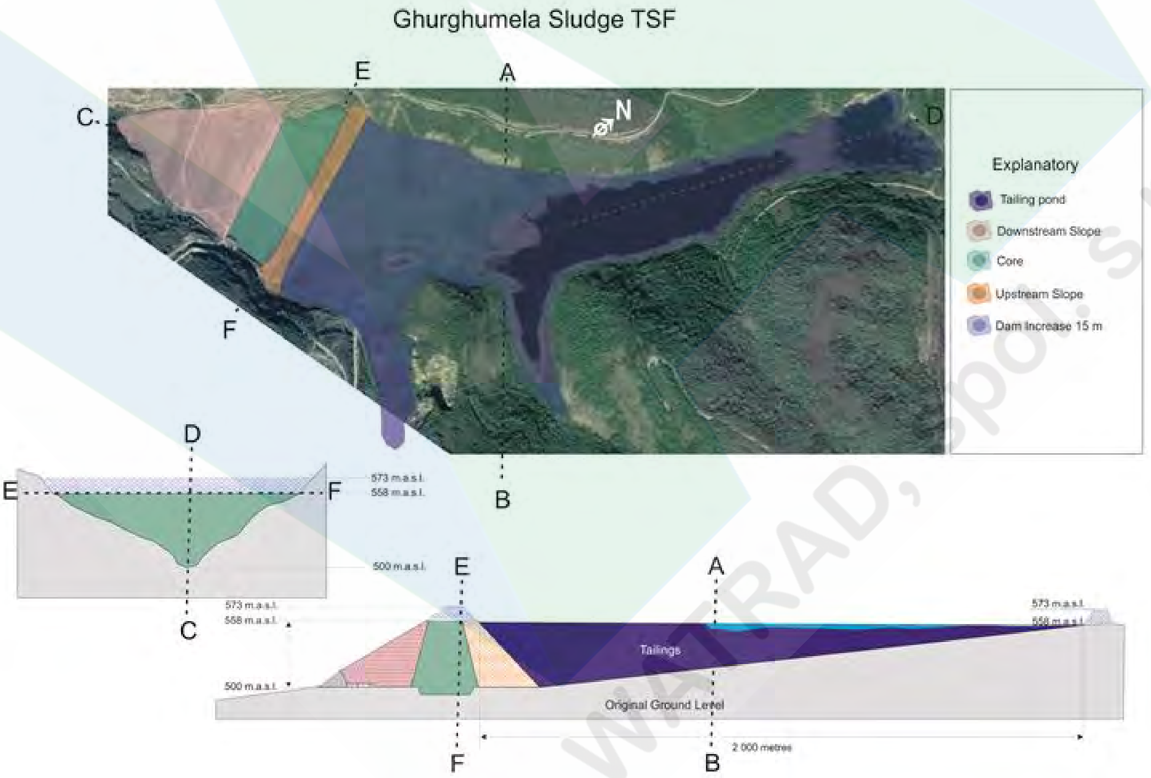


Figure 4: Scenario No. 03

If the tailing dam will be increased by 15 m, the sludge usability will be extended by another 10 - 15 years. In order to increase the dam body by 15 m while ensuring safe operation, it is essential to evaluate the stability of the existing dam body and to build a monitoring network on the outside of the dam.

The Ghurghumela Sludge TSF can be put into the operation de-facto immediately and at the same time start to raise the old dam. The siting of the Ghurghumela Sludge TSF seems to be ideal, because the valley below the dam is V-shaped. This location is also suitable from the viewpoint of public pressure. The public has already become accustomed to placing the tailings in this site and any protests should not be so intense.

In order to mark this site as perspective for further use, it is necessary to assess the stability of the tailing dam.

3.4 Scenarios description, comments and selection

3.4.1 Scenario No. 01

The first scenario leaves all small manganese ore processing plants in operation. Existing enrichment plants, including small ones, must be equipped with a closed sludge treatment and process water recycling system. At the site of operation of each ore processor, a sump of used technological water will be built connected to the screw filter press. In the screw filter press the strain is filtered and the process water is cleaned. Process water free of rock residue after manganese ore processing will be returned by the pump to the technology. The compacted sediment that will fall out of the filter press will be weighed at least once a day to the central dump.

