The European Union's 2008 IPA Programme for Albania, Bosnia and Herzegovina, Croatia, the former Yugoslav Republic of Macedonia, Montenegro, Serbia, Kosovo*, Turkey and Iceland

Infrastructure Projects Facility Technical Assistance Window (IPF TA) Western Balkans

Europe Aid/128073/C/SER/MULTI

Sub project: WB4-MNE-ENV-12F

Analysis of the Way of Collection, Transport and Treatment of Waste from Old Royal Capital of Cetinje and Preparation of Conceptual Design and Tender Documents for the Rehabilitation of "Vrtijeljka" Dumpsite

Activity 2.2 Conceptual Design of Rehabilitation of the Vrtijeljka Dumpsite

October 2013

This project is funded by the European Union

COWI • IPF CONSORTIUM

*) This designation is without prejudice to positions on status, and is in line with UNSCR 1244 and the ICJ Opinion on the Kosovo declaration of independence.

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List of Abbreviations

COWI-IPF	The Consortium carrying out the present project
ENV	Environment
EU	European Union
HDPE	High density poly ethylene
ICJ	International Court of Justice
IPA	Instrument for Pre-Accession Assistance
LFG	Landfill Gas
MNE	Montenegro
REC	Regional Environmental Centre
ToR	Terms of Reference
UNHCR	United Nations High Commissioner for Refugees
WB	World Bank

1 Introduction

This Report, Activity 2.2 Conceptual Design is the second output of Task 2 of the Sub Project WB4-MNE-ENV-12 F ; "*Analysis of the Way of Collection, Transport and Treatment of Waste from Old Royal Capital of Cetinje and Preparation of Conceptual Design and Tender Documents for the Rehabilitation of "Vrtijeljka" Dumpsite.*"

Objectives

Objective of this Report is preparation of the Conceptual design based on the assumptions and conclusions made in previous reports Task 1 Analysis Report and Activity 2.1 Analysis of Existing Situation Report.

Specific objective

Specific objective of this Report is to provide design solution for closure and rehabilitation of the "Vrtijeljka" Dumpsite i.e.:

- Dumpsite body modelling (replacement of waste, preparation for the closure/covering),
- Installation of cover layer,
- Installation of storm water drainage system,
- Calculation of the expected amount of dumpsite gas,
- Installation of gas collection and treatment system,
- Fence installation.

Report structure

In the further chapters of the Report, in Chapter 2, the Consultant describes adopted design solution in line with relevant regulations giving description of possible alternatives and the adoption of relevant one, describes construction works and cover layer to be installed. Chapter 3 deals with gas generation, calculation of generated gas and gas collection system. In Chapter 4 the Consultant describes necessity of aftercare and monitoring programme. Chapter 5 gives summary of cost estimates.

2 Design solution

In the process of adoption and definition of design solution for the rehabilitation of Vrtijeljka" dumpsite, the Consultant, considering the EU and Montenegrin regulations relevant to this assignment, performed activities to define alternatives for rehabilitation and selected the most reasonable one. At this stage, total amount of waste that will be disposed on the "Vrtijeljka" dumpsite location until end of 2013 has also been calculated.

2.1 Regulations

Design solution for the rehabilitation of "Vrtijeljka" dumpsite has been defined in accordance with the latest updates of the following EU and Montenegrin regulations:

- Council Directive 2008/98/EC on Waste;
- Council Directive 1999/31/EC on the Landfill of Waste;
- Rulebook on detailed characteristics of landfill site, construction conditions, sanitary-technical conditions, operating mode and closure of landfills; education degree and qualifications for landfill operator; and types of waste and waste acceptance ("Official Gazette of Montenegro", 84/2009 and 46/2011);
- Law on Waste Management ("Official Gazette of Montenegro", 64/2011);
- Law on Spatial Planning and Construction ("Official Gazette of Montenegro", 51/08, 40/10, 34/11, 40/11, 47/11, 35/13, 39/13)

2.2 Alternatives

The Consultant's experience so far leads to three possible solutions that are applicable in the case of rehabilitation of non-sanitary landfills (dumpsites) as follows:

Alternative 1 — Relocation of waste from the existing dumpsite to the regional landfill, in case the amount of waste deposited at the existing dumpsite is relatively small and if it is located close to the site of the regional landfill;

Alternative 2 — Partial rehabilitation – isolation (covering) of top layers of the dumpsite, in cases where groundwater is deep enough and have no contact with solid waste from the dumpsite body;

Alternative 3 — Complete rehabilitation - isolation of top and bottom layers of the dumpsite, in case groundwater is high and can be endangered (polluted) in contact with solid waste from the landfill body.

Deterministic factors for the selection of appropriate alternative are existing waste amount disposed at the "Vrtijeljka" dumpsite and groundwater level.

With reference to the Task 2.1 Existing Situation Report, Chapter 5.3.2, volume of waste disposed on the dumpsite location until August 2012 was estimated at approximately 99,400 m^3. Considering this amount, "Vrtijeljka" dumpsite cannot be defined as a small dumpsite or a specific large dumpsite but the deposited waste is too large for considering alternative 1.

During geotechnical investigations it is found out that groundwater[1] does not exist up to the depth of 6 m; therefore the groundwater is not expected to be endangered from pollution as the groundwater is not in directly contact with the waste body, which makes Alternative 3 not preferable which is the most expensive solution.

Considering above arguments, it comes out that most reasonable solution for the rehabilitation of "Vrtijeljka" dumpsite is alternative 2 – partial rehabilitation. The Consultant has prepared the Conceptual Design for rehabilitation of "Vrtijeljka" dumpsite accordingly, considering Alternative 2.

Leachate

Alternative 2 includes a top layer construction with an impermeable HDPE liner resulting in no leachate generation after remediation of the site.

In the present situation leachate is generated and will seep through the below laying geological structures and eventually reach the groundwater reservoir. As the thickness of the waste in the dumpsite is limited (average 6-7 m) and as the geological conditions below consist of karst rock with a high overall permeability, leachate will flow in fissures and cracks etc. The traveling time for generated leachate until it reaches to the groundwater is very short (assumed < 1 year).

The leachate inside the waste body and in subsoil (karts rock) at the time where the dumpsite is rehabilitated will quickly disappear and it will be non-feasible to attempt to capture it. Besides it is almost not possible to capture the leachate inside the waste body or in the below karts rock since most likely there is no coherent water (leachate) table inside the waste body. Due to this reason it will be impossible to collect the leachate, so vertical wells as well as horizontal pipes will have no effect. The karts rock consists of a large number of fissures, cracks etc. and the travelling pattern of water (leachate) in these (unsaturated) geological conditions are unpredictable and location of wells in the groundwater reservoir (depth unknown) will be uncertain as the area affected by the leachate from the dumpsite is unknown.

This is also the reason why groundwater monitoring upstream and downstream the dumpsite is not recommended as influence area of the dumpsite cannot be defined (without excessive investigations).

[1] Geotechnical survey

It is recommended to rely on a robust top cover construction that prevent any future leachate generation as described for alternative 2.

2.3 Waste amount

With reference to the Task 1 Analysis Report, solid waste from Cetinje Municipality will be disposed to "Livade" landfill in Podgorica starting from 2014. Therefore, as the preparation for the conceptual design, the Consultant calculated total solid waste amount until end of the year 2013, that will need to be treated i.e., covered and rehabilitated on the "Vrtijeljka" dumpsite.

The Amount of waste deposited at "Vrtijeljka" dumpsite starting from 1987 until the end of 2013 is shown in Table 1.

Table 1 Amount of waste at "Vrtijeljka" dumpsite till the end of 2013[2]

Year	Disposed Waste (m^3)	Cover material (m^3)	Total Waste (m^3)
1987	2,225	0	2,225
1988	2,243	0	2,243
1989	2,261	0	2,261
1990	2,357	0	2,357
1991	2,468	0	2,468
1992	2,637	0	2,637
1993	2,668	0	2,668
1994	2,741	0	2,741
1995	2,811	0	2,811
1996	3,047	0	3,047
1997	3,201	0	3,201
1998	3,230	0	3,230
1999	3,509	150	3,659
2000	3,594	154	3,748
2001	3,670	183	3,853
2002	3,787	216	4,003
2003	4,213	225	4,438
2004	4,265	398	4,663
2005	4,364	465	4,829
2006	4,410	529	4,939
2007	4,490	599	5,089
2008	4,632	741	5,373
2009	5,161	774	5,935

[2] Activity 2.1 Analysis of Existing Situation Report

Year	Disposed Waste (m^3)	Cover material (m^3)	Total Waste (m^3)
2010	5,270	823	6,093
2011	5,736	829	6,565
08/2012	3,859	502	4,361
SUBTOTAL	**92,849**	**6588**	**99,437**
08-12/2012	2,756	358	3,114
2013	8,341	1,376	9,717
TOTAL	**103,946**	**8,322**	**112,268**

Source: Consultant's assessment and calculations

As seen in Table 1 total waste amount to be referred for design is approximately 112,300 m3.

2.4 Remodelling and other design facilities

Layout

The basic layout used for the preparation of the Conceptual design is Geodetic survey for dumpsite "Vrtijeljka" on cadastre produced by "Sami inzenjering d.o.o." in August 2012, given in Appendix 1 of this Report. This layout gives the information on the dumpsite area with elevations, surrounding terrain, and cadastre parcels.

Existing solid waste

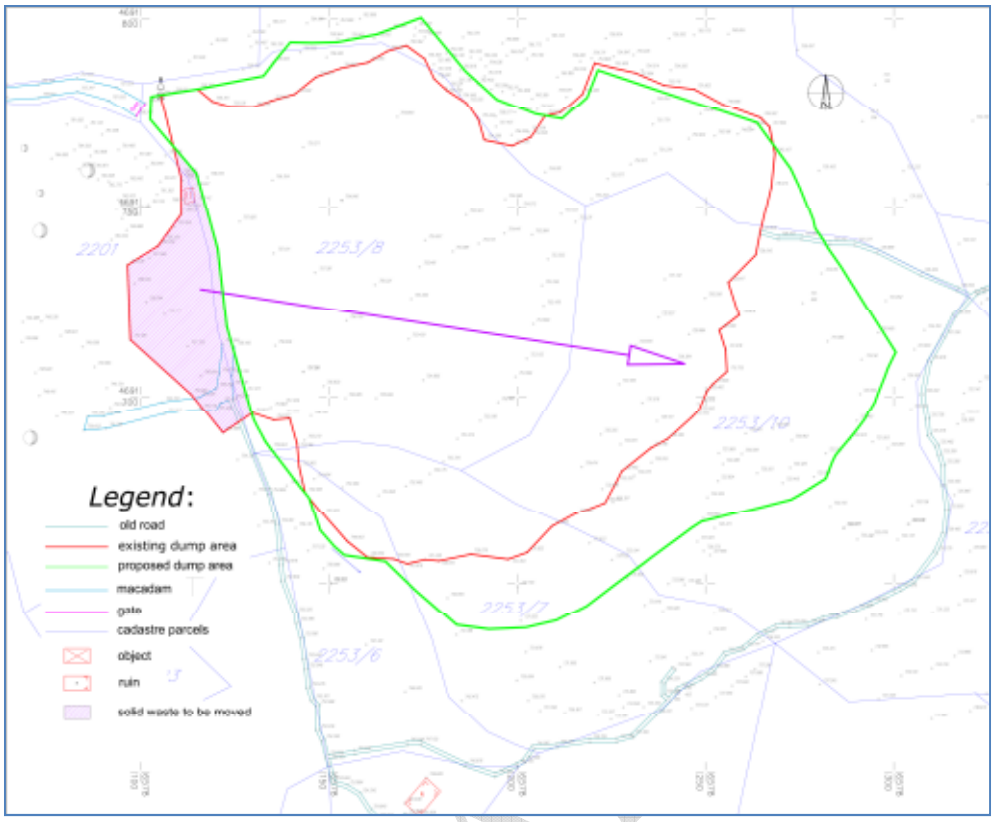
With reference to geodetic survey, existing dumpsite is approximately 16,300 m^2. Waste is being deposited in layers, over years, which resulted forming a flattened top surface and very steep side slope, around 60%. Top surface has area of 10,500 m^2 and elevations vary from 750 m to 758 m above sea level. Elevations of slope base are 719 m to 730 m above sea level and accordingly, height of the waste body varies up to 39 m.

Remodelling

Having in mind existing waste situation on the "Vrtijeljka" dumpsite and in order to ensure stable and compact dumpsite body which will be permanently covered, the Consultant has performed remodelling of the solid waste, with implementation of the following:

Limited amount of waste (Consultant's estimation is approx. 1500 m^3) is deposited on private parcel, parcel No. 2201. Cetinje Municipality should clarify this issue with the landowner before commencement of the works. The Consultant proposes this waste to be replaced prior to commencing work on the closure of the "Vrtijeljka" dumpsite. Position of waste to be replaced is shown in Figure 1.

Figure 1 Replacement of solid waste



Source: Consultant's design

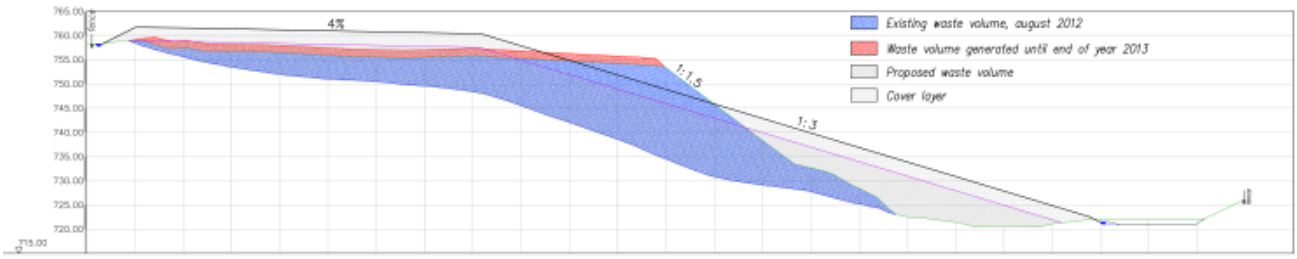
1. The Consultant has calculated additional amount of solid waste that will be generated and disposed on "Vrtijeljka" dumpsite till the end of year 2013 as shown in Table 1. This amount, 12,800 m^3 is assumed to be placed on the top of the existing solid waste.

2. Considering precipitation that occurs in Cetinje, min. 4% slope on surface is recommended to ensure sufficient surface water run-off from the site. Also, having in mind seismic characteristics of the terrain, it is recommended to use maximum slope grade 1:3 to ensure stability of slopes.

When remodelling of waste is completed, the next step is to perform necessary compaction of waste by minimum 3 passes of a heavy (min. 25 tons) steel wheel compactor. After compaction, waste will be prepared to be covered and closed with layers that are described in detail in Chapter 2.5 of this report.

Figure 2 presents existing dumpsite body, additional solid waste and designed solid waste profile that will be permanently covered.

Figure 2 Cross section of the dumpsite body, additional solid waste and designed solid waste profile

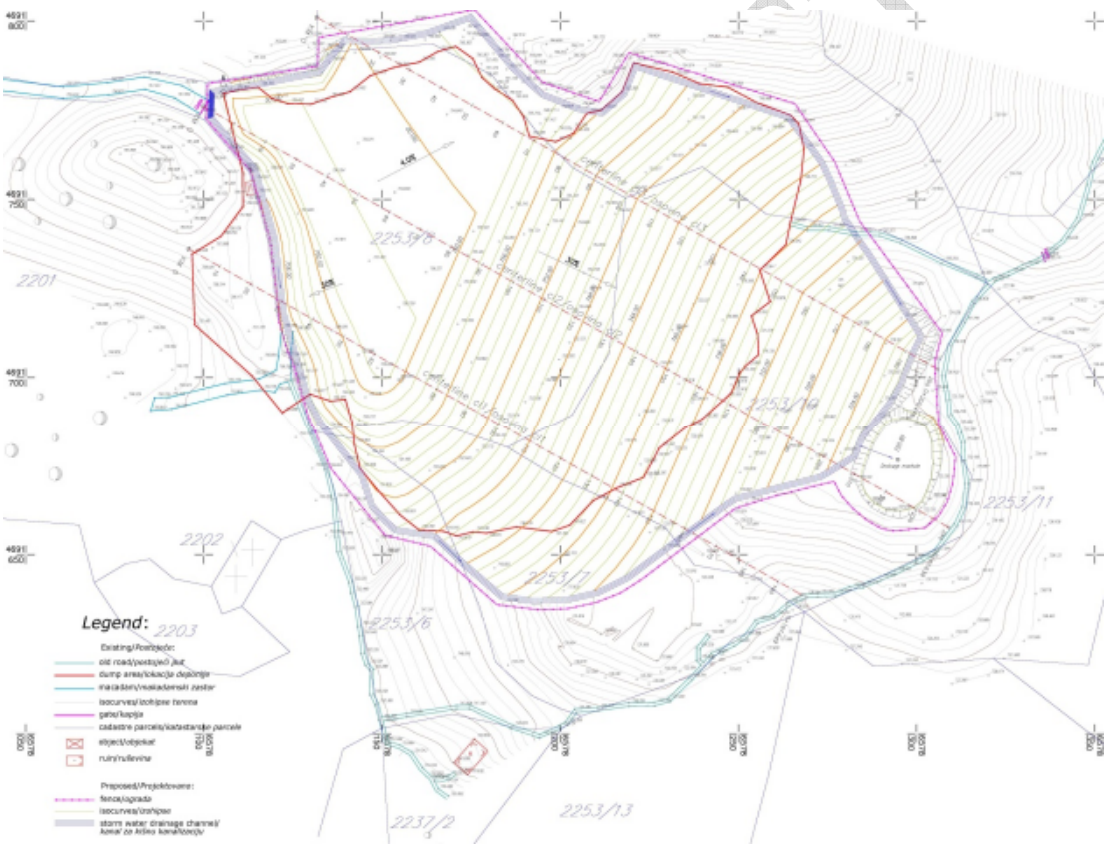


Source: Consultant's design

Proposed layout

As the final result of the design the solid waste is proposed to be placed with a total land occupation of 20,500 m^2 and in average height of waste at 5.5m. Top surface will reach elevations between 759 and 761 m above sea level, with an average slope of 4% and an approximate area of 3,800 m^2. Proposed side slopes are 3H:1V. The lowest elevation at the slope will be 721 m above sea level. Elevation plan for the covered solid waste is presented in Figure 3, also presented in Appendix 6 drawing number 3.

Figure 3 Proposed solid waste with cover layer, elevation plan



Source: Consultant's design

Storm water control

For protection from storm water, a concrete channel in total length of 590 m has been proposed on the periphery of the closed solid waste body. Water collected from the channel will be discharged at the lowest elevation point into proposed pond.

Geography of the location and geometry of the waste body defines grades of the channel which are mostly up to 20-30%. In this situation, the channel capacity does not depend on the size of the channel profile as such grades does not allow water accumulation i.e. water practically runs through the channel, reaches the lowest point where it is being discharged. Storm water channel profile is shown in Figure 4.

Based on the geotechnical investigations it is clear that location site consists mostly of karst rocks with high fracture porosity. On the other hand, existing relief of the location is forming shape that looks like inverted cone. Accordingly, existing situation gives one lowest point which is in a role of retention and discharge point. Design solution has proposed this point for position of pond. Approximate available area for the pond is 600m^2 with depth of 1-1,5m and bottom elevation at around 720m above sea level.