In case of first scenario to keep the recipient (Kvirila River) clean, it would mean running a large number of separate sludge treatment plants and ensuring sludge transport to the sludge landfill from each sub-treatment plant, which would be very demanding in terms of organization and difficult to control.

If small ore processing plants will be left, a wastewater management system will have to be built at the site of each plant. The basic principle of the system being operated by each operator will be:

reservoir water → technology → ore wash → chamber filter press → reservoir

Water to the reservoir will be replenished from near watercourse.

The operation of the waste water technology must be built in such a way that it does not allow waste water from the technology to be drained directly into the watercourse.

The scenario assumes that it will be necessary to transport the sludge produced from each operator to the central heap. There are two ways of handling the separated sediment = cake:

- The central slag heap will be located at No. 01. From the central slag heap the material will be transported to the tailing area by a belt conveyor.
- The cake track enters directly into the tailing area, where it folds the material to a designated location.
- All plants will be connected to the process water pipeline with the tailing area.

Positives:

- Transfer of responsibility for wastewater management to manganese ore plant operators.
- The construction of the wastewater management system will be demanded by GM from the technology operator, including the provision of transport to the central repository.
- Minimum financial burden on GM from all possible solution scenarios.

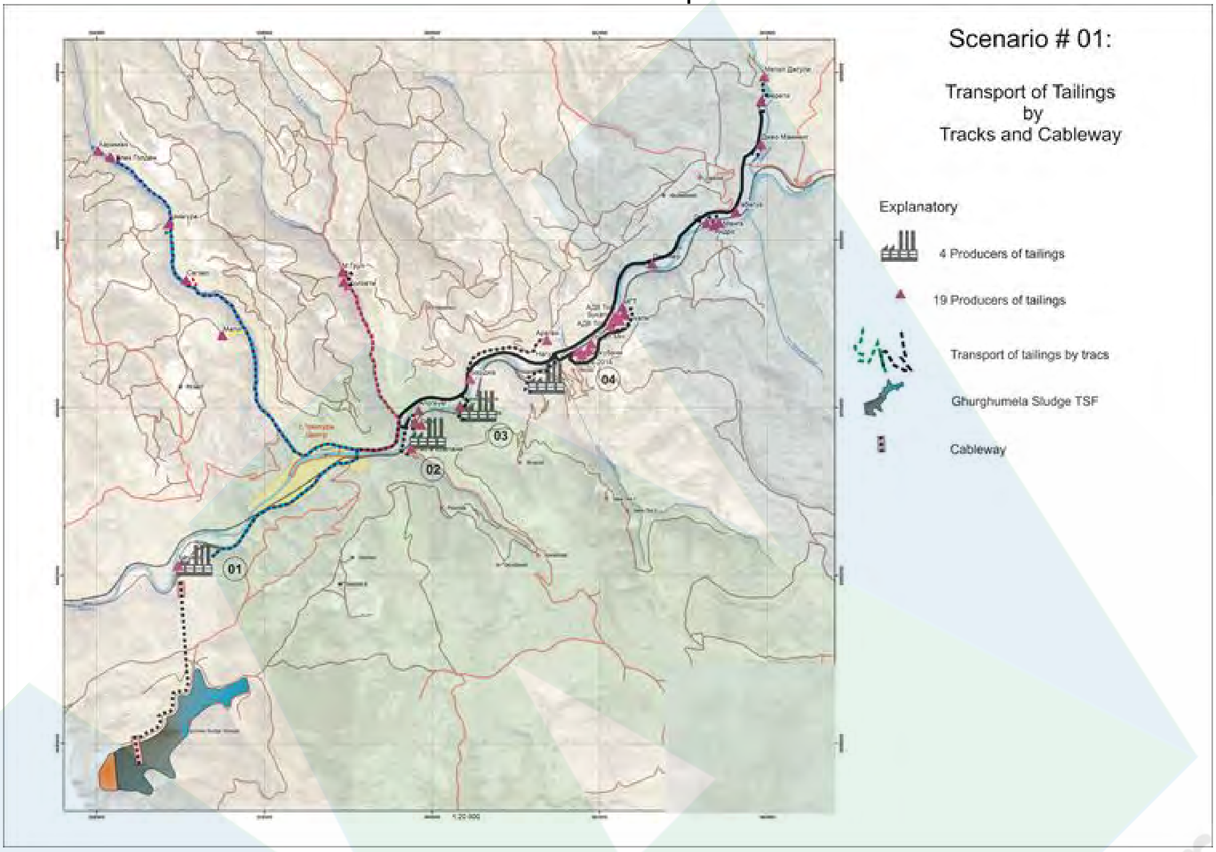


Figure 5: Scenario No. 01

Negatives:

- In case of sludge removal by truck:
  There are about 23 manganese ore processors, which means that minimally 23 tracks full filed with sludge will be transported daily to the central repository. All transport routes must use the road on the right bank of the Kvirila River. The both of existing Ghurghumela Sludge or planned Dallakhauri Sludge are located on the left bank of the Kvirila River. There is only one bridge crossing the both Kvirila River and railway. This bridge is in the center of town Chiatura. At least 3 trucks will pass over the bridge in the city center every hour to transport the cake from each producer to the central repository.
- In case of sludge floating through process water piping:
  The pipeline may need to be routed over the surface. This means that all four right-bank side valleys will be intertwined by several kilometers of pipes with a diameter of about 50 cm connecting each producer with disposal site of tailings. The pipelines will have to be two side-by-side, one for so-called clean water and the other for process water with sludge. It is essential that water is constantly flowing in the sludge piping, otherwise the piping will become

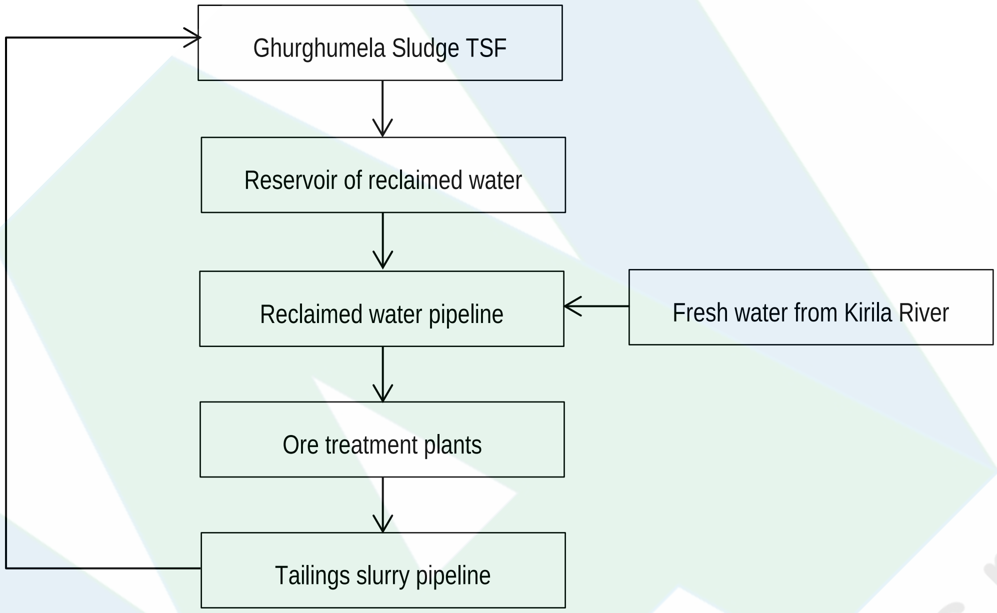
clogged. It will be necessary to synchronize the sludge draining from the individual devices. The city will be intertwined by pipelines and pumping stations.

From a technical and economic reasons it is for treatment and wastewater recycling process much more advantageous to centralize ore treatment plant into a few selected locations, that`s why is this solution elaborated in more details in following.

3.4.2 Scenario No. 02

The second scenario assumes that all ore processing operations will be concentrated in 4 ore treatment plants - factories. These factories will be connected by two piping systems. One piping system will be designed for "clean" process water, while the other piping system will be designed for liquid suspensions containing braces.

The basic principle of the system will be:



Technological water losses will be replenished with water from the river.