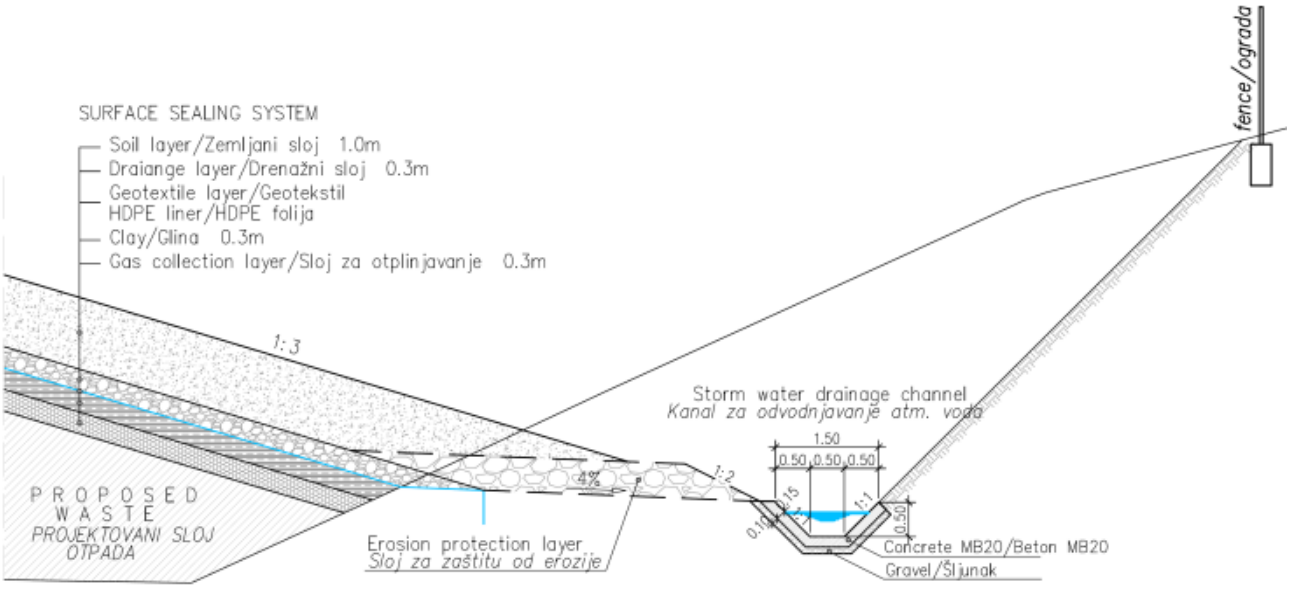
The Consultant has carried out calculations to verify pond capacity using following assumptions:

- Applicable rainfall of 428.3mm, maximum 24 hour rainfall measured at Cetinje meteorological station;
- Catchment area: 2.05ha of covered waste and 1.95ha of surrounding terrain, in total 4.0ha;
- Runoff coefficient: 0.5 for covered waste and 0.1 for terrain.

Based on the calculation, the capacity of the pond should be extended with minimum one drainage well, at the bottom of the pond, to connect pond with the underground infiltration zones and to ensure seepage at maximum value of 54 l/s. Drainage well should be a simple hole in the ground, with diameter of 1m and minimum depth of 10m, filled in with crushed natural rocky material (grain size 100-200mm) obtained from the excavation works.

Position of the pond and drainage well is shown in drawing no.7, Appendix 6.

Figure 4 Storm water channel profile



Source: Consultant's design

Electrical supply

Existing situation on site is that there is no electrical infrastructure except recent public lightning. As per designed gas collection system, described in detailed in Chapter 3.3 of this Report, it is necessary to provide electrical supply at minimum capacity of 10kW for collection and burning of landfill gas from dumpsite body.

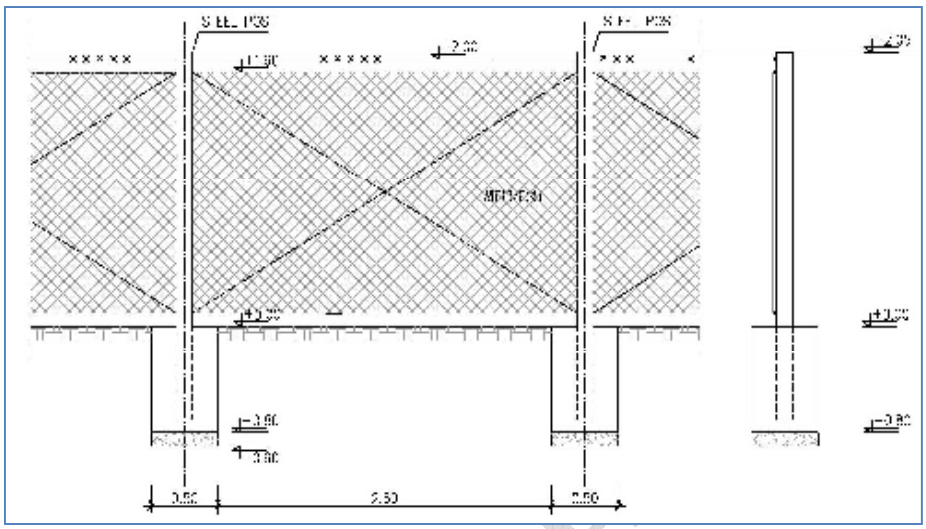
Based on the verbal information received which is not officially confirmed yet, the closest substation is in neighbour Roma settlement approximately 350 m away from the dumpsite location. This substation will be connection point for the new electrical cable. Assessed length of the cable is 400 m. Electrical cable and all associated equipment (e.g. automatic lightning protection) is to be ex-proof and secured from any possible impact derived from landfill gas. Position of the cable is shown in drawing no.8, Appendix 6.

As soon as the location of the substation is confirmed officially, above information will be updated if necessary in the Tender Documents Volume III, Technical Specifications.

Fence

The area around the landfill body will be surrounded by a fence of 2.05 m high. Detail of the fence is shown in Figure 5.

Figure 5 Fence



Source: Consultant's design

Figures 4 and 5 are presented also in Appendix 6, drawing number 7, Details.

Drawings

Design solution is documented with drawings presented in Appendix 6, i.e.:

- Drawing no. 1, Site map,
- Drawing no. 2, Existing state,
- Drawing no. 3, Elevation plan,
- Drawing no. 4, Longitudinal profile cl1,
- Drawing no. 5, Longitudinal profile cl2,
- Drawing no. 6, Longitudinal profile cl3,
- Drawing no. 7, Details.

2.5 Cover layer

Final cover of the dumpsite has to be installed in order to:

- prevent storm water filtrating into the waste;
- prevent gas emissions by a controlled gas collection;
- prevent erosion;
- support vegetation.

As mentioned earlier in the Report the Consultant has taken into consideration Montenegrin Rulebook related to sanitary landfills[3]. After reviewing the docu-

[3] Rulebook on detailed characteristics of landfill site, construction conditions, sanitary-technical conditions, operating mode and closure of landfills; education degree and qualifications for landfill operator; and types of waste and waste acceptance

ment Consultant made a conclusion that Rulebook deals only with new landfills and does not mention rehabilitation of old landfills i.e. dumpsites.

Therefore, design solution for multi-layer final cover has been proposed in line with best known practice for rehabilitation of old dumpsites and consists of the following layers from bottom to top:

1. Gas collection layer, with minimum thickness of 0.3 m, composed of material with hydraulic conductivity of minimum 1 x 10^{-4} m/s,

2. Compacted mineral layer (clay), with thickness of 0.3 m, with hydraulic conductivity ≤ 1 x 10^{-9} m/s,

3. HDPE liner, 1 mm thick and a protective geotextile layer (below HDPE liner) of 500 g/m² ,

4. Drainage layer, with of 0.3 m, with hydraulic conductivity of minimum 1 x 10^{-4} m/s,

5. Soil layer with thickness of 1 m, mixed with top humus layer with minimum thickness 0.1-0.3 m. The soil layer should be "rocky" material and should include the top humus (vegetal soil) as it is specified in Table 2.

Table 2 Soil layer material

PHYSICAL CHARACTERISTICS				
TYPE	Granulometry		Fine Soil	
	Maximum size	Coarse materials	Clay	Sands
Vegetal Soil	0% > 25 cm	< 60%	< 25%	< 30%
Soil	0% > 25 cm	< 75%	< 15%	< 20%

Source: Consultant's design

3 Generation and collection of landfill gas

In general, one of the products of deposited municipal waste is landfill gas - biogas (LFG). Landfill gas is harmful to the environment due to its high content of carbon dioxide and methane. Collection and treatment of LFG significantly reduces its emission to the atmosphere, prevent explosions, eliminate odours, and prevent possible underground distribution of gas outside the boundaries of the landfill.

In particular, for the closure of the "Vrtijeljka" dumpsite the Consultant has performed calculation of the gas generation over years, and based on the calculation results the adequate gas collection system has been designed.

Prior to gas calculation, the Consultant made estimation on the composition of municipal waste and total amount of waste deposited on the "Vrtijeljka" dumpsite. Composition of municipal waste is presented in Table 3. Waste amount deposited on the Dumpsite is already presented in Table 1 of this Report.

Table 3 Composition of disposed waste at "Vrtijeljka" dumpsite (%)

Component	Participation (%)
Paper and carton	17
Glass	7
Metal	4
Plastics	10
Textiles	5
Organic	25
Other	32

Source: Activity 2.1 Analysis of Existing Situation Report

3.1 Generation of gas

LFG arise in the landfill body during the anaerobic decomposition of deposited solid and complex organic waste components. Decomposition process occurs due to certain amount of oxygen remained in the landfill body after the compaction of waste.

Typical composition of landfill gas is given in Table 4 and

Table ***5*** presents characteristics of the landfill gas.

Table 4 Typical composition of the landfill gas (methane phase)

Component	Content in the dry gas (vol.%)
Methane	45 – 60
Carbon dioxide	40 – 60
Nitrogen	2 – 5
Oxygen	0,1 – 1
Sulphide, disulphide, mercaptans	0 – 1
Ammoniac	0,1 - 1
Hydrogen	0 - 0,2
Carbon monoxide	0 - 0,2
The ingredients in traces	0,01 - 0,6

Source: Tchobanoglous, Theisen, and Vigil 1993; EPA 1995

Table 5 Characteristics of the landfill gas

Characteristics	Value
Temperature (°C)	38- 50
Density (kg/Nm^3)	1,02- 1,06
Humidity	saturation
Heat power, (kJ/Nm^3)	14900- 20500

Source: Tchobanoglous, Theisen, and Vigil 1993; EPA 1995

3.2 Calculation of gas generated on "Vrtijeljka" dumpsite

Estimation of the production of LFG in municipal waste includes parameters related to the physical and chemical characteristics of waste, way of depositing and covering of waste, local climatic and hydro-geological conditions. When calculating the amount of gas to be produced at the landfill, the Consultant started with the morphological structure of integrated wet waste being disposed. Table 6 shows the average moisture content and composition of certain dry components of municipal solid waste.

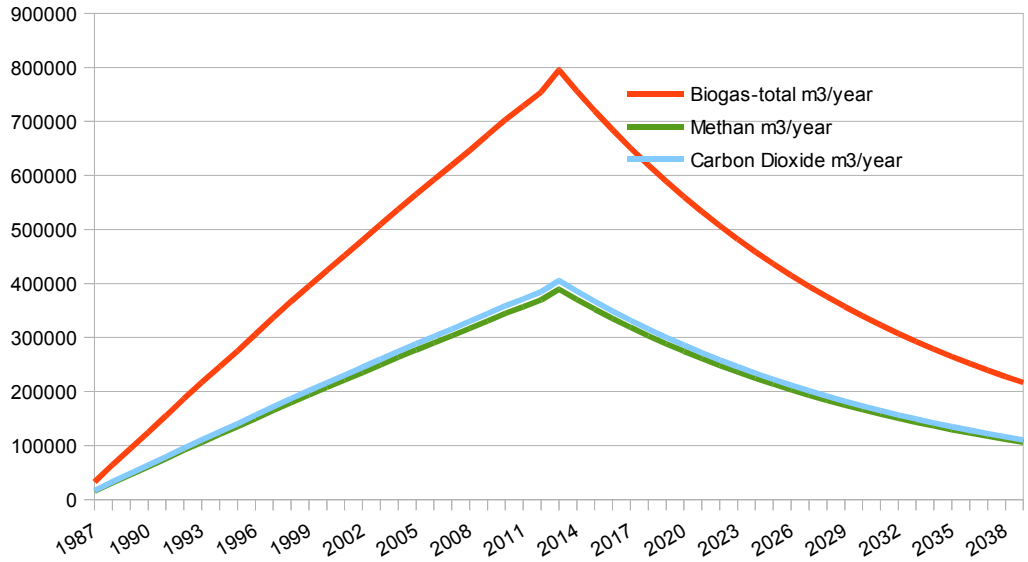
Table 6 Average moisture content and composition of certain dry components of municipal solid waste

Component	Humidity	C	H	O	N	S	Other
	(%)						
Food waste	70,00	48,00	6,40	37,60	2,60	0,40	5,00
Textile	10,00	48,00	6,40	40,00	2,20	0,20	3,20
Leather	10,00	60,00	8,00	11,60	10,00	0,40	10,00
Garden waste and wood	60,00	46,00	6,00	38,00	3,40	0,30	6,30

Source: Tchobanoglous, Theisen and Vigil (1993): Integrated solid waste management

Considering composition of waste, gas generation process and amount of waste deposited on the "Vrtijeljka" dumpsite the Consultant performed calculation of gas generation. Figure 6 presents generation of gas on the "Vrtijeljka" dumpsite as final result of calculation. Detailed calculation is given in Appendix 3 of this Report.

Figure 6 Generation of gas on the "Vrtijeljka" dumpsite



3.3 Designed gas collection system

Uncontrolled emission of landfill gas is unacceptable because of its harmful effects. The high content of methane in landfill gas increases the risk of fire and explosion in the landfill area. Methane is explosive at concentrations in the air ranging from 5-15%. Accordingly, it is necessary to provide controlled extraction and neutralisation of landfill gas.

With the installation of cover layer, the release of landfill gas into the atmosphere through the top cover is prevented. However landfill gas can still, if not otherwise controlled, migrate horizontal from the dumpsite in the cast geological conditions. To avoid the risk for uncontrolled migration of landfill gas from the dumpsite an active gas collection system is included. This system will, to the extent possible, ensure that the pressure inside the waste body always is lower than the atmospheric pressure.

For the collection of gas generated from the dumpsite the Consultant has adopted the design solution, including following:

- Gas collection wells,
- Main pipe system
- Blower and
- Gas flare.

Gas collection wells

Purpose of the gas collection wells is collect and direct the gas extraction from the waste body to the desired points. Bio-wells are vertical perforated HDPE pipes, coated with a protective layer of gravel to prevent the closure of perfora-

tions with waste material. The effective radius of the wells for collecting the gas is approximately 30 m. For the gas collection from the "Vrtijeljka" dumpsite eight gas collection wells has to be installed. Anchoring of each well in the initial phase of installation should be performed using gravel gabions.

Main pipe system

Gas collection wells are interconnected with the HDPE pipe network system. Pipe network discharges collected landfill gas from the wells to the gas flare for safe burning. Pipe network is placed in soil layer (0,85m from the top surface of cover layer), already defined in Chapter 2.5 of this Report.

Gas Flare and Blower

Gas flare and blower are installed at the end of gas collecting system where gas is prepared for burning. Gas flare consists of valves, condensate separator, regulator with arrestor and burner. On the main pipeline, just before the burner, installation of blower (vacuum device) is planned in order to facilitate the evacuation of landfill gas. Blower provides the required pressure in the gas collection system and over pressure needed for burner to work. Burner is placed in closed chamber to provide controlled gas burning.

Gas flare is given indicatively as a technical solution. However, different gas disposal systems may be applied, e.g. biofilter, as far as active system for gas collection is ensured with the blower included.

Drawings

Gas collection system is documented with graphic drawings presented in Appendix 6, i.e.:

Drawing no. 8, Gas collection system layout,

Drawing no. 9, Technological scheme,

Drawing no. 10, Gas collection well,

Drawing no. 11, Gas Flare.

4 Monitoring

An aftercare control and monitoring programme must be established after the closure and rehabilitation of dumpsite. Every site is different and the development of monitoring requirements should follow site-specific, respectively risk-based techniques.

According to relevant legislation, listed in chapter 2.1of this Report, for the rehabilitation of "Vrtijeljka" dumpsite monitoring of environmental parameters such as surface and ground water pollution, air pollution, ground pollution, visual site inspection, are considered and given indicatively. In the next stage, according to Montenegrin legislative, Environmental Impact Assessment Study (EIA) should be prepared. This Study will define precise measures for the monitoring and will define locations for the necessary sampling. These measures will be mandatory for the construction and aftercare works.

Surface water

According to geotechnical survey, Appendix 2, no surface water exists close to the Dumpsite.

Ground water

According to geotechnical survey, Appendix 2, ground water has not been found on the depth of 6 m. Considering location consist of karst rock formations with fracture porosity, the Consultant assumes that underground water could be deep in the ground, at depths higher than 20m.

Once Dumpsite is being covered and closed, and integrity of top cover layer is being controlled and ensured, there will be no risk of storm water infiltration into the waste body and leachate. With reference to the above, the Consultant assumes that there is no risk for ground water to be polluted.

Air

Air quality monitoring shall be conducted with reference to the mitigation measures to be defined as the result of the EIA to be prepared.

Ground

Considering Consultant's assumptions above, there is no risk for ground and surface water to be polluted, and also, after covering the Dumpsite it is assumed that there will be no risk of storm water infiltration into the waste body and leachete into the ground. Accordingly, the Consultant assumes that there is no risk of ground to be polluted as well.

Visual site inspection

During the first two years, visual site inspection should be done 2 times a year, after 2 years it should be done once a year and after 10 years, once every 5 years until the end of the 30 years, unless the competent authority decides otherwise.

Visual inspection includes the following:

- Condition of the cover layer and if necessary control drilling to verify the thickness of cover layer;
- Settlement of landfill body;

- Condition of storm drainage channels.

All necessary activities regarding taking samples and analysing, should be carried out by authorized, accredited institutions.

5 Cost estimates

Based on the adopted design solution for the rehabilitation of the "Vrtijeljka" dumpsite, the Consultant has estimated the cost. Summary of cost estimation is presented in Table 7. Detailed estimation is given in Appendix 4. These forecast of costs is serving limited to the purpose of establishment of the draft investment budget and in no way should be perceived as a tool to imply, impose or guide the tenderers, as the tender will be launched with a Design and Construction Contract asking a lump sum financial proposal (using the FIDIC Yellow Book Conditions of Contract).

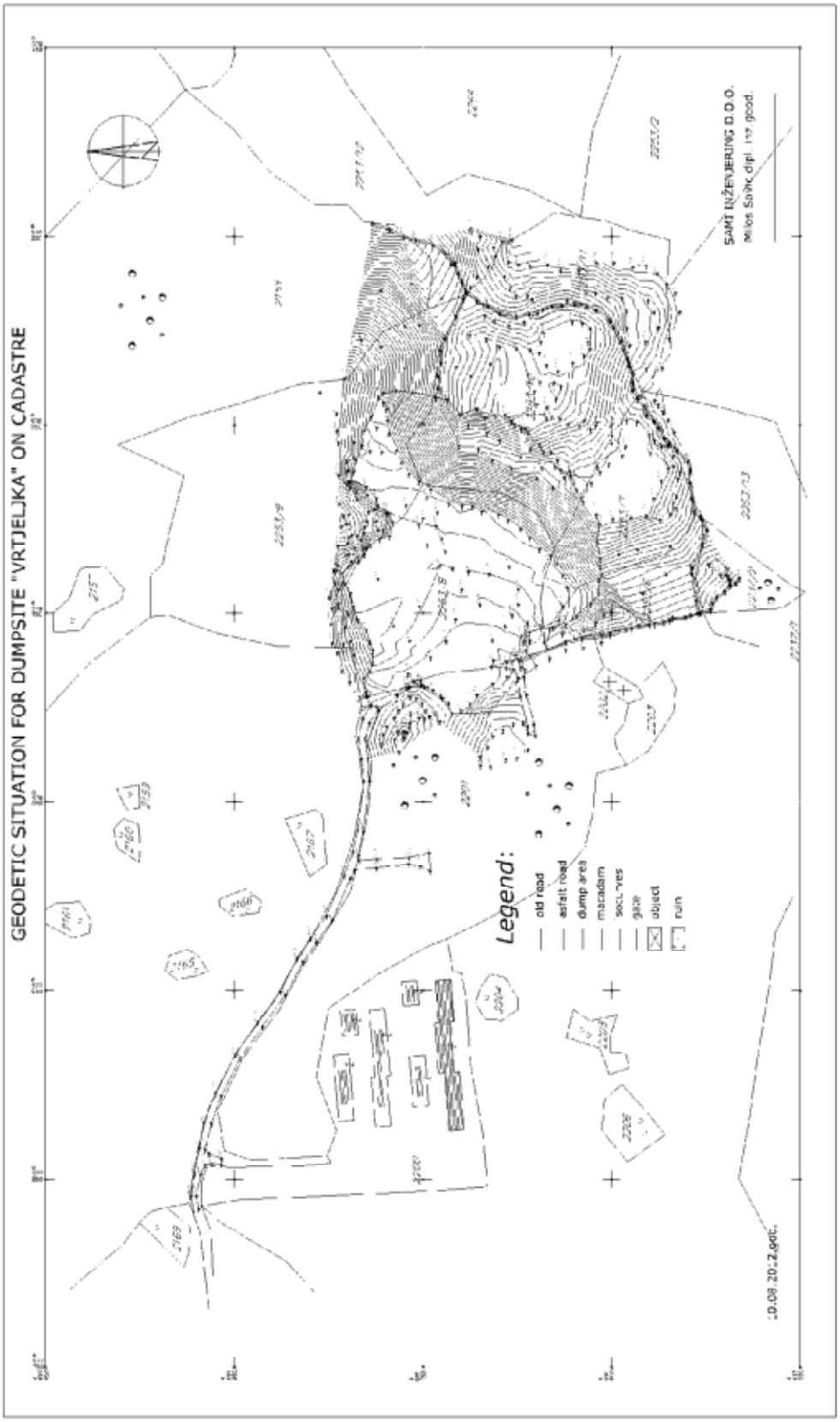
Table 7 Summary of cost estimation

No.	Work	Price (Euro)
1	CIVIL WORKS	
1.1	Preliminary works	7.500,00 €
1.2	Earth works	24.000,00 €
1.3	Top soil cover	536.000,00 €
1.4	Other works	98.000,00 €
1	**Subtotal (Civil works)**	**665.500,00 €**
2	GAS COLLECTION SYSTEM	
2.1	Gas flare	60.000,00 €
2.2	Main pipe system	9.500,00 €
2.3	Gas collecting wells	10.000,00 €
2	**Subtotal (Gas collection system)**	**79.500,00 €**
3	ELECTRICITY SUPPLY	12.000,00 €
4	**General Items**	**50.000,00 €**
1+2+3+4	**Total**	**807.000,00 €**

6 Technical Specifications

The Conceptual Design Report includes the particular technical specification for all the works which shall be carried out by the Works Contractor. Particular technical specifications are given in Appendix 5.

Appendix 1 Topographic survey


GEODETIC SITUATION FOR DUMPSITE "VRTJELJKA" ON CADASTRE
Legend:
old road
asfalt road
dump area
macadam
sociives
gate
object
ruin
SAMI INŽENJERING D.O.O.
Miloš Savić, dipl. inž. geod.
10.09.2012.

Appendix 2 Geotechnical survey

MONTENEGRO GEOTEHNIKA

D.O.O. projecting, engineering and supervision

E L A B O R A T E

THE GEOTECHNICAL PROPERTIES OF THE GROUND FOR STUDY OF REHABILITIATION OF EXISTING SANITARY LANDFILL ''VRTIJELJKA'' FOR CITY OF CETINJE

NIKSIC,
September, 2012.

E L A B O R A T E

THE GEOTECHNICAL PROPERTIES OF THE GROUND FOR STUDY OF REHABILITIATION OF EXISTING SANITARY LANDFILL ''VRTIJELJKA'' FOR CITY OF CETINJE

PROJECT MANAGER:

Andrija Delibašić, M.Sc. geol.

GENERAL MANAGER:

Vukašin Gredić, M.Sc. geol.

Study:	**THE GEOTECHNICALPROPERTIES OF THE GROUND FOR STUDY OF REHABILITATION OF EXISTING SANITARY LANDFILL ''VRTIJELJKA'' FOR CITY OF CETINJE**
Holder of Elaborate:	"GEOTEHNIKA Montenegro" d.o.o., Nikšić
Project manager:	Andrija Delibašić, M.Sc. geology
Associates:	Dragomir Vukašinović, M.Sc. geology Vukašin Gredić, M.Sc. geology
Issuing date:	September, 2012.

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Strana

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2. GEOLOGICAL MAP OF WINDER STUDY AREA, R 1:25 000,
3. ENGINEERING GEOLOGICAL TERRAIN MAP, R 1:1 000,
4. GEOTECHICAL CROSS-SECTION OF TERRAIN 1-1' I 2-2', R 1:500,
5. ENGINEERING GEOLOGICAL PROFILES OF RESEARCH BOREHOLES, R 1:100,
6. ENGINEERING GEOLOGICAL PROFILES OF RESEARCH TRIAL PITS, R 1:50.

THE DOCUMENTARY MATERIAL:

1. RESULTS OF LABORATORY ANALYSES OF SAMPLES

1. INTRODUCTION

"GEOTEHNIKA Montenegro" d.o.o. from Niksic performed detailed geotechnical field explorations of existing sanitary landfill "Vrtijeljka", city of Cetinje, for the rehabilitation Study purpose based on the accepted offer, number 0606/012 dating from 06.06.2012, by the Investor of the project. With its implementation the Elaborate will be done to obtain necessary geotechnical basis for rehabilitation Study.

Exploration has consisted of field, laboratory and cabinet work. From the field work was carried out reconnaissance of the site, engineering-geological mapping of the field, drilling exploratory wells, core mapping of the exploration wells, digging of exploration trial pits and mapping of it, sampling for laboratory testing, installation piezometric structures in boreholes and geotechnical supervision of field work. In the laboratory was carried out detail analysis of samples. Subsequently, based on the results obtained and data collected from the fund documentation and literature, Elaborate on geotechnical properties of the terrain has been done for sanitary landfill rehabilitation Study purpose.

In the Study are presented data on the morphology, geological structure, hydrogeological characteristics and seismic properties of the ground as well as the engineering-geological properties of the specific formations. In the specific chapters the geotechnical conditions for rehabilitation of the landfill has been presented as well as recommendations for project managers.

On the performance of field and laboratory work and in Elaborate work out Dragomir Vukašinović M.Sc. geology, Andrija Delibasic M.Sc. geology and Vukašin Gredić M.Sc. geology have been participated.

The works were carried out in August and September 2012.

2. POSITION OF EXPLORATION AREA

Location of the existing sanitary landfill is on the left side of the main road Cetinje-Budva, locality Vrtijeljka. Landfill location is situated about 1 km from the main road and is connected with the local road. Exploration area, geodetically mapped, is situated on area of approximately 4.50 ha and existing sanitary landfill occupies area of some 1.65 ha.

Location is presented In Appendix No. 1.

3. TYPE AND SCOPE OF PERFORMED WORKS

3.1. Field works

Next field works have been performed:

- reconnaissance of the micro-location; aimed at preliminary detection of location and research activities planning;
- engineering-geological mapping of the terrain; was performed on the entire site that has been geodetically mapped around (4.5 ha). For field mapping, method of spring and engineering-geological processes detection was used. Engineering-geological map of the terrain is presented in appendix 3;
- exploration drilling; 6 exploration geomechanical wells has been drilled with depths from 3.0 to 15.0m. Successively with the drilling of the wells, core of the boreholes has been mapped. Engineering-geological profiles of the exploration wells are given in Appendixes No. 5. The following table provides an overview of the performed exploration wells:

Table No 1: Performed exploration wells:

Well	Depth (m)	Coordinate Y	Coordinate X	Elevation Z
B-1	3.00	4 691 752.15	6 578 141.36	756.10
B-2	3.00	4 691 744.38	6 578 179.92	755.35
B-3	15.00	4 691 749.50	6 578 208.14	753.75
B-4	15.00	4 691 692.46	6 578 153.71	755.70
B-5	3.00	4 691 704.26	6 578 141.22	757.45
B-6	3.00	4 691 710.27	6 578 127.01	757.65

- the installation of piezometric construction; in performed exploration wells 42.0 m length of piezometric structure has been installed. Piezometric structure is pipe with the cover both made from PVC with bottom perforations;

- digging of exploration trial pits; exploration trial pit was dug to the depth of 1.0 m. After was mapped. Engineering-geological profile is given in Appendixes No. 6. The following table provides an overview of the performed trial pit:

Table No 2: Performed exploration pit:

Pit mark	Dimension (m)	Coordinate		Elevation
		Y	X	Z
R-1	2.50 x 0.50 x 1.00	4 691 678.33	6 578 138.56	755.10

- taking of samples for laboratory geotechnical analysis; during mapping of the core exploration boreholes and exploration pit 8 samples of the soil sample and 2 rock samples were taken, as well as 1 sample for Proctor and CBR test.

- the expert-geotechnical supervision was performed continuously during performance of field exploration works by the geotechnical engineer.

3.2. Laboratory analysis

Soil samples from sanitary landfill were taken. Partial geomechanical analyses have been performed on taken soil samples. Only identification-classification tests were performed with determination of: lithology, specific gravity, density and dry density.

Rock samples were determined with: density, compressive strength, angle of internal friction and cohesion.

Sample from exploration pit was tested for moisture condition with Proctor test and also CBR values were determined.

3.3. Cabinet works

In cabinet, the interpretation of results of exploration work has been done, also its processing and synthesis with data from the fund documentation and literature. Based on all of that, the Elaborate on the geotechnical properties of the terrain for rehabilitation Study of an existing sanitary landfill, city of Cetinje locality “Vrtijeljka”, has been done.

4. EXPLORATION RESULTS

4.1. Morphological characteristics of the terrain

Morphology of sanitary landfill "Vrtijeljka" location is typical Karst with characteristic landforms like sinkholes, depressions and reefs. Landfill plateau depicts with size (100.0 m wide and 120.0 m long), with to slopes spreading one to the East and second to the South with inclinations 35º to 45º. Elevation terrain on the plateau of the landfill 750.0 to 758.0 m above sea level. Elevation below slopes of landfill is 720.0 to 730.0m above sea level.

Location morphology is presented in engineering-geological map and profiles given in Appendixes No. 3 and No. 4.

4.2. Geological structure of terrain

Geological structure of terrain can be seen on Basic Geological Map "Kotor" 1:100 000 with interpreter (Institute for Geological and Geophysical Research, Belgrade, 1962-1969). Terrain of wider exploration includes Upper Triassic formations (T_3) of dolomitic limestones and massive limestones, gradationally developing from Ladinian (T_2^2) limestones with chert. Dolomitic limestones and dolomites are widely distributed on area, going to the South, from Cetinje to Vrela i Očinići. Dolomites are usually in tick banks, rarely stratified or massive, changing occasionally with dominant limestones. Blocks are separated but without apparent continuality.

Youngest, Quaternary depositions consist from deluvial (dl) red clay dominantly seen in depressions and sinkholes, while rarely seen on terrain surface. Fractures and caverns in limestones are filled with red clay and fine debris.

Terrain of wider exploration area by the geotectonic structure belongs to “High karst” zone and “Old Montenegro” anticlinorium (axis is dipping Southeast) changing to “lower Zeta” sinclinorium. Paleorelief is cross-sected with faults differently orientated. Deep faults were mapped on this area; generally spreading Northwest-Southeast and Northwest-Southeast are also directions of seismic activity.

Geological map of the wider area is presented in Appendix No. 2

4.3. Hydrogeological characteristics of the terrain

Based on hydrogeological characteristics and functions of the terrain very well water permeable rocks and complexes were depicted.

As permeable rocks of fracture-karst porosity in the terrain we can sort out all the carbonate rocks with the exception of solid dolomites who appear very rarely. Intensive mechanical separation and degree of karstification indicate that prevails karst porosity and such terrains are without surface waters. The terrain made of very well water permeable rocks forms scattered karts aquifer type. On exploration area fractures, caverns and depressions, that usually accompany faults, can be seen. They are the main sinking zones on the site. Water that falls on the ground quickly, through a network of open fractures, caverns and caves infiltrate deep into the ground. At great depth scattered karst aquifer is formed. Discharge of this aquifer is through the spring of Crnojevića River (Obodska springs). Karstification base is very deep in this part of the terrain, almost to the level of Skadar Lake.

Deluvial clays with debris are classified as low permeability rocks of intergranular and capillary porosity. Their distribution on the surface is minimal, and they do not have a significant impact on the hydrogeological characteristics of the field.

During exploration drilling (August 2012.) there was no underground water appearance in exploration wells.

4.4. Seismicity of the terrain

According to the map of seismic microzonation of urban areas Cetinje with Ivanova Korita, Njeguši and Rijeka Crnojevića, this location is a part of seismic area B_3. For the mentioned area B_3, the maximum expected earthquake is with intensity of VII degree MCS scale. Seismic parameters for return periods of time for 50, 100 and 200 years are:

Table No 3: seismic parameters

Zone	Characteristic zones of the terrain	Return period t (god)	Maximum acceleration of the soil a_{max}	Seismic coefficient k_s
B_3	Limestone and dolomite complexes, stratified and banked in textures, tectonically folded and karstified.	50	0.12	0.03
		100	0.17	0.04
		200	0.25	0.06

4.5. The modern geological processes and phenomena

From modern geological processes and phenomena at the site of exploration planar erosion and karstification are present.

Planar erosion has affected the entire field and the intensity is different depending on the type of environment in which it takes place. Mostly eroded surface deluvial sediments are subject to planar erosion. In the limestone dominant formation, planar erosion intensity is low.

Karstification is expressed in the limestone since the limestone is highly tectonically fractured. It is estimated that karstification depth goes up to several hundred meters. In terms of engineering-geological characteristics terrain is stable.

4.6. Engineering-geological characteristics of selected areas

Based on the analysis of existing documentation relating to the location and other related terrains, engineering-geological location mapping and exploration drilling can be concluded that the field is basically built out of solid rock (limestone and dolomite). At one end of location is existing landfill. Sections viewed from the surface are:

- Mound (DR, PR)n - an artificial mound, and materials of the existing landfill (in terrain profile it is section numbered 1). Material composition is heterogeneous, unsorted, medium consolidated. It is compiled from debris and limestone blocks, dust and various municipal waste. It covers part of the site. Mound thickness is variable, from minimal to over 10.0 m (central part of the landfill between wells B-3 and B-4). According to building standards GN-200 this material belongs to Class II and III of the excavation. Physical and mechanical parameters of this section are not considered as a landfill material is not sorted and there is a large range of values (from limestone blocks to the waste of plastic, metal, wood or construction debris).

- Limestone (K, D) - massive dolomitic limestone or dolomite that forms the base and the back of the field to a wider area (in terrain profile it is section numbered 2). These are massive rocks, fractured on surface, degraded and karstified, whitish in colour. When drilling or digging this dolomitic limestone is broken into pieces, debris or dust. Fractures and caverns in the surface zone are enlarged by karstification and filled with

red clay and limestone debris. Limestones are stable and well-supporting formation. The water level is deep in the ground. According to building standards GN-200 this material belongs to the category V to VI of the excavation. A good basis for founding. Physical and mechanical parameters of this environment (based on founding documentation and immediate field assessment) are given in the following table:

Table 4: Physical-mechanical parameters for limestone

Parameters	Range of the values
γ (kN/m^3)	26.0 - 27.0
φ (^{0})	30.0 - 35.0
c (kN/m^2)	400.0 - 500.0
q_u (kN/m^2)	1000.0 - 15000.0
E (MPa)	1700.0 - 2000.0
ν	0.25 - 0.28

Engineering-geological units are shown in Appendixes No.4, 5 and 6.

5. GEOTECHNICAL CONDITIONS FOR REHABILITATION OF THE LANDFILL

Geotechnical conditions for rehabilitation of the landfill are complex. Section that is favourable in geotechnical terms for construction of necessary facilities is the limestone section. On the site they are partially covered with a thick layer of the existing landfill. Landfill itself is not suitable for any construction on it. If any facility is planned to be build it is required to remove the landfill from the site and perform the founding in the limestone.

Allowed load capacity of limestone is good while the subsidence is negligible because it is virtually undeformable. To calculate the allowable loads Goodman's formula for ultimate bearing capacity of foundations in fractured rock formations:

$$q_f = q_u\left[1+tg^2(45+\varphi/2)\right]$$

Where are:

q_f - limit load of the foundation in the fractured rocks
q_u - uniaxial compressive strength of rocks under the foundation
φ - angle of internal friction of the rock mass under the foundation.

Permitted load q_a is obtained when the ultimate bearing capacity is reduced for the safety factor value ($q_a=q_f/F_s$). Value of the safety factor F_s range from 3 to 5. In this case, the adopted value for Fs is 5. The adopted values for parameters used in the calculation are:

$\varphi = 30^o$, $q_u = 1200$ kN/m^2, $F_s = 5$

Result of calculation:

$q_f = q_u\left[1+tg2(45+\varphi/2)\right]$ - limit load
$q_f = 1200\left[1+tg2(45+30/2)\right] = 4800$ kN/m^2
$q_a = q_f / F_s$ - allowable load
$q_a = 4800/5 = 960$ kN/m^2

As it can be seen from the calculation allowable load of the substrate is high. Subsidence is negligible since it is practically undeformable formation.

Limestone is good in terms of allowable load, subsidence and stability. It is not suitable in terms of hydrogeological properties since it is tectonically fractured, faulted, cracked and karstified, high permeable rock. All the water that falls on the ground infiltrates deep into the ground where they form scattered karst aquifer. This aquifer is discharged through springs of Crnojevića River (Obodska springs). This means that the water takes all pollution from the landfill deep underground.

It is necessary to provide waterproof basis for future landfill, waters from landfill should not be washed down and drained in the ground without purification.

6. RECOMMENDATIONS FOR THE PROJECT MANAGERS AND CONTRACTORS

In the design and construction of the facilities to keep in mind the following recommendations:

- excavation for the facilities foundations can be performed completely by machines, with excavator and pikamers, since the material belongs to the II and III to V and VI category excavation by GN-200 categorisation,
- landfill has poor geotechnical properties on one side so it needs to be removed if any facilities are planned there,
- all facilities should be founded in the limestone since they have good geotechnical properties,
- Large fractures and caverns if they occur in the initial excavation is necessary to clean of red clay and debris and space should be filled with broken stone or lean concrete,
- for future landfill waterproof surface at the basis should be provided since limestone basis is well-permeable and karstified,
- wastewaters from the landfill must be purified before being released to the ground,
- geotechnical engineers presence is recommended in the execution of foundation excavation and groundwork.

7. CONCLUSION

Landfill terrain site "Vrtijeljka" in Cetinje from engineering-geological aspect is built from underlying limestones. At one end is existing landfill. Foundation conditions are generally favourable in geotechnical but are problematic in terms of hydrogeological conditions. Location is stable under natural conditions.