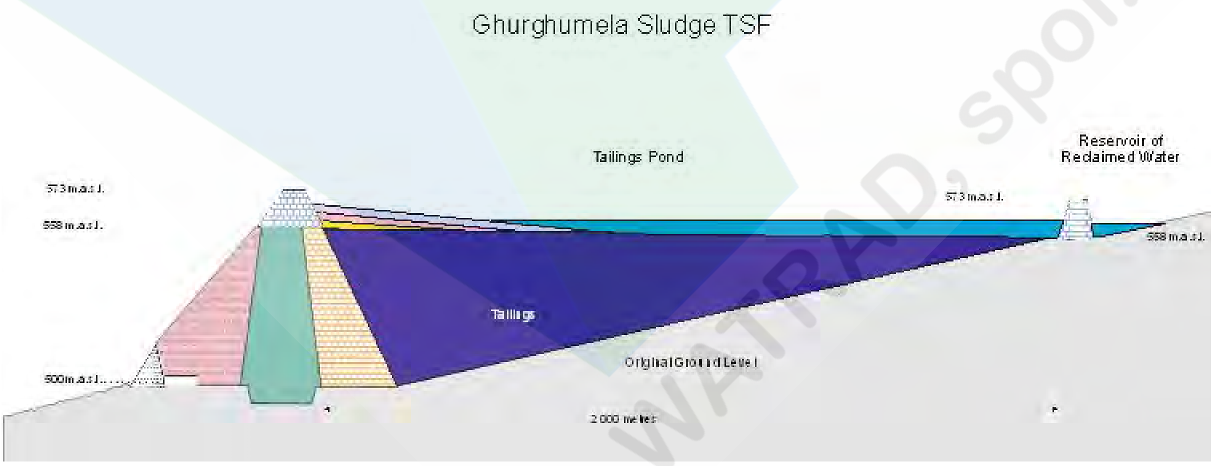


Figure 6: Position of reclaimed water reservoir

At each factory there will be a pumping technology that will pump the liquid suspension – tailing slurry – to the tailing slurry pipeline. Tailing slurry will flow to the central pumping station on the site of the factory marked 4 (see Figure Scenario No. 2) and by a powerful pump system will be driven to the central tailing pond – Ghurghumela Sludge TSF. The sludge will be filled away from the tailing dam to the dam of reservoir of reclaimed water. Separation of tailings from process water will occur spontaneously in the sludge using gravity.

For the accumulation of “clean” technological water, a collection tank will be built at the northern edge of the mud. From this tank the process water will be returned to the processing process. The missing volume of “clean” technological water will be pumped from the Kvirila River.

A recovery unit will be built on the downstream branch of the “clean” process water pipeline at the Factory No. 1, which will supply part of the electricity to the service station.