From the hydrogeological point of view, the terrain is one of the well-permeable, fractured and karstic porosity. The water level is deep inside the ground where it forms a scattered karts aquifer.

The facility is in seismic zone with the expected maximum earthquake intensity of VIII degree MCS scale.

Permitted load of limestone as a base for foundation of buildings is high (over 500 kN/m^2), while the subsidence is negligible. Basic excavations can be carried out completely by machines. Excavation of foundations and groundwork should be run with geotechnical monitoring.

Nikšić, September 2012.

Project manager:

_____

Andrija Delibašić, M.Sc. geology

LITERATURE AND FUND DOCUMENTATION

- Antonijević R. et al., (1962-1969): ***Basic geological map of "Kotor" 1:100 000 with an interpreter,*** Institute for Geological and Geophysical Research, Belgrade,

- Jokić D., Ivanović K. et al., (1983): ***Seismogeological basis and seismic microregionazation of urban area Cetinje with Njeguši, Ivanova Korita and Rijeka Crnojevića,*** Institute of Geological Exploration SR Montenegro - Titograd,

- Radulović M., (2000): ***Hydrogeology of Montenegro karst,*** Special edition, book XVIII, Podgorica,

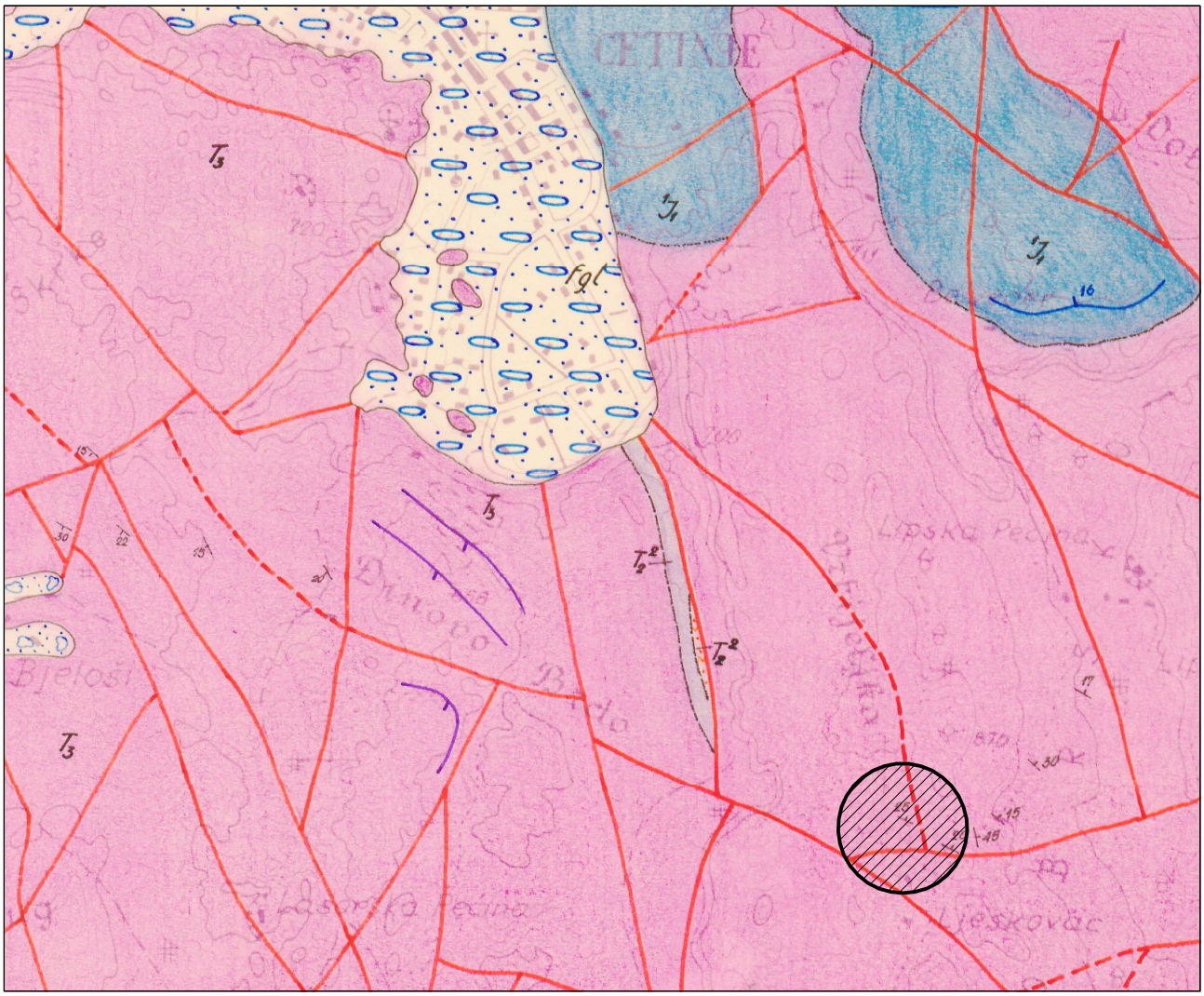
- **Fund documentation**: "GEOTEHNIKA Montenegro" d.o.o., Nikšić.

GRAPHICAL APPENDIX

Study area

MONTENEGRO GEOTEHNIKA Nikšić

ELABORATE THE GEOTECHNICAL PROPERTIES OF THE GROUND FOR STUDY OF REHABILITATION OF EXISTING SANITARY LANDFILL "VRTIJELJKA" FOR CITY OF CETINJE	Date: September, 2012.
GEOGRAPHICAL LOCATION OF THE STUDY AREA Scale 1:25 000	Appendix No 1.



LEGEND:

ts	Terra-rossa
fgl	Flucial-glacial material
gl	Moraine material
$^1J_1$	Massive and bedded limestone with litotisis and rare ammonites
T_3	Dolomites, dolomitic limestones and limestone
T_2^2	Calcarenites, micrites wiwth layers of dolomites

	Geological boundary: observed and supposed
25	Dip of bed elements
	Traces of beds observed by the field
	Fault: observed and supposed
	Study area

MONTENEGRO GEOTEHNIKA Nikšić

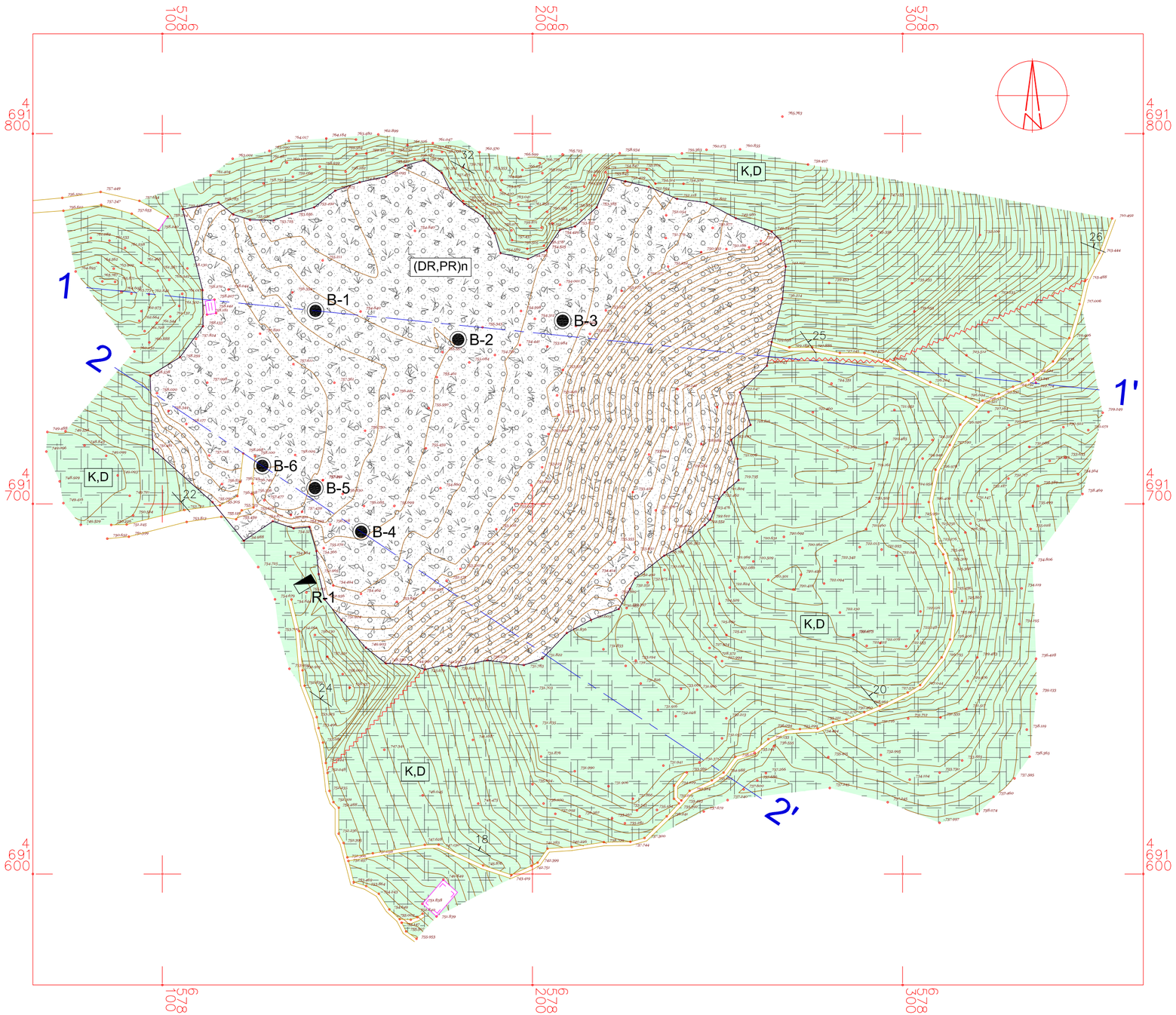
ELABORATE THE GEOTECHNICAL PROPERTIES OF THE GROUND FOR STUDY OF REHABILITATION OF EXISTING SANITARY LANDFILL "VRTIJELJKA" FOR CITY OF CETINJE

Date: September, 2012.

GEOLOGICAL MAP OF WINDER STUDY AREA, 1:25 000

(based on OGK "Cetinje", 1:25 000, ,,Zavod za geološka i geofizička istraživanja", Beograd, 1962-1969.)

Appendix No 2.



LEGEND:

1. ENGINEERING-GEOLOGICAL UNITS:

(DR,PR)n	Mound; waste landfills and waste
K,D	Limestone and dolimite; bedded and massive limestone, dolomitic limestone and dolomite. The layers are degraded and karstified. The series generally decrease toward the northeast at an angle of 15 to 35 °.

2. ENGINEERING-GEOLOGICAL SYMBOLS

— — —	Engineering-geological budary
	Gully
25	Dip of bed

3. OTHER SYMBOLS:

B-1	The position of performed boreholes
R-1	The position of performed tria pits
1 — - — 1'	The position of geological cross-section of the terrain

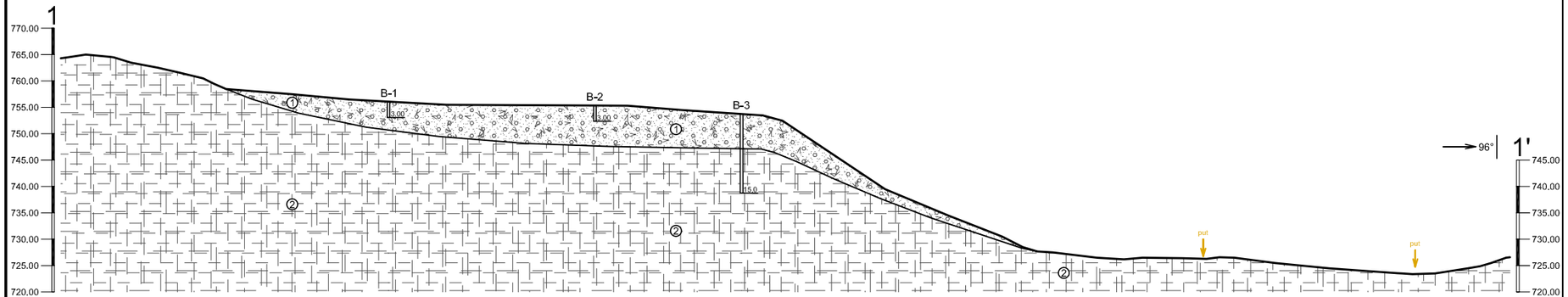
MONTENEGRO GEOTEHNIKA Nikšić

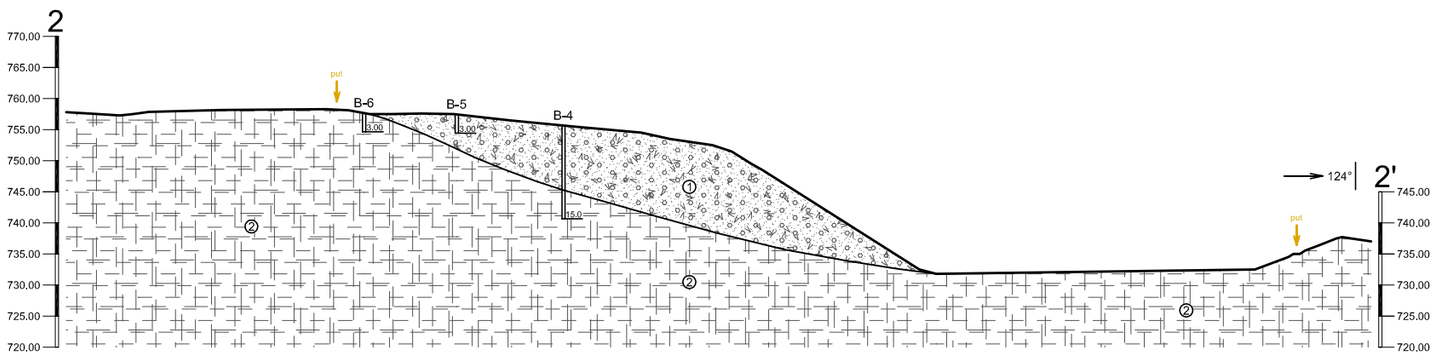
ELABORATE THE GEOTECHNICAL PROPERTIES OF THE GROUND FOR STUDY OF REHABILITATION OF EXISTING SANITARY LANDFILL "VRTIJELJKA" FOR CITY OF CETINJE

Date: September, 2012.

ENGINEERING GEOLOGICAL TERRAIN MAP, Scale 1:1 000

Appendix No 3.





LEGEND:

1. ENGINEERING-GEOLOGICAL UNITS:

② (DR,PR)n Mound; waste landfills and waste

⑤ K,D Limestone and dolimite; bedded and massive limestone, dolomitic limestone and dolomite. The layers are degraded and karstified. The series generally decrease toward the northeast at an angle of 15 to 35 °.

2. ENGINEERING-GEOLOGICAL MARKS:

Observed and supposed boundary

B-4 Location of performed borehole

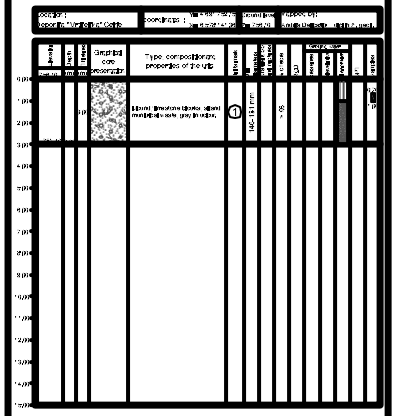
15.00

MONTENEGRO GEOTEHNIKA Nikšić

ELABORATE THE GEOTECHNICAL PROPERTIES OF THE GROUND FOR STUDY OF REHABILITATION OF EXISTING SANITARY LANDFILL "VRTIJELJKA" FOR CITY OF CETINJE	Date: September, 2012.
GEOTECHICAL CROSS-SECTION OF TERRAIN 1-1' I 2-2', Scale 1:500	Appendix № 4.

BOREHOLE

B-1



ELABORATE THE GEOTECHNICAL PROPERTIES OF THE GROUND FOR STUDY OF REHABILITATION OF EXISTING SANITARY LANDFILL "VRTIJELJKA" FOR CITY OF CETINJE

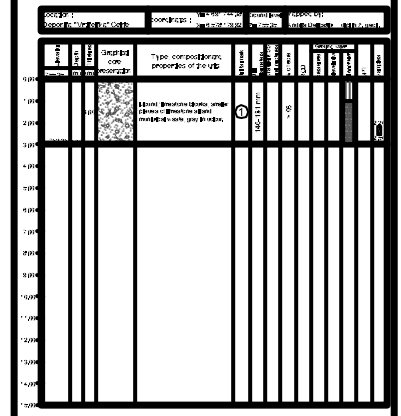
Date: September 2012.

ENGINEERING GEOLOGICAL PROFILES OF RESEARCH BOREHOLES B-1, Scale 1:100

Appendix no 5.

BOREHOLE

B-2



ELABORATE THE GEOTECHNICAL PROPERTIES OF THE GROUND FOR STUDY OF REHABILITATION OF EXISTING SANITARY LANDFILL "VRTIJELJKA" FOR CITY OF CETINJE

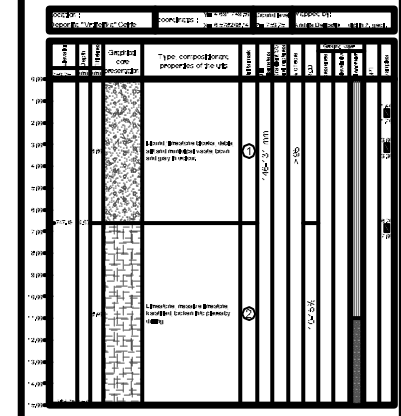
Date: September 2012.

ENGINEERING GEOLOGICAL PROFILES OF RESEARCH BOREHOLES B-2, Scale 1:100

Appendix no 5.2

BOREHOLE

B-3



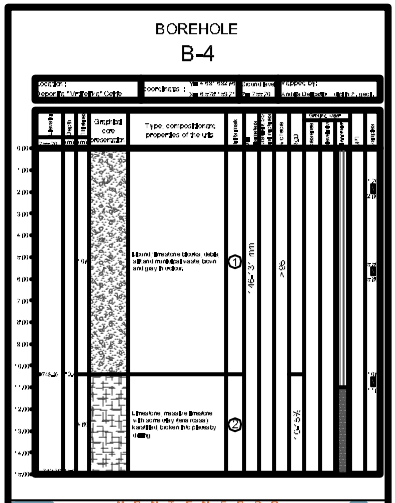
ELABORATE THE GEOTECHNICAL PROPERTIES OF THE GROUND FOR STUDY OF REHABILITATION OF EXISTING SANITARY LANDFILL "VRTIJELJKA" FOR CITY OF CETINJE

Date: September 2012.

ENGINEERING GEOLOGICAL PROFILES OF RESEARCH BOREHOLES B-3, Scale 1:100

BOREHOLE

B-4



ELABORATE THE GEOTECHNICAL PROPERTIES OF THE GROUND FOR STUDY OF REHABILITATION OF EXISTING SANITARY LANDFILL "VRTIJELJKA" FOR CITY OF CETINJE

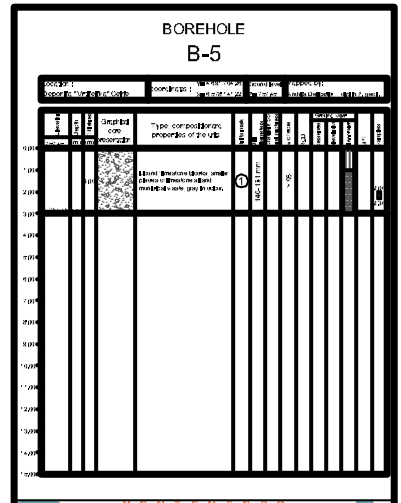
Date: September 2012.

ENGINEERING GEOLOGICAL PROFILES OF RESEARCH BOREHOLES B-4, Scale 1:100

Appendix no 5.4

BOREHOLE

B-5



ELABORATE THE GEOTECHNICAL PROPERTIES OF THE GROUND FOR STUDY OF REHABILITATION OF EXISTING SANITARY LANDFILL "VRTIJELJKA" FOR CITY OF CETINJE

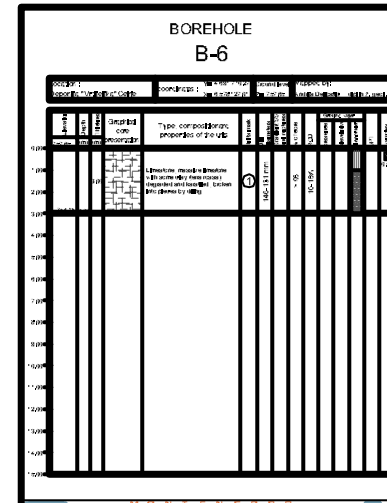
Date: September 2012.

ENGINEERING GEOLOGICAL PROFILES OF RESEARCH BOREHOLES B-5, Scale 1:100

Appendix no 5.5

BOREHOLE

B-6



ELABORATE THE GEOTECHNICAL PROPERTIES OF THE GROUND FOR STUDY OF REHABILITATION OF EXISTING SANITARY LANDFILL "VRTIJELJKA" FOR CITY OF CETINJE

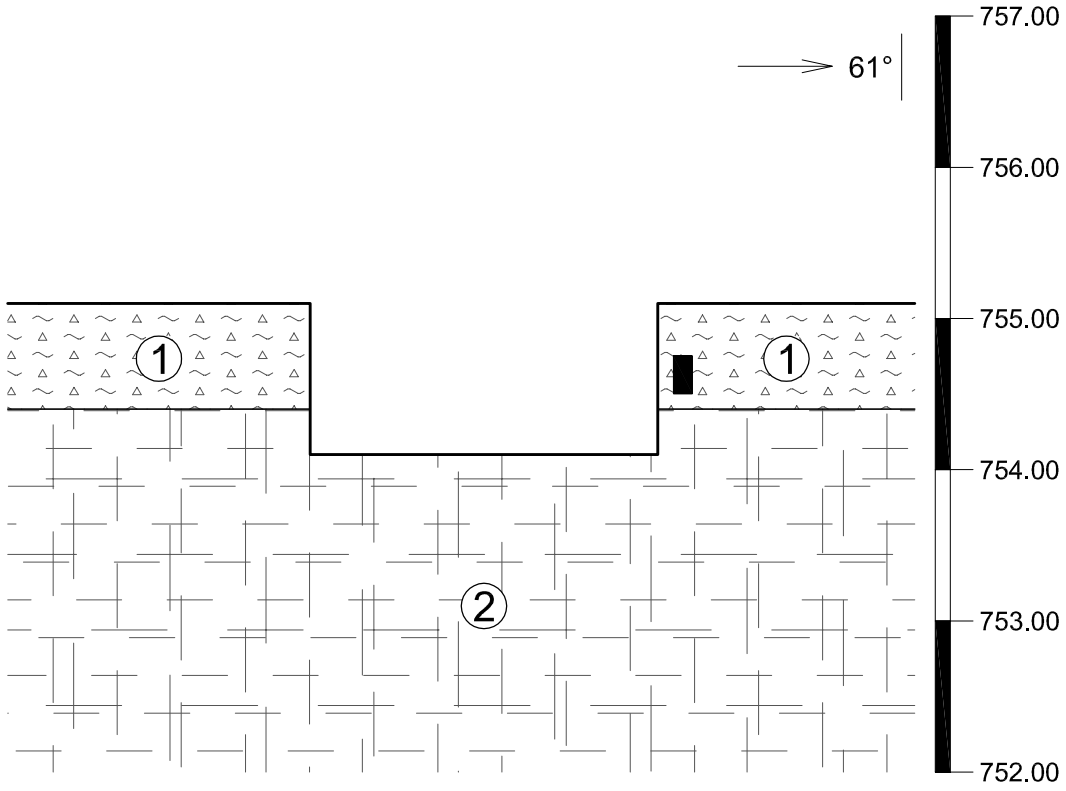
Date: September 2012.

ENGINEERING GEOLOGICAL PROFILES OF RESEARCH BOREHOLES B-6, Scale 1:100

Appendix no 5.6

TRIAL PIT R-1

Object:	**SANITARY LANDFILL „Vrijeljka"** Cetinja	Koordinates X= 6 578 138.56 Y= 4 691 678.33
Location:	Mjesto Vrtijeljka, pored puta Cetinje-Budva	Ground level Z= 755.10
Dimensions: 2.50 x 0.50 x 1.00	Mapped by: Dragomir Vukašinović, dipl.inž. geol.	



LEGEND:

1 (G,DR,BL)dl — Deluvijum; crvenica sa krečnjačkom drobinom i krečnjačkim blokovima, prašinasta i humificirana, tamno-braon i braon-crvene boje.

2 K — Krečnjaci; bankoviti krečnjaci, ispucali i karstifikovani. Pukotine su proširene i zapunjene crvenicom i krečnjačkom drobinom.

Engineering-geological boundaries

Place of soil sampling

MONTENEGRO GEOTEHNIKA Nikšić

ELABORATE THE GEOTECHNICAL PROPERTIES OF THE GROUND FOR STUDY OF REHABILITATION OF EXISTING SANITARY LANDFILL "VRTIJELJKA" FOR CITY OF CETINJE

Date: September, 2012.

TRIAL PIT R-1, Scale 1:50

Appendix No 6.1

THE DOCUMENTARY MATERIAL

IZVJEŠTAJ O ISPITIVANJU BROJ __12/08/012__

Naziv podnosioca zahtjeva:
Broj zahtjeva/ugovora:
Datum podnošenja zahtjeva:
Adresa:
Telefon/fax: /

Objekat: Deponija "Vrtijeljka", Opština Cetinje
Vrsta materijala: tlo
Broj uzoraka: 8
Datum uzorkovanja: avgust 2012. godine
Zahtijevano ispitivanje: identifikaciono-klasifikaciona i otporno-deformabilna svojstva po standardima
Uzorkovao: "GEOTEHNIKA Montenegro" d.o.o., Nikšić

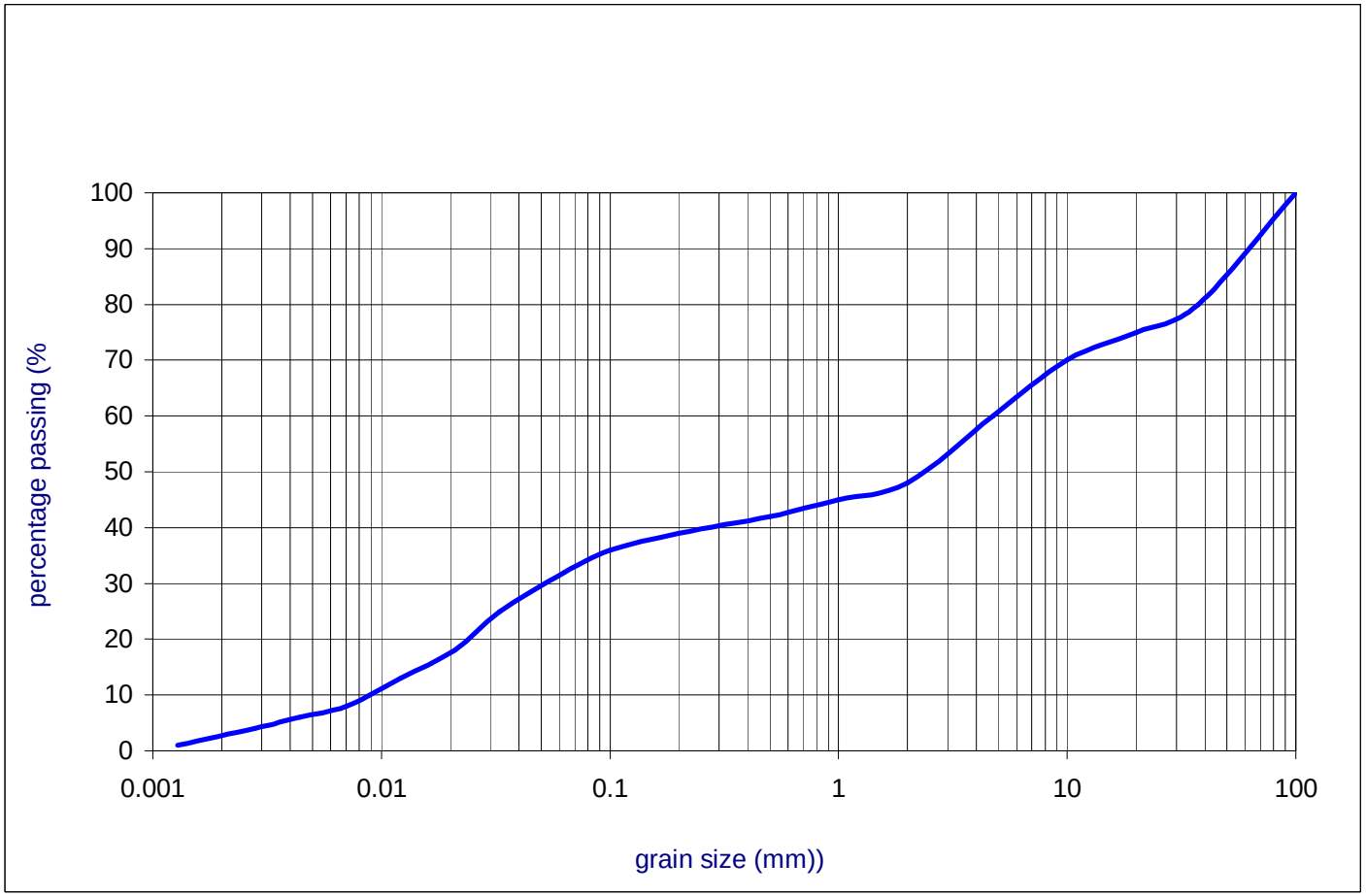
TABELARNI PRIKAZ REZULTATA LABORATORIJSKIH ISPITIVANJA

oznaka uzorka	dubina uzorkovanja	γ	γ_d	γ_s	e	n	W	frakcija					LL	PL	PI	CI	modul stišljivosti M_v (MPa)				φ	c	USCS
		(g/cm^3)				(%)	(%)	> 60.0	2.0-60.0	0.06-2.0	0.06-0.002	<0.002	(%)				0-50	50-100	100-200	200-400	(^{O})	(kPa)	
B-1	(0.70-1.00)	1.88	1.76	2.63	0.49	33.08	6.82	10	42	17	29	2	N.P.										
B-2	(2.20-2.50)	1.92	1.81	2.62	0.45	30.92	6.08	21	44	18	14	3	N.P.										
B-3	(1.40-1.70)	1.89	1.77	2.64	0.49	32.95	6.78	16	38	30	12	4	N.P.										
B-3	(3.00-3.30)	1.95	1.83	2.68	0.46	31.72	6.56	10	41	15	34	0	N.P.										
B-4	(1.70-2.00)	1.97	1.86	2.66	0.43	30.08	5.91	6	27	21	42	4	N.P.										
B-4	(5.50-5.80)	1.90	1.81	2.58	0.43	29.84	4.97	5	26	31	34	4	N.P.										
B-5	(2.00-2.30)	1.98	1.85	2.60	0.41	28.85	7.03	0	42	16	38	4	N.P.										
B-6	(0.20-0.50)	1.97	1.84	2.65	0.44	30.57	7.07	9	33	19	34	5	N.P.										

LABORATORY TESTS- ROCK

No	Borhole number	Sampling depth	Uniaxial compress. strenght	Poin load test	Water contenet	Unit weight	Specif. gravity	Density index	Porosity		Young's modulus	Poisson's ratio
			σ_c	σ_i	W	γ_w	γ_s		n	e	E	v
			MPa	MPa	(%)	g/cm^3	g/cm^3		%		MPa	
1	B-3 (6.7-7.0)		17.84	1.1	4.8	2.437	2.667	0.914	8	0.09	24321	0.31
2	B-4 (10.6-11.0)		35.30	4.2	4.20	2.644	2.690	0.983	2	0.02	21.442	0.32