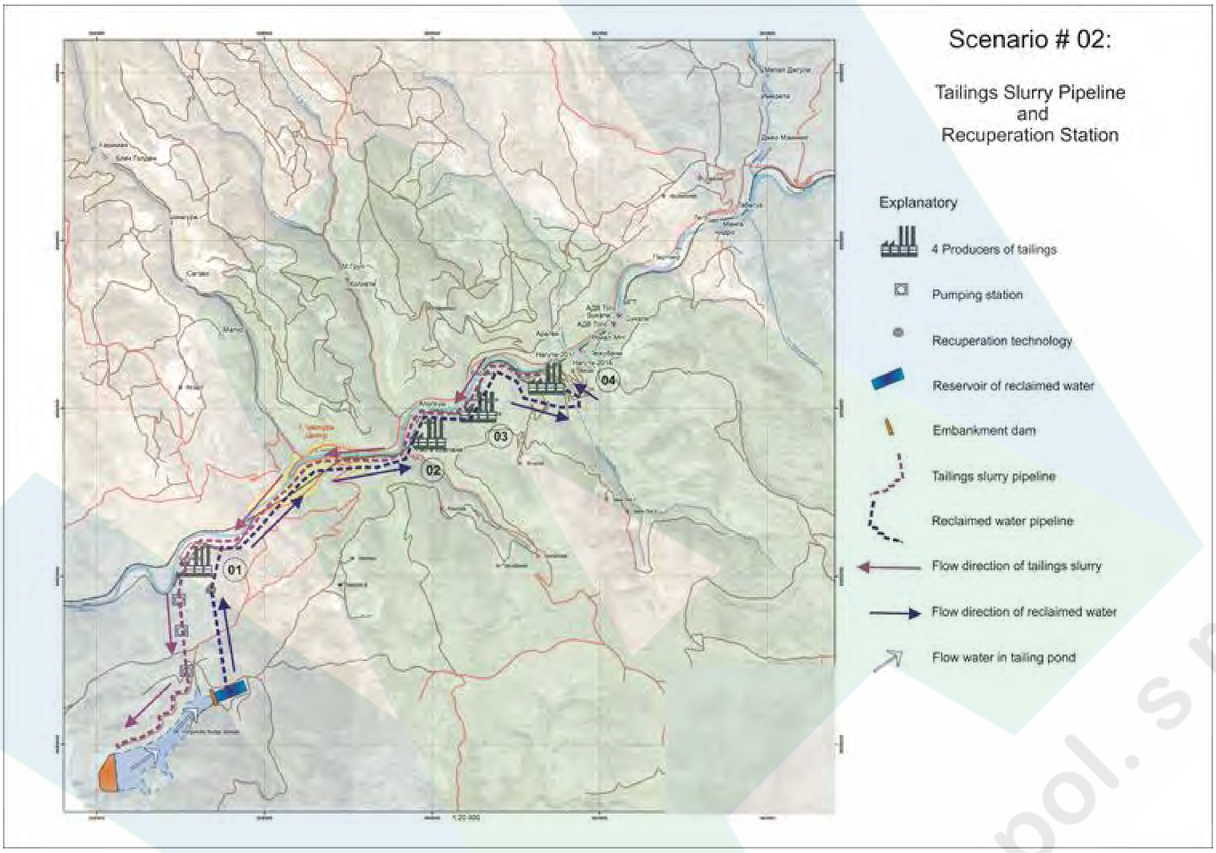


Figure 7: Scenario No. 02

Positives:

- Minimum operations
- Minimizing impacts on human health and the environment
- Reduced operating costs
- Utilization of energy potential of pipeline downstream branch
- In the case of dam stability high operational safety

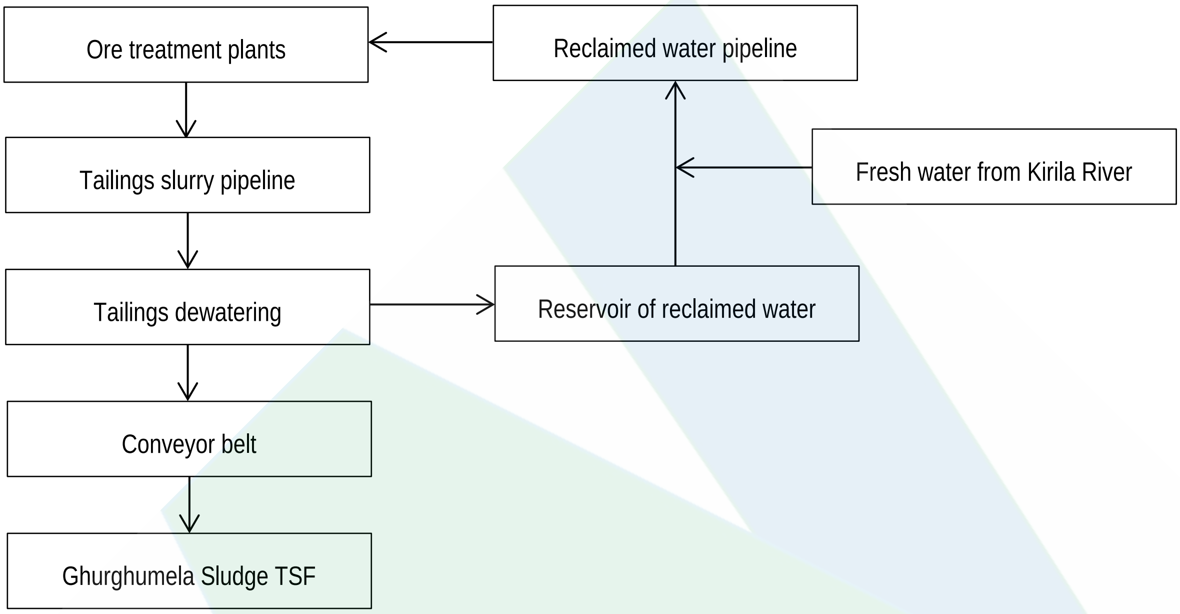
Negatives:

- Higher investment costs
- Increased system maintenance

3.4.3 Scenario No. 03

The third scenario assumes that all ore processing operations will be concentrated in max. 4 ore treatment plants - factories. These factories will be connected by two piping systems. One piping system will be designed for reclaimed water, while the other piping system will be designed for tailing slurry.