PERTICLE SIZE DISTRIBUTION CHART



Location: Vrtijeljka-Cetinje

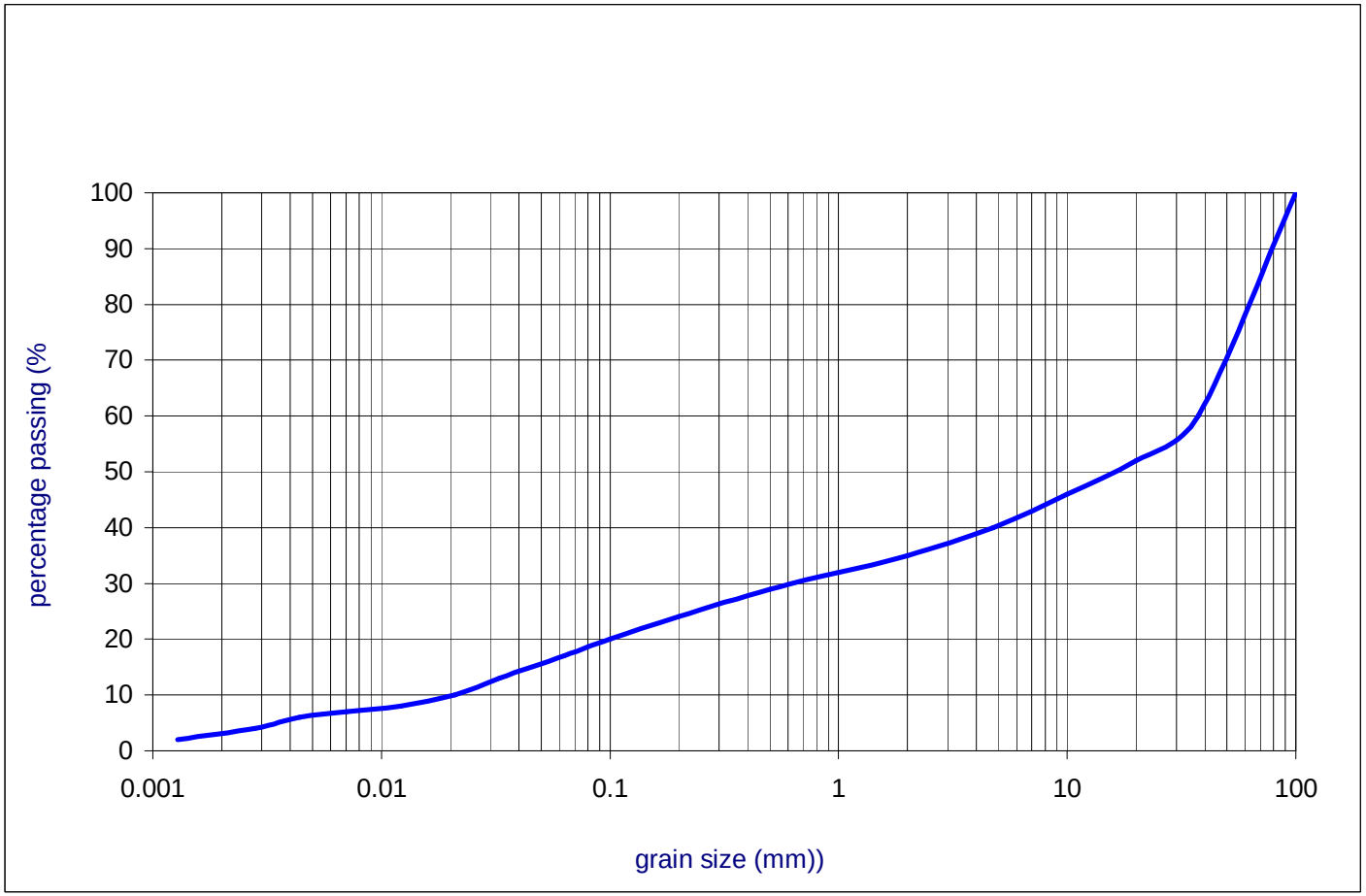
Sample: B-1_0.7-1.0

fractions	%
> 60	10
2.0-60.0	42
0.06-2.0	17
0.002-0.06	29
< 0.002	2

DATE: avgust 2012, Nikšić

standard: JUS U.B1.018

PERTICLE SIZE DISTRIBUTION CHART



Location: Vrtijeljka-Cetinje

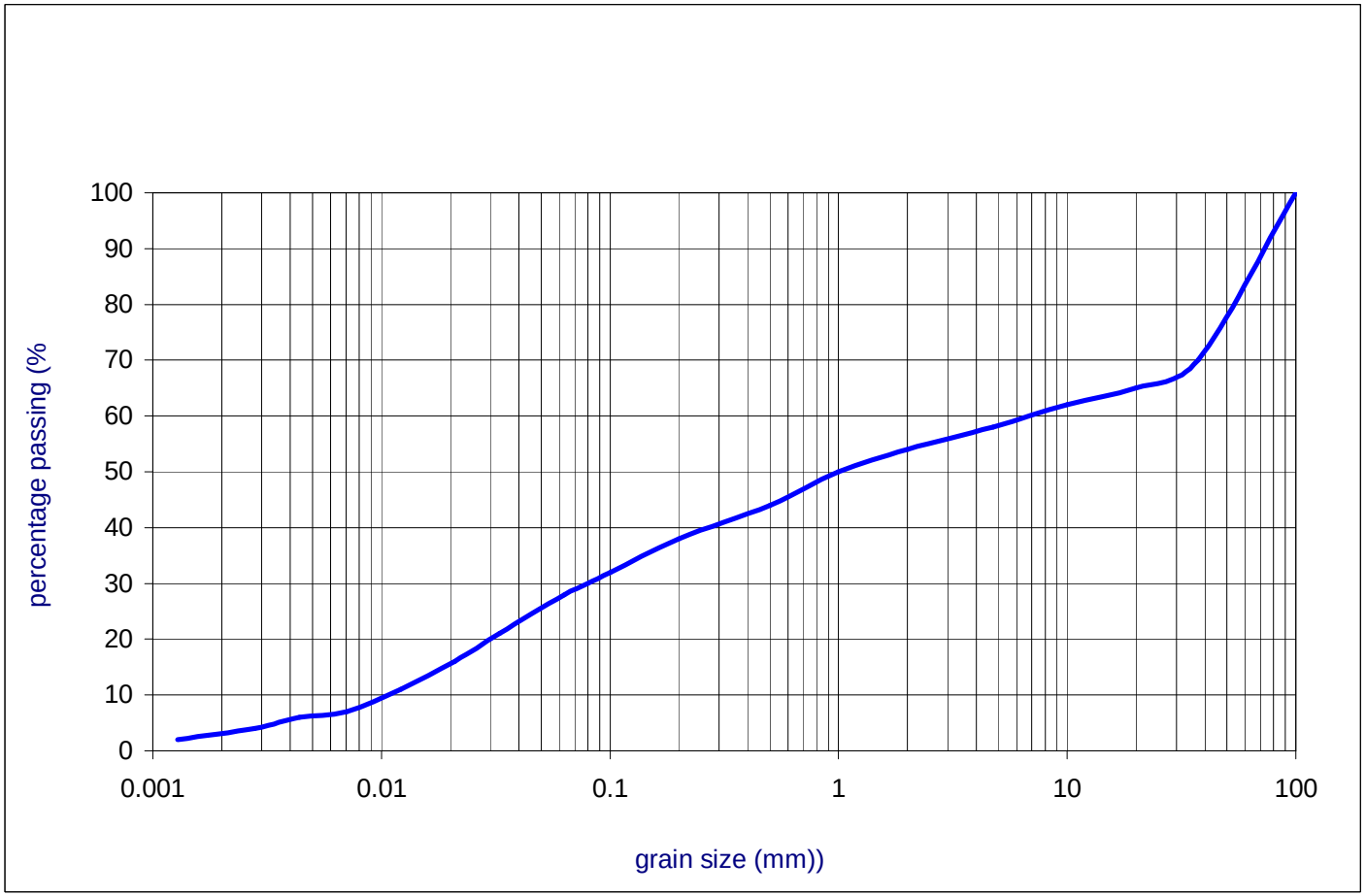
Sample: B-2_2.2-2.5

fractions	%
> 60	21
2.0-60.0	44
0.06-2.0	18
0.002-0.06	14
< 0.002	3

DATE: avgust 2012, Nikšić

standard: JUS U.B1.018

PERTICLE SIZE DISTRIBUTION CHART



Location: Vrtijeljka-Cetinje

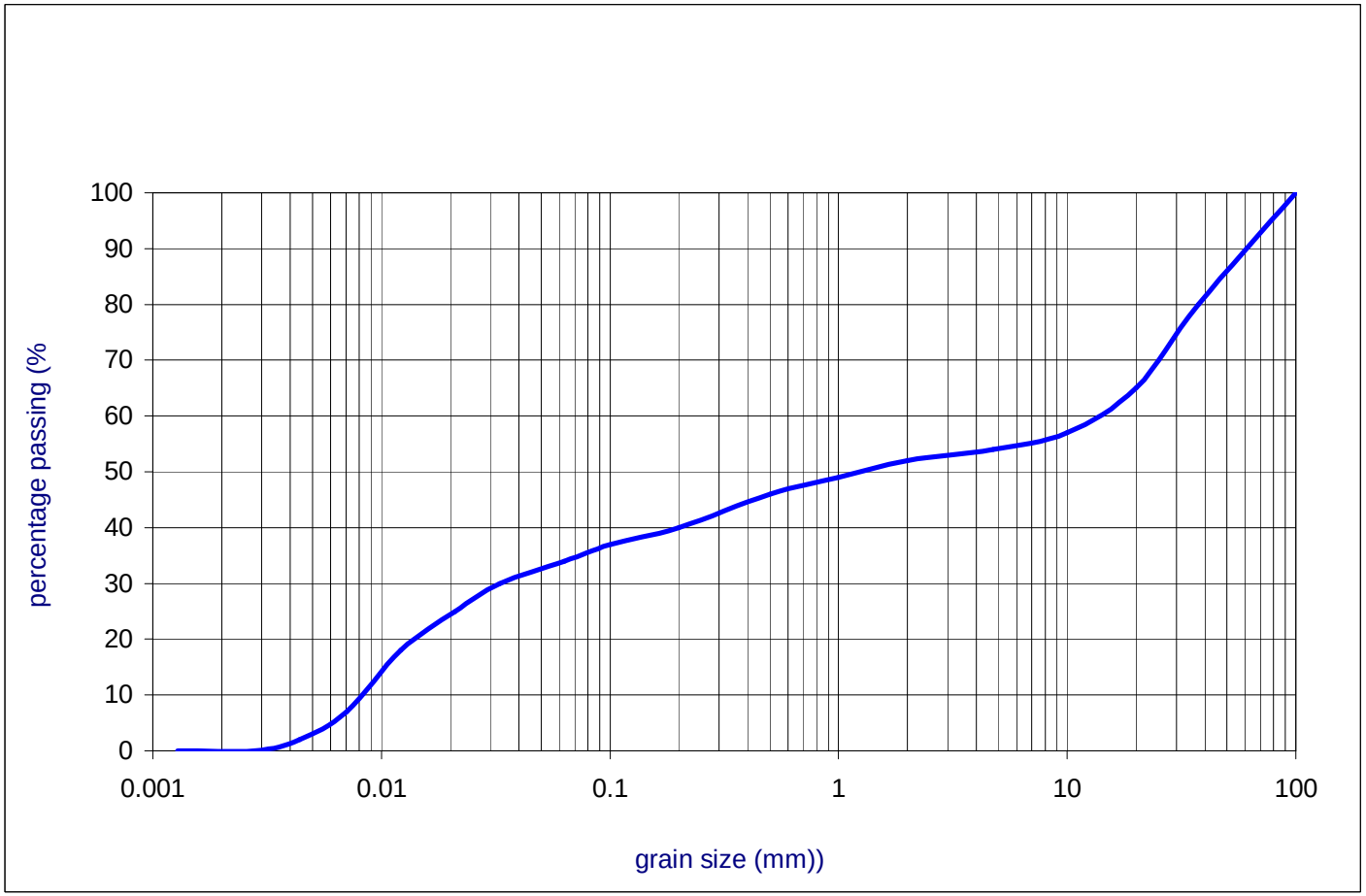
Sample: B-3_1.4-1.7

fractions	%
> 60	16
2.0-60.0	38
0.06-2.0	30
0.002-0.06	12
< 0.002	4

DATE: avgust 2012, Nikšić

standard: JUS U.B1.018

PERTICLE SIZE DISTRIBUTION CHART



Location: Vrtijeljka-Cetinje

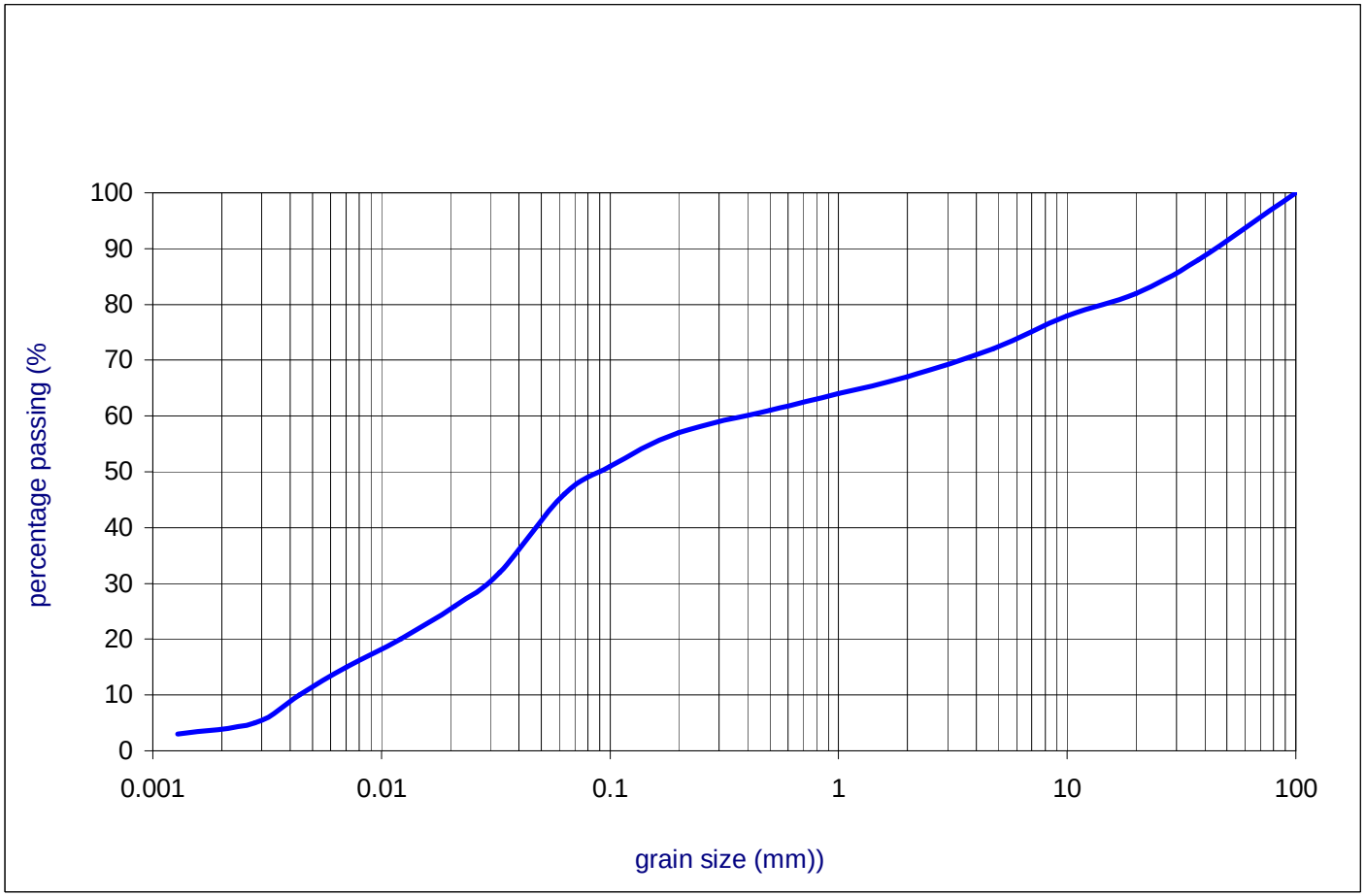
Sample: B-3_3.0-3.3

fractions	%
> 60	10
2.0-60.0	41
0.06-2.0	15
0.002-0.06	34
< 0.002	0

DATE: avgust 2012, Nikšić

standard: JUS U.B1.018

PERTICLE SIZE DISTRIBUTION CHART



Location: Vrtijeljka-Cetinje

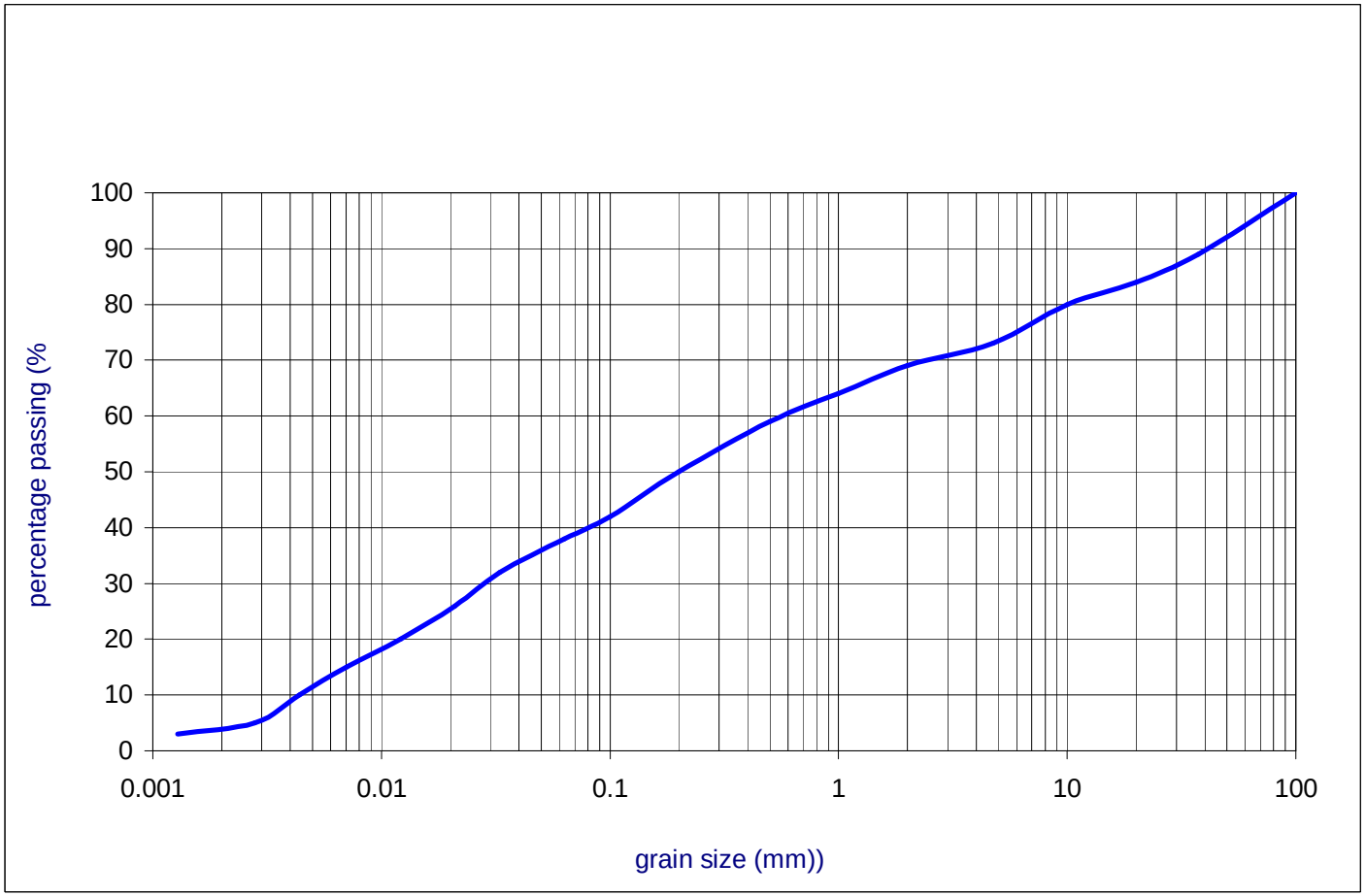
Sample: B-4_1.7-2.0

fractions	%
> 60	6
2.0-60.0	27
0.06-2.0	21
0.002-0.06	42
< 0.002	4

DATE: avgust 2012, Nikšić

standard: JUS U.B1.018

PERTICLE SIZE DISTRIBUTION CHART



Location: Vrtijeljka-Cetinje

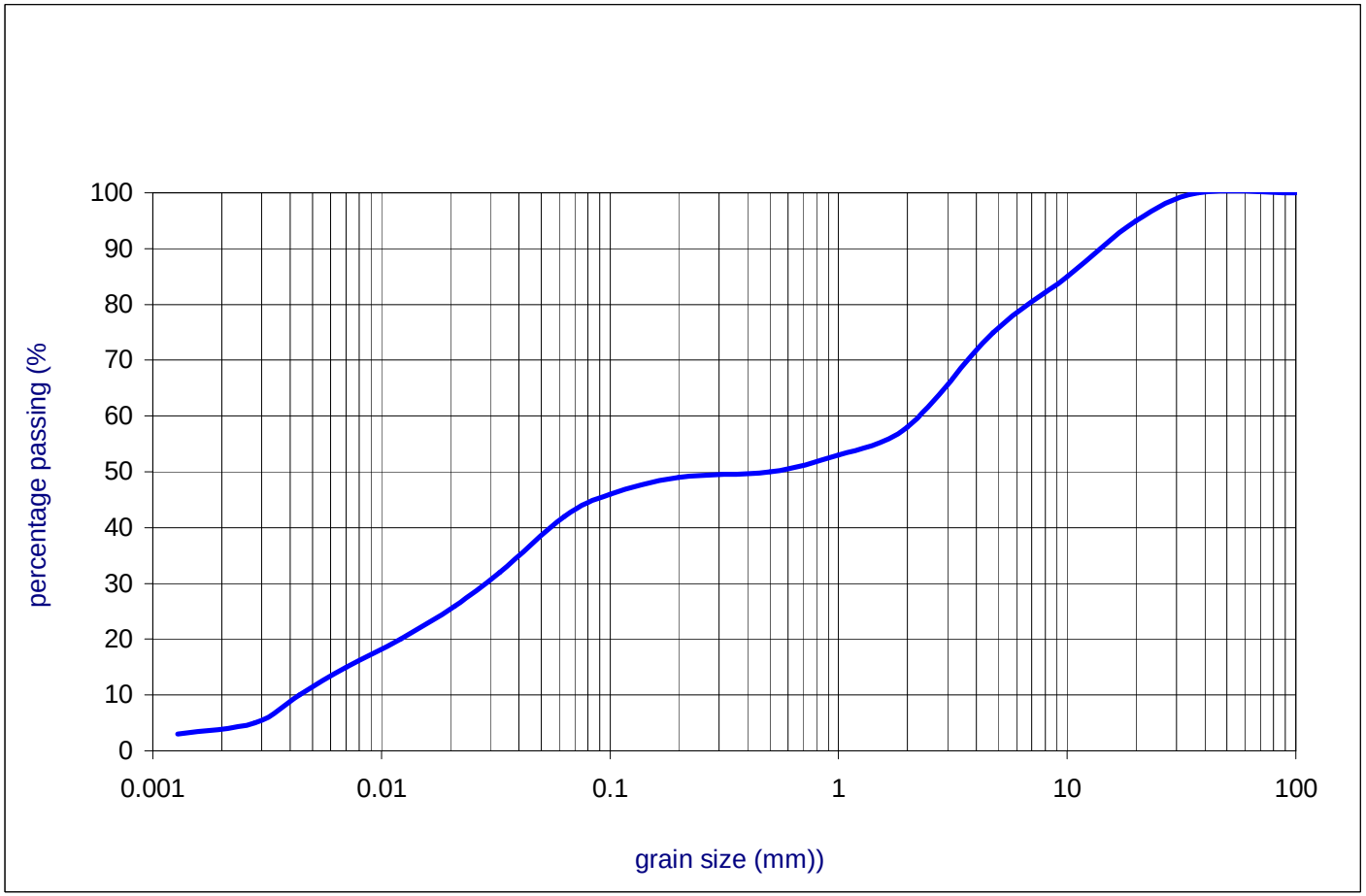
Sample: B-4_5.5-5.8

fractions	%
> 60	5
2.0-60.0	26
0.06-2.0	31
0.002-0.06	34
< 0.002	4

DATE: avgust 2012, Nikšić

standard: JUS U.B1.018

PERTICLE SIZE DISTRIBUTION CHART



Location: Vrtijeljka-Cetinje

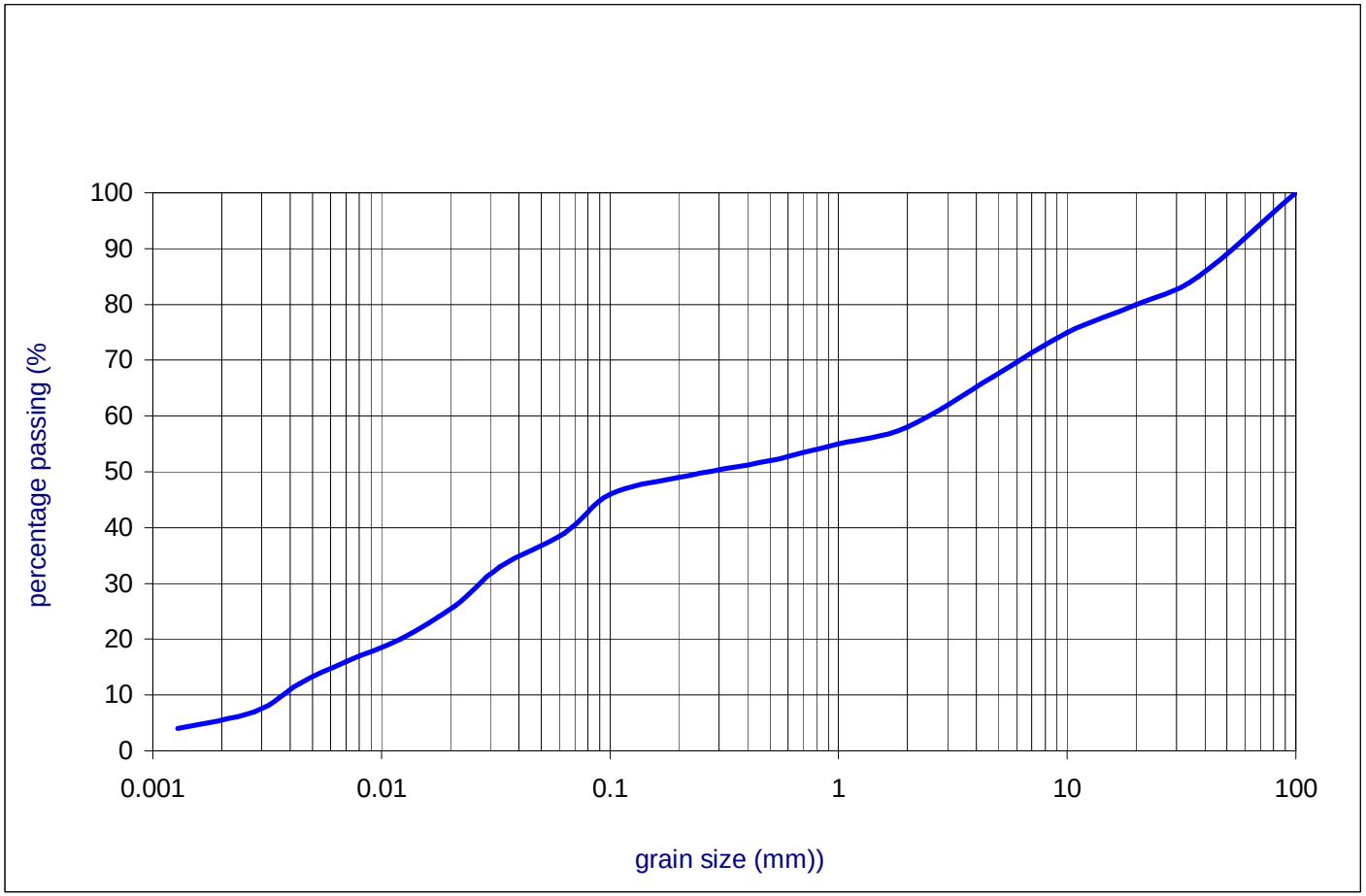
Sample: B-5_2.0-2.3

fractions	%
> 60	0
2.0-60.0	42
0.06-2.0	16
0.002-0.06	38
< 0.002	4

DATE: avgust 2012, Nikšić

standard: JUS U.B1.018

PERTICLE SIZE DISTRIBUTION CHART



Location: Vrtijeljka-Cetinje

Sample: B-6_0.2-0.5

fractions	%
> 60	9
2.0-60.0	33
0.06-2.0	19
0.002-0.06	34
< 0.002	5

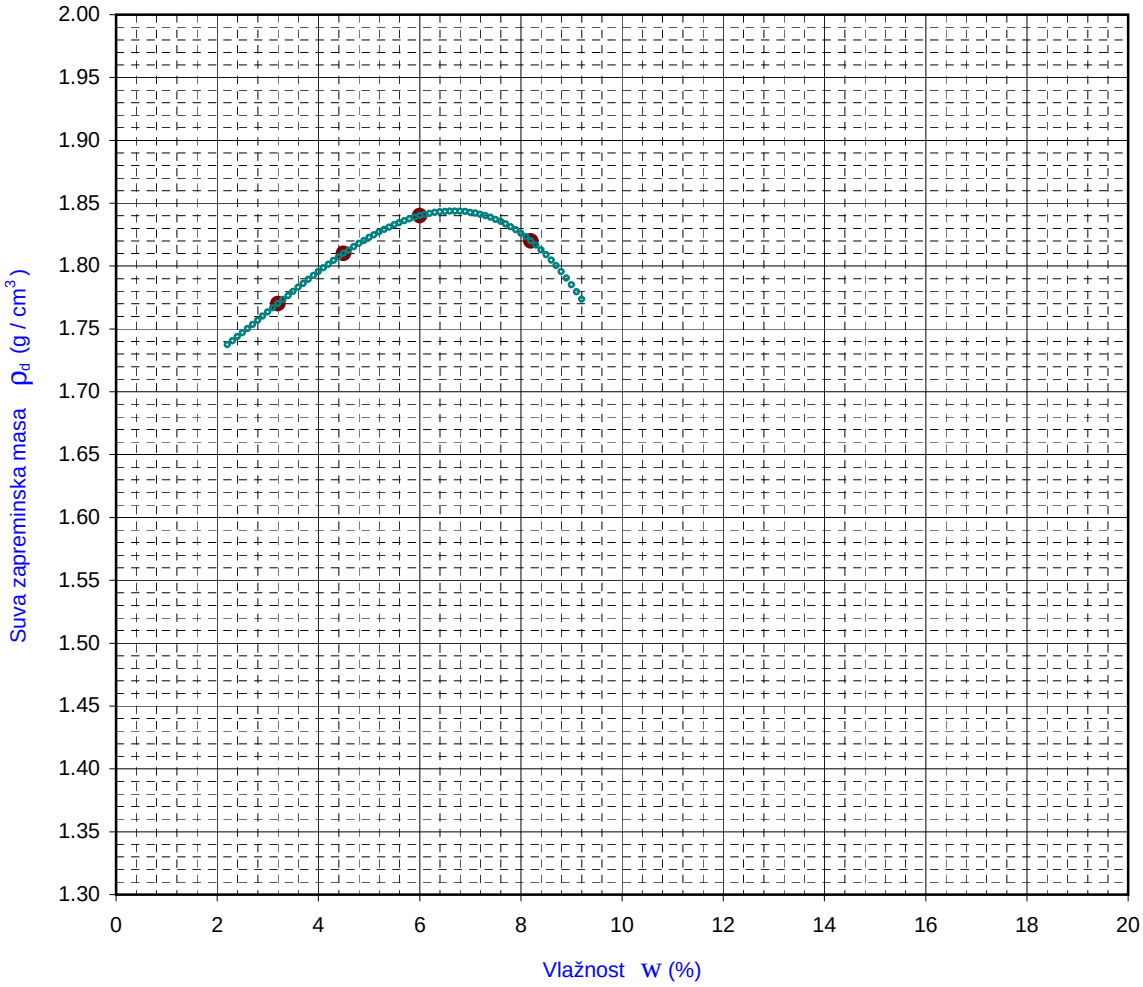
DATE: avgust 2012, Nikšić

standard: JUS U.B1.018

PROKTOROV OPIT

Objekat: Vrijeljak Cetnje

Porijeklo materijala: R-1



Laboratorijski broj 101

REZULTATI ISPITIVANJA:

..... E= **600** kNm/m^3	$\rho_{d\,max}$ = **1.84** g/cm^3 ; w_{opt} = **6.7** %	Specifična težina ρ_s = **2.67** g/cm^3 ;

LEGENDA:

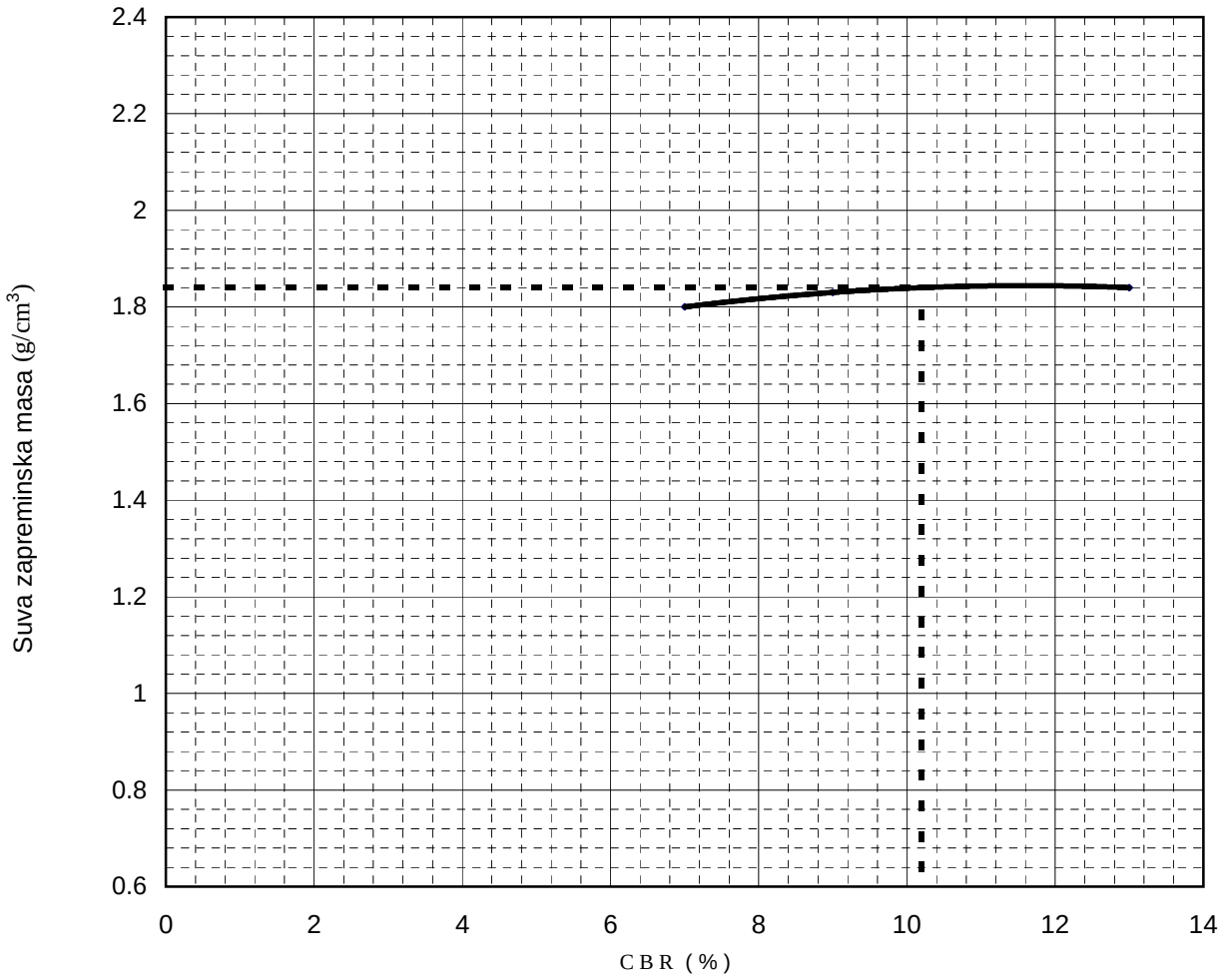
- Linija zasićenja pri stepenu zasićenosti Sr=100 %
- ○ Intpretacija krive Lagranžovim polinomom
- ● Eksperimentalne tačke

Ispitao: Intepretirao: Ovjerio:

MONTENEGRO GEOTEHNIKA Nikšić

Objekat: Vrtijeljaka Cetinje

Porijeklo materijala: R-1



PODACI ISPITIVANJA			
Broj udaraca - N	10	14	30
CBR vrijednost (%)	7	9	13
Bubrenje (%)	0	0	0
Suva zaprem.masa (g/cm^3)	1.8	1.83	1.84
Vlažnost prije opita (%)	6.2		
Vlažnost posle opita (%)	6.2	6.19	6.18

PROKTOROV OPIT

E = 600 $kN\ m/m^3$

Optimalna vlažnost w_{opt} = 6.7 (%)

Maksimalna suva zapreminska masa $\rho_{d\,max}$ = 1.84 (g/cm^3)

CBR (100 % $\rho_{d\,max}$) = **10.2** (%)

Ispitao: Intepretirao: Overio:

Appendix 3 Gas collection system

ESTIMATED VALUE OF DEPOSITED WASTE:

TABLE 3

Landfill closure-year			2013		Inital recycling		
The percentage of incr.in the amount of waste					Inital recycling		0
Landfill open-year			1987		Targeted recycling		0,00%
Year	-	Annual waste, m3 (incompacted)	Annual waste, m3 (compacted)	Annual Inert material, m3 (compacted)	Annual total landfill , m3 (compacted)	Annual tonnage land filled dry waste (t)	Dry Waste, Cumulative (t)
1987	1	3531,64	2224,93	0,00	2224,93	1765,82	1765,82
1988	2	3559,89	2242,73	0,00	2242,73	1779,95	3545,76
1989	3	3588,37	2260,67	0,00	2260,67	1794,19	5339,95
1990	4	3741,17	2356,93	0,00	2356,93	1870,58	7210,53
1991	5	3918,22	2468,48	0,00	2468,48	1959,11	9169,64
1992	6	4185,84	2637,08	0,00	2637,08	2092,92	11262,56
1993	7	4234,65	2667,83	0,00	2667,83	2117,33	13379,88
1994	8	4283,13	2741,21	0,00	2741,21	2141,57	15521,45
1995	9	4392,29	2811,07	0,00	2811,07	2196,15	17717,60
1996	10	4760,42	3046,67	0,00	3046,67	2380,21	20097,81
1997	11	4924,65	3201,03	0,00	3201,03	2462,33	22560,13
1998	12	4969,00	3229,85	0,00	3229,85	2484,50	25044,64
1999	13	5013,18	3509,22	150,40	3659,62	2506,59	27551,22
2000	14	5134,30	3594,01	154,03	3748,04	2567,15	30118,37
2001	15	5242,64	3669,85	183,49	3853,34	2621,32	32739,69
2002	16	5409,58	3786,70	216,38	4003,09	2704,79	35444,48
2003	17	5617,60	4213,20	224,70	4437,91	2808,80	38253,28
2004	18	5687,33	4265,50	398,11	4663,61	2843,67	41096,95
2005	19	5818,65	4363,99	465,49	4829,48	2909,32	44006,27
2006	20	5880,01	4410,01	529,20	4939,21	2940,01	46946,28
2007	21	5986,28	4489,71	598,63	5088,34	2993,14	49939,42
2008	22	6175,88	4631,91	741,11	5373,02	3087,94	53027,36
2009	23	6450,79	5160,63	774,10	5934,73	3225,40	56252,76
2010	24	6587,56	5270,05	823,45	6093,49	3293,78	59546,54
2011	25	6373,85	5736,47	828,60	6565,07	3186,93	62733,47
2012	26	6615,34	6615,34	859,99	7475,33	3307,67	66041,14
2013	27	8340,92	8340,92	1376,25	9717,17	4170,46	70211,60
		140423,19	103945,99	8323,93	112269,92	70211,60	

Current status:

Volume V = 99194.56 m³

Area P = 16308.48 m²

ESTIMATED PRODUCTION OF THE LANDFILL GAS:

To estimate the production of landfill gas was used a model for the emission of landfill gas (LandGEM), U.S.
Agency for Environmental Protection (Environmental Protection Agency).
The annual amount of produced methane can be determined using the following equation:

$$Q_{CH_4} = \sum_{i=1}^{n} \sum_{j=0,1}^{1} k \cdot L_0 \cdot \left(\frac{M_i}{10} \right) \cdot e^{-kt_{ij}}$$

Where:

Q_{CH_4} annual amount CH4 (m3/god);

i increment(1 godina);

n initial year for the waste acceptance;

j increment (0,1 godina);

k speed of forming CH4 (god-1);

L_0 potential capacity of forming CH4 (m3/t);

M_i mass of waste deposited in the i-year (t);

t_{ij} age of the j- section of waste mass Mi deposited in the i-year;

Theparameters used foragiven model are:

Start depositing 1987

$k = 0{,}050 \left(god^{-1} \right)$

$L_0 = 170 \left(m^3 / t \right)$

content CH4 : 49 vol. %

content CO2 : 50 vol. %

other : 1 vol. %

Estimated production of landfill gas at the landfill , depending on the year of disposal is:

TABLE 4

Year	Biogas-total		Methane		Carbon Dioxide	
	m3/year	m3/h	m3/year	m3/h	m3/year	m3/h
1987	32866,9	3,8	16104,78	1,8	16762,1	1,9
1988	64393,8	7,4	31552,95	3,6	32840,8	3,7
1989	94648,1	10,8	46377,58	5,3	48270,5	5,5
1990	124848,9	14,3	61175,97	7,0	63672,9	7,3
1991	155224,5	17,7	76060,02	8,7	79164,5	9,0
1992	186609,3	21,3	91438,55	10,4	95170,7	10,9
1993	216917,7	24,8	106289,65	12,1	110628,0	12,6
1994	246199,1	28,1	120637,55	13,8	125561,5	14,3
1995	275068,3	31,4	134783,47	15,4	140284,8	16,0
1996	305955,5	34,9	149918,19	17,1	156037,3	17,8
1997	336864,7	38,5	165063,73	18,8	171801,0	19,6
1998	366679,3	41,9	179672,85	20,5	187006,4	21,3
1999	395450,8	45,1	193770,90	22,1	201679,9	23,0
2000	423946,4	48,4	207733,73	23,7	216212,7	24,7
2001	452060,5	51,6	221509,63	25,3	230550,8	26,3
2002	480357,0	54,8	235374,92	26,9	244982,1	28,0
2003	509209,4	58,1	249512,62	28,5	259696,8	29,6
2004	537303,7	61,3	263278,80	30,1	274024,9	31,3
2005	565249,8	64,5	276972,41	31,6	288277,4	32,9
2006	592404,1	67,6	290278,01	33,1	302126,1	34,5
2007	619223,0	70,7	303419,29	34,6	315803,8	36,1
2008	646498,5	73,8	316784,28	36,2	329714,3	37,6
2009	675002,2	77,1	330751,07	37,8	344251,1	39,3
2010	703388,5	80,3	344660,38	39,3	358728,1	41,0
2011	728401,6	83,2	356916,79	40,7	371484,8	42,4
2012	754442,1	86,1	369676,65	42,2	384765,5	43,9
2013	795271,6	90,8	389683,11	44,5	405588,5	46,3
2014	756485,8	86,4	370678,04	42,3	385807,8	44,0
2015	719591,5	82,1	352599,86	40,3	366991,7	41,9
2016	684496,6	78,1	335403,36	38,3	349093,3	39,9
2017	651113,4	74,3	319045,54	36,4	332067,8	37,9
2018	619358,2	70,7	303485,51	34,6	315872,7	36,1
2019	589151,7	67,3	288684,35	33,0	300467,4	34,3
2020	560418,5	64,0	274605,04	31,3	285813,4	32,6
2021	533086,5	60,9	261212,40	29,8	271874,1	31,0
2022	507087,6	57,9	248472,92	28,4	258614,7	29,5
2023	482356,6	55,1	236354,75	27,0	246001,9	28,1
2024	458831,8	52,4	224827,59	25,7	234004,2	26,7
2025	436454,3	49,8	213862,62	24,4	222591,7	25,4
2026	415168,2	47,4	203432,42	23,2	211735,8	24,2
2027	394920,2	45,1	193510,90	22,1	201409,3	23,0
2028	375659,7	42,9	184073,27	21,0	191586,5	21,9
2029	357338,6	40,8	175095,91	20,0	182242,7	20,8
2030	339911,0	38,8	166556,38	19,0	173354,6	19,8
2031	323333,3	36,9	158433,33	18,1	164900,0	18,8
2032	307564,2	35,1	150706,44	17,2	156857,7	17,9
2033	292564,1	33,4	143356,40	16,4	149207,7	17,0
2034	278295,6	31,8	136364,83	15,6	141930,7	16,2
2035	264722,9	30,2	129714,24	14,8	135008,7	15,4
2036	251812,2	28,7	123388,00	14,1	128424,2	14,7
2037	239531,2	27,3	117370,30	13,4	122160,9	13,9
2038	227849,1	26,0	111646,08	12,7	116203,1	13,3
2039	216736,8	24,7	106201,04	12,1	110535,8	12,6