The basic principle of the system will be:



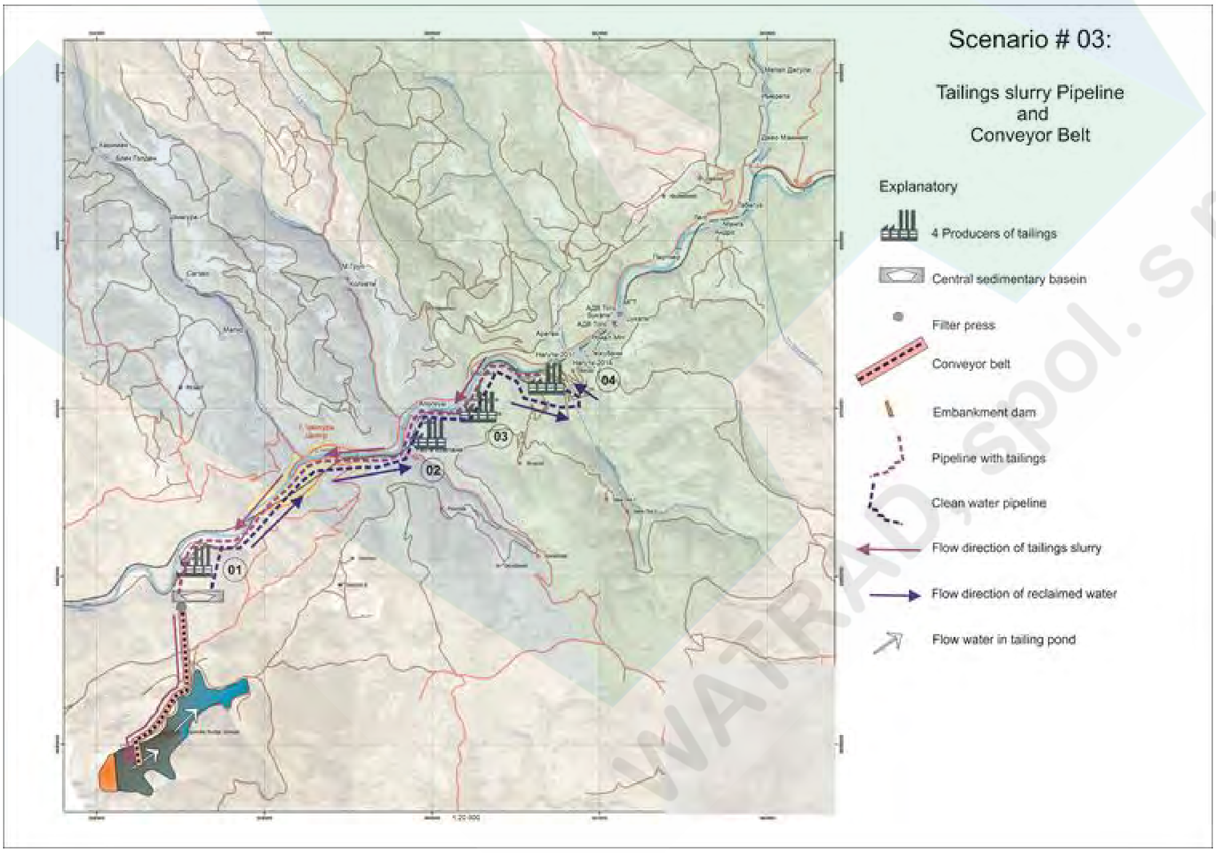


Figure 8: Scenario No. 03

At each factory there will be a pumping technology that will pump the liquid suspension – tailing slurry – to the tailing slurry pipeline. Tailing slurry will flow to the central pumping station on the site of the factory marked 1 (see Figure Scenario No. 3) where will tailings be dewatered. Dry tailings will be transported by conveyor belt to the Ghurghumela Sludge TSF.

Processing water from tailing dewatering stage will flow to reservoir of reclaimed water placed nearby factory No. 1. From reservoir the reclaimed water will flow by pipeline back to ore treatment plants. Technological water losses will be replenished with water from the river.

Positives:

- Minimizing impacts on human health and the environment
- Reduced operating costs
- In the case of dam stability high operational safety
- High disposal capacity Ghurghumela Sludge TSF

Negatives:

- High investment costs
- Increased system maintenance

4. Risk

It is necessary to define the risk associated with sludge storage. Risk can simply be defined as the effects of something on objectives; such effects might be positive or negative and may be multidimensional, incorporating aspects such as health and safety, environment, finances, and social elements. It could also define as the potential loss in health and safety, environment, economic associated with an event or activity. Potential risks associated with mine tailings are detailed in following table. The both geochemical and geotechnical risks are included in the potential risks associated with mine tailings.

Table 1: Potential risks associated with mine tailings

Phase	Potential risks
Operation	Leaking of tailings slurry pipeline
	Geotechnical failure
	TSF overflow
	Seepage through containment wall
	Seepage infiltration to ground water
	Particulate Matter (PM): dust or gas emissions
	Interaction of wildlife or livestock with tailings
	Mine acid pollution into the water: ground water and surface water
Closure	Erosion of containment wall
	Spillway failure
	Overtopping by rainfall run-off
	Failure of land cover system on tailings surface

These risks should be managed and monitored to prevent or eliminate the hazards that may occur. Managing and monitoring risks is one of the steps outlined in risk management principles. Risk management can be streamlined into seven stages: problem definition, data and information collection, risk identification, causes and controls, assessment and analysis, planning and action, and monitoring and review. This cycle is a continual improvement process where the monitoring and review stages act to produce further improvement initiatives.

Worldwide experts argue that the application of risk management will provide advantages for tailings management. These advantages are as follows:

1. Minimize tailings incidents associated with tailings transportation and storage,
2. Minimize the likelihood of environmental, health, safety, and business risks,
3. Minimize the risks associated from the initial mine tailings step, planning and design, through to the final step of post-closure,
4. Prioritization of having an action plan associated with hazards or risks in place.

5. Price estimation

5.1 Technological part

5.1.1 Scenario No. 2 Mechanical part supply – Price estimation

Coarse mechanical pre-treatment for each enrichment plant & Sludge suspension pumping station, 8 pcs

- Gravel trap equipment 4x 33 000 = 132 000,- €
- Pumps 8x 360 000 = 2 880 000,- €

Collection tanks, 2 pcs

- Steel enamelled tank 1400 m3, 2 pcs 2x 126 000 = 252 000,- €

High pressure pumping station

- 4 pumps, 4x 650 000 = 2 600 000,- €
- Pipe line of sludge suspension, 2 km, 192 000,- €
- Floating pumping station, 115 000,- €
- Pipe line of process water, 2 km, 154 000,- €

Electro part, I&C

- 480 000,- €

TOTAL: 6 805 000,- €

5.1.2 Scenario No. 3 Mechanical part supply – Price estimation

Coarse mechanical pre-treatment for each enrichment plant & Sludge suspension pumping station, 8 pcs

- Gravel trap equipment 4x 33 000 = 132 000,- €
- Pumps 8x 360 000 = 2 880 000,- €

Collection tanks, 2 pcs

- Steel enameled tank 1400 m3, 2 pcs 2x 126 000 = 252 000,- €
- Pumping station, 4 pumps, 4x 27 000 = 108 000,- €

Mechanically scrapped settling tanks, 4 pcs

- Concrete tank – see civil part
- Mechanical part – 4x 185 000 = 740 000,- €

Homogenization tanks, 8 pcs

- 8x 35 000 = 280 000,- €

Sludge dewatering system- filter press, 6 pcs

- 6x 580 000 = 3 480 000,- €

Transport of dewatered sludge to the storage area

- 4 000 000,- €

Accumulation and distribution system of treated water

- High pressure pumps 2 pcs, 2x 360 000 = 720 000,- €
- Pipeline 9 km 865 000,- €

Electro part, I&C

- 290 000,- €

TOTAL: 13 757 000,- €

5.2 Civil part - Price estimation

5.2.1 Scenario No. 02 Construction work

– demolition work for construction site release	360.000,- €
– excavation and supporting construction of pipeline between enrichment plants No.1 – 4 (pipe price is not included)	470.000,- €
– gravel extraction - underground construction (4x)	110.000,- €
– sludge pumping station (including all construction, site leveling	
– roads and compacted areas, networks, etc.)	290.000,- €
– sludge suspension pipe + recycled water pipeline foundations	120.000,- €
– adjustment for sludge suspension pipeline around reservoir	40.000,- €
– auxiliary and complementary civil works	160.000,- €
Total	1.550.000,- €

5.2.2 Scenario No. 03 Construction work

– demolition work for construction site release	360.000,- €
– excavation and supporting construction of pipeline between enrichment plants No.1 – 4 (pipe price is not included)	470.000,- €
– ogravel extraction - underground construction (4x)	110.000,- €
– sludge treatment plant (including all construction, site leveling roads and compacted areas, networks, etc.)	1,370000,- €
– opipe conveyor route foundations	60.000,- €

–	auxiliary and complementary civil works	230.000,- €
	Total	2.600.000,- €

5.3 Ghurghumela sludge tailing dam – Price estimation

–	Geological site investigation	305 000,- €
–	PCB to increasing the dam by 15 m	40 000,- €
–	Increasing the dam by 15 m (rough estimation)	7 000 000,- €
–	Total	7.345 000,- €

6. Conclusion

Three possible scenarios for the treatment of sludge produced in the manganese ore processing in Chiatura were compared. The aim of this study is to compare and justify the technical acceptability of possible solutions for further analysis.

The first scenario based on the unchanged number of treatment plants is the least appropriate. The operations are spread over a large area and use not only the main flow of the Kvirila River but also all its tributaries to operate. The location of small operators makes life unpleasant for a large number of city inhabitants. They burden the environment with both raw material supply and product and waste transport. There is only one transport route for tailing storage that runs through the city center and a single bridge crossing the both the river and rail. The adoption of this scenario is the most technologically complex and will have devastating impacts on infrastructure and urban life.

The basic principle of the second scenario is to concentrate the manganese ore process into a few plants linked to two pipelines. One branch of the pipeline will be used to divert tailings from operation to the storage area while the other branch will distribute the tails-free water back to the manganese ore processing technology. The branch of the pipeline, which flows through the tailings from operation, runs uninterrupted to the tailing pond. The attractiveness of this scenario lies in the simplicity of the technical solution, minimization of tailings handling processes and the possibility of utilizing the energy potential on the downstream branch of the pipeline. The disadvantage is the necessary modifications at the tailing pond area, where it will be necessary to build, respectively increase the second dam, which ensures the accumulation of water free of gravity from the tailings. From there the water will be returned to the production process.

Similarly to the second scenario, the third scenario is based on the concentration of manganese ore processing into a minimum number of technologies. Again, these technologies are interconnected by piping systems with the same functionality as in scenario two. The difference, however, is that the piping system will be interrupted in the valley below the tailing pond area. At this point a separation station will be built where the tailings will be separated from the water and dried. In the dry condition, the tailings will be transported by a conveyor belt to the sludge site where they will be deployed with the aid of further mechanization. The advantage of this scenario is the possibility of piling dry tailings in the form of heaps and the need to increase only one dam. There is no need for construction, respectively modifications of a small dam at the northern edge of the Ghurghumela Sludge TSF. The disadvantage is a large number of handling processes that clearly reduce the efficiency of tailing.

Based on the above arguments, we recommend only two of the scenarios for further evaluation. Only Scenario No. 02 and Scenario No. 03 are beneficial for mitigating the environmental impact of manganese ore mining and processing in the Chiatura area.

– Scenario No. 02

◦ Mechanical part	6 805 000,- €
◦ Civil part	1 550 000,- €
◦ Ghurghumela sludge tailing dam	7 345 000,- €
◦ Total	14 900 000,- €

– Scenario No. 03

◦ Mechanical part	13 757 000,- €
◦ Civil part	2 600 000,- €
◦ Ghurghumela sludge tailing dam	7 345 000,- €
◦ Total	23 702 000,- €

10.12.2019

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7. Literature

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