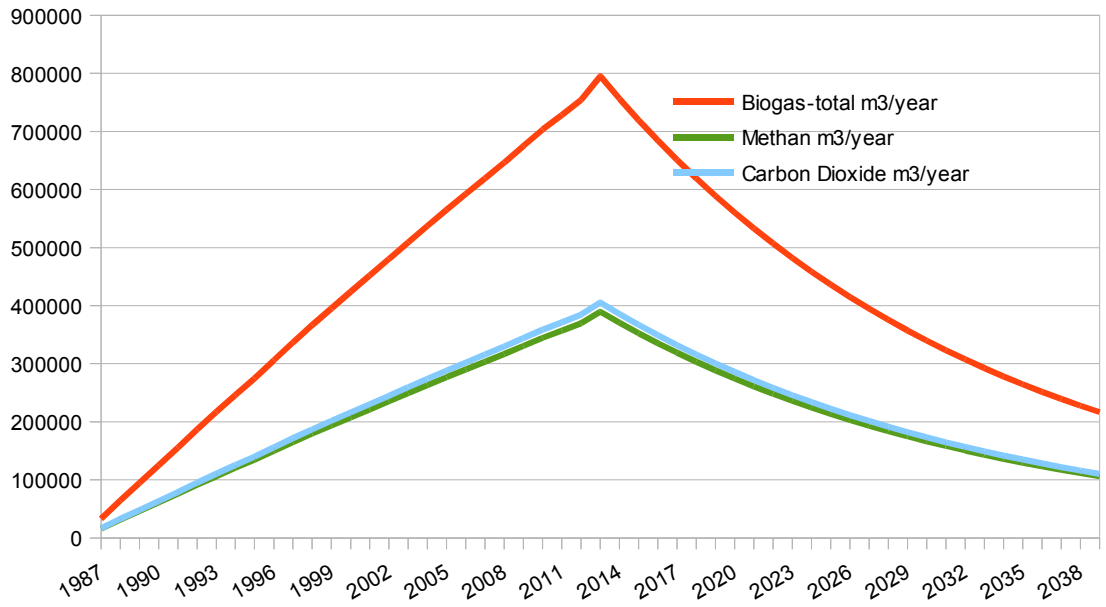


TABLE 5

LANDFILL GAS PRODUCTION RECAP. FOR THE PERIOD BETWEEN 2012 – 2064		
TOTAL PRODUCTION OF LANDFILL GAS	22568325,26	m3/year
TOTAL PRODUCTION OF METHANE	11058479,38	m3/year
CARBON DIOXIDE TOTAL PRODUCTION	11509845,88	m3/year
MAXIMUM PRODUCTION OF LANDFILL GAS	90,78	m3/h
MAXIMUM PRODUCTION OF METHANE	44,48	m3/h
CARBON DIOXIDE MAXIMUM PRODUCTION	46,30	m3/h

DEGASSING SYSTEM CALCULATION FOR THE WASTE LANDFILL“VRTIJELJKA”

INPUT DATA:

Landfill characteristics

Landfill location	42° 21' 57.49" N 18° 56' 37.74" E , Municipal Cetinje, MNE;
Landfill area	cca. 3,1 Ha;
Deposited waste volume	cca. 103946,00 m^3;
Deposited waste mass	cca. 70211,60 t;

Specific production of the landfill gas :

$$G_{uk} = \frac{24 \cdot Q_{uk}}{M} \left[m^3 / tdan \right]$$

$Q_{uk} = 90{,}78 \left[m^3 / h \right]$ Max.production of the landfill gas (TABLE 5);

$$G_{uk} = 310{,}3 \cdot e^{-4} \left[m^3 / tdan \right]$$

Methan specific production

$$G = \frac{24 \cdot Q}{M} \left[m^3 / tdan \right]$$

$Q = 44{,}48 \left[m^3 / h \right]$ Max.production of the methan (TABLE 5);

$$G_{uk} = 152{,}1 \cdot e^{-4} \left[m^3 / tdan \right]$$

Waste characteristics

Awerage age	20 years.;
Landfill waste specific weight	D= 0,712 t/m3;
Max. height of the landfill waste	tmax.= 14 m;

Covering layer: Gas collection layer, with minimum thickness of 0.3 m, composed of material with hydraulic conductivity of minimum 1 x 10-4 m/s, Compacted mineral layer (clay), with thickness of 0.3 m, with hydraulic conductivity ≤ 1 x 10-9 m/s, HDPE liner, 1 mm thick and a protective geotextile layer (below HDPE liner) of 500 g/m² , Drainage layer, with of 0.3 m, with hydraulic conductivity of minimum 1 x 10-4 m/s, Soil layer with thickness of 1 m, mixed with top humus layer with minimum thickness 0.1-0.3 m.

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GAS FLOW IN THE COLLECTING GASSES WELL

$$Q_{BT^{CH_4}} = \pi \cdot \left(R^2 - r^2\right) \cdot t \cdot D \cdot G\left[m^3 / dan\right]$$

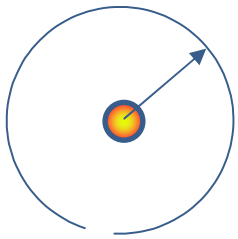
The flow of methane in collecting gasses well depending on the depth of the waste;

$$Q_{BT^{UK}} = \pi \cdot \left(R^2 - r^2\right) \cdot t \cdot D \cdot G_{uk}\left[m^3 / dan\right]$$

The flow of the landfill gas in the collecting gasses well depends on the depth of waste;;

$R = 30\,[m]$ Radius of coll.gass.well inf;

$r = 0{,}60\,[m]$



$t = 1 - 14\,[m]$ Dep. waste layer height;

$$\Delta P = \mu \cdot G_{UK} \cdot D\left[R^2 \cdot \ln(R/r) + \left(r^2/2\right) - \left(R^2/2\right)\right] / 2 \cdot K_s\,[Pa]$$

The required pressure differential between the outer border zone collecting gasses wellinfluence and exhaust pipes

$\mu = 1{,}21 \cdot 10^{-5}\left[Ns / m^2\right]$ The absolute viscosity of the landfill gas ;

$K_s = 15[darcy] = 1{,}48 \cdot 10^{-11}\left[m^2\right]$ The apparent permeability of the deposited waste;

TABLE 6

t	QBTCH4	QBTUK		ΔP
m	m3/day	m3/day	m3/min	Pa
1	30,60	62,44	0,043	315,38
2	61,20	124,89	0,087	
3	91,79	187,33	0,130	
4	122,39	249,78	0,173	
5	152,99	312,22	0,217	
6	183,59	374,66	0,260	
7	214,18	437,11	0,304	
8	244,78	499,55	0,347	
9	275,38	562,00	0,390	
10	305,98	624,44	0,434	
11	336,57	686,88	0,477	
12	367,17	749,33	0,520	
13	397,77	811,77	0,564	
14	428,37	874,22	0,607	

COLLECTING GASSES WELL SCHEDULE WITH THE PIPE INSTALLATION ROUTES IS GIVEN IN THE GRAPH ATTACHMENT OF THIS PROJECT.

TOTAL PREASSURE DROP IN THE DEGASSING SYSTEM

$\Delta P^{Li}{}_U = \Delta P + \Delta P_C + \Delta P_L [Pa]$ Total preassure drop in the degassing system;

$\Delta P = 315{,}38 [Pa]$ The required pressure differential between the outer border zone collecting gasses well influence and exhaust pipes of the collecting gasses well.(TABLE 6);

$\Delta P_C = \lambda \cdot \frac{l}{d} \cdot \frac{\rho}{2} \cdot v^2 [Pa]$ Loss of pressure in the flat part of the pipeline (Darcy);

$\lambda = f(R_e) = \frac{0{,}3164}{R_{e^{0,25}}}$ Darcy friction factor in the function of the number of Reynolds number for the new smooth pipes(Blazijus equations) ;

$R_e = \frac{v \cdot d_u}{v}$ Reynolds number;

$v = \frac{\eta}{\rho} (m^2 / sec)$ Kinematic viscosity of the landfill gas ;

$l [m]$ Length of straight section of the degassing system pipeline ;

$d = d_s - 2 \cdot s [m]$ The inner diameter of the pipes system for degassing;

$d_s [m]$ Outer diameter of the pipes system for degassing;

$s [m]$ Pipes wall thickness of the degassing system ;

$\rho = P \cdot M / R_u \cdot T [kg / m^3]$ The landfill gas density ;

$P = P_A - P_V [Pa]$ The absolute pressure in the degassing system main pipe ;

$P_A = 101325 [Pa]$ The atmospheric pressure;

$P_V = 7500 [Pa]$ Implied value of under pressure in the degassing system main pipe (adopted size);

$P = 93825 [Pa]$

$$M = 0{,}49 \cdot M_{CH4} + 0{,}51 \cdot M_{CO2} = 0{,}49 \cdot (12 + 4) + 0{,}51 \cdot (12 + 2 \cdot 16) = 30{,}28 [kg / kg - mol]$$

$M = 30{,}28 [kg / kg - mol]$ The molecular weight of the landfill gas ;

$R_U = 8{,}314427 [m^3 Pa / molK]$ Universal gas constant;

$T = 316{,}5 [K]$ The absolute temperature;

$\rho = 1{,}0796 [kg / m^3]$ Specific weight of the landfill gas for pressure in the pipeline degassing system;

$$v = \frac{Q_{uk} \cdot 4}{d^2 \cdot \pi \cdot 3600} [m/sec]$$ The actual flow velocity of the landfill gas ;

$$\Delta P_L = \sum \xi \cdot \frac{\rho}{2} \cdot v [Pa]$$ Local losses of pressure;

ξ The coefficient of local losses;

$$N = \frac{Q_{uk} \cdot \Delta P^{Li}}{\eta} [W]$$ Blower engine power ;

$\eta = 0,5$ The degree of blower usage ;

TABLE 7

ΔP=	315,38	Pa
P_A=	101325,00	Pa
P_V=	7500,00	Pa
P=	93825,00	Pa
M=	30,28	kg/kg-mol
R_U=	8,31	m3Pa/molK
T=	316,50	0K
	43,35	0C
ρ=	1,08	kg/m3
μ=	1,21E-005	Ns/m2
ν=	1,12E-005	m2/sec

TABLE 8

Mat.	Nom. ID	dS	s	d	d	A	A	Standard
	DN	[mm]	[mm]	[mm]	[m]	mm2	m2	-
PEHD	90	90	6,5	77	0,0770	4657	0,0047	DIN8074
St36.5	100	114,3	3,2	107,9	0,1079	9144	0,0091	DIN2448
PEHD	110	115	6,5	102	0,1020	8171	0,0082	DIN8074

TABLE 9

Route	Gas well	Depth	Flow	Valve	Tees	Elbow	Arestor	Kond separator.	Σξ
L	#	[m]	Q [m3/sec]	2	1,3	0,7	2	2	-
	1	4	0,0029	1	1	1			4
	2	4	0,0029	1	1	1			4
	3	6	0,0043	1	1	1			4
	4	5	0,0036	1	1	1			4
	5	12	0,0087	1	1	1			4
	6	12	0,0087	1	1	1			4
	7	7	0,0051	1	1	1			4
	8	7	0,0051	1	1	1			4

No. well	velocity	Nom. ID	length of pipe	Lok. Resistance	Rejnolds.No.	ΔP	ΔPC	ΔPL	ΔPLiU
#	[m/sec]	DN	l [m]	ξ	Re	Pa	Pa	Pa	Pa
Gas collection from the waste body									
6	1,86	90		4		315,38		4,02	
L6-6	1,86	90	55		12795,59		39,79		
									359
3	0,93	90		4		315,38		2,01	
L3-6	2,79	90	30		19193,39		44,12		
									362
8	1,86	90		4		315,38		4,02	
L8-8	1,86	90	20		12795,59		14,47		
									334
5	1,86	90		4		315,38		4,02	
L5-8	4,66	110	45		42375,02		113,86		
									433
1	0,62	90		4		315,38		1,34	
L1-1	5,28	110	52		48025,02		163,79		
#6									481
2	0,62	90		4		315,38		1,34	
L2-2	5,90	110	27		53675,03		103,32		
									420
7	1,86	90		4		315,38		4,02	
L7-7	1,86	90	52		12795,59		37,62		
									357
4	0,78	90		4		315,38		1,68	
4-7	1,86	90	57		12795,59		41,24		
									358
									3104
Blower suction side									
I29-30	7,76	100		8		8000,00		33,51	
	7,76	100	7		74710,21		40,36		
	7,76	110	3		70625,04		18,56		8092
Maximum Vacuum in demanding well # 6									481
Blower pressure side									
Thorch	7,76	100		7,6		12000,00		31,84	
	7,76	100	10		53314,98		62,73		
									12095
									23771
Blower engine power							1198,92W		

BLOWER CHARACTERISTICS

$Q_{max} = 100\,[m^3/h]$	The maximum gas flow in the ventilator
$Q_{min} = 10\,[m^3/h]$	The minimum gas flow in the ventilator;;
$P_u = -80\,[mbar]$	Required under pressure at the entrance to the plant;

Adopted blower engine power 1,5 kW

THORCH CHARACTERISTICS

$Q_{max} = 100\,[m^3/h]$	The maximum gas flow in the burner;
$Q_{min} = 10\,[m^3/h]$	The minimum gas flow in the burner;
$P_B = 120\,[mbar]$	Required over pressure at the entrance of torch;
Heat capacity of the burner	max 500 kW min 100 kW
The temperature of burning	1000- 1200 0C
Resistance time	>0,3 sec.
Connecting flange	DN100NP10

Appendix 4 Cost Estimates

ESTIMATION OF WORKS AND EQUIPMENT

Facility: MUNICIPAL SOLID WASTE LANDFILL"VRTIJELJKA" Cetinje

1. CIVIL WORKS

A) PRELIMINARY WORKS					
Pos.	WORKS DESCRIPTION	Unit	Quantity	Price per unit (EUR)	Total price (EUR)
1	GEODETIC SURVEY Marking the characteristic points	lump sum	1	5,400.00	5,400.00
2	SITE CLEANING Removal of trees, bushes, existing guardhouse etc. with transport to disposing area.	lump sum	1	2,000.00	2,000.00
TOTAL (EUR):					**7,400.00**

B) EARTH WORKS					
Pos.	WORKS DESCRIPTION	Unit	Quantity	Price per unit (EUR)	Total price (EUR)
1	MECHANICAL EXCAVATION In the ground of V and VI category, for the formation of slopes, with transport to disposing area.	m3	2,000.00	12.00	24,000.00
TOTAL (EUR):					**24,000.00**

C) TOP SOIL COVER					
Pos	WORKS DESCRIPTION	Unit	Quantity	Price per unit(EUR)	Total price (EUR)
1	EXISTING WASTE Replacement and compaction.	m3	35,000.00	3.00	105,000.00
2	DEGASIFICATION LAYER With thickness of 0,3m, composed of material with hydraulic conductivity of minimum 1x10-4m/s. Also includes procurement, delivery and layer installation.	m3	7,050.00	8.00	56,400.00
3	COMPACTED MINERAL LAYER (CLAY) With a minimum thickness of 0,3m, with hydraulic conductivity of minimum 1x10-9m/s. Also includes procurement, delivery and layer installation.	m3	11,750.00	6.00	70,500.00
4	HDPE LINER 1mm thick and a protective geotextile layer with 500g/m². Includes procurement, delivery and layer installation.	m2	23,500.00	5.20	122,200.00
5	DRAINAGE LAYER With a minimum thickness of 0,3m, with hydraulic conductivity of minimum 1x10-4m/s. Also includes procurement, delivery and layer installation.	m3	11,750.00	5.00	58,750.00
6	SOIL LAYER With thickness of 1m which can be mixed with top humus layer with minimum thickness 0,1 – 0,3m or sewerage sludge which meets conditions defined in regulation. Also includes procurement, delivery and layer installation.	m3	23,500.00	5.00	117,500.00
7	Preparation of top soil, application of fertiliser, planting grass and 20 bushes	m3	23,500.00	0.20	4,700.00
					535,050.00

D) OTHER WORKS					
Pos	WORKS DESCRIPTION	Unit	Quantity	Price per unit(EUR)	Total price (EUR)
1	WATER STORM DRAINAGE CHANNEL Includes placing concrete landfill protection channel, around landfill body, including preliminary works, excavation, preparation of sub base etc.	m'	590	45.00	26,550.00
2	DRAINAGE WELL DN1000, depth min 10m. Includes excavation works, works related to crushing of excavated stone (grain size 100-200mm).	pcs	1.00	1,500.00	1,500.00
3	POND, min. 600m3 Includes removeing of topsoil and vegetation, excavation works.	pcs	1	4,000.00	4,000.00
4	FENCE Includes procurement, transport, delivery, placing, construction of all materials that are necessary for placing fence, including gate, all concrete work, excavation, etc.	m'	650	100	65,000.00
5	GATE Construction of slide gate 1.5m high. The position includes development, transport and installation in everything according to detail.	pcs	1	1,000.00	1,000.00
TOTAL (EUR):					**98,050.00**

TOTAL COSTS:

1. CIVIL WORKS

A) PRELIMINARY WORKS	7,400.00 €
B) EARTH WORKS	24,000.00 €
C) TOP SOIL COVER	535,050.00 €
D) OTHER WORKS	98,050.00 €
TOTAL:	**664,500.00 €**

ESTIMATION OF WORKS AND EQUIPMENT
Facility: MUNICIPAL SOLID WASTE LANDFILL"VRTIJELJKA" Cetinje

2. GAS COLLECTION SYSTEM

A) GAS FLARE

Note: All items, unless specifically noted, include the supply and installation of new materials and equipment

Pos.	WORKS DESCRIPTION	Unit	Quantity	Price per unit(EUR)	Total price (EUR)
1	BLOWER Minimum engine power of 1.5kW	pcs	1	700	700.00
2	TORCH Minimum capacity of burning 10 Nm3/h Thermal power of 100- 500kW Connecting flange DN100 Electrical device for firing with the transformer 14000V	set	1	34,250.00	34,250.00
3	Radial gas fan capacity of 100 m3/h, working differential pressure 80 mbar, connecting dimensions DN100 Electric fan power 1,7 kW, EEx execution, IP54, 3x400/230V 50 Hz,protection 40A- slow	set	1	1,620.00	1,620.00
4	Flame arrestor with an automatic regulating valve, EN12784, DN100NP10	pcs	1	1,250.00	1,250.00
5	Pipe vibration compensator, DN100NP10	pcs	2	256.00	512.00
6	Gas shut valve, DN100NP10	pcs	2	680.00	1,360.00
7	Condensate separator with integrated filter to remove contaminants	pcs	1	850.00	850.00
8	Transitional insulating flange connection PEHD/St 35.6, DN100NP10	pcs	1	150.00	150.00
9	Flanges of steel St 35.6, DN100NP10	pcs	10	36.00	360.00
10	Consoles	kg	40	6.00	240.00
11	Gas temperature gauger 0-100 0C Sensor PT100, EEx Analog signal output1-20 mA Connected control system	set	1	180.00	180.00
12	Gas pressure gauger Sensor piezo-resistant EEx perfomance Analog signal output1-20 mA Measuring range 0-350 mbar	set	1	1,850.00	1,850.00
13	Pipe fittings St 35.6, 1,5D, DN100	pcs	5	32.00	160.00
14	Steel pipes DIN2448, DN100 (Ø114,3x3,2)	m	16	98.00	1,568.00
15	Galvanized strip for system grounding≠3x 25mm	m	40	12.00	480.00
16	Gas valves on ports for sampling and manual measurement of pressure, DN20NP10	pcs	4	56.00	224.00
17	Manometer measuring range of 0-350 mbar, Ø120, R1/2"	pcs	1	186.00	186.00
18	Vakummetar measuring range of 0-100 mbar, Ø120, R1/2"	pcs	1	225.00	225.00
19	Preparatory-final works	lump sum	1	14,000.00	14,000.00
TOTAL (EUR):					**60,165.00**

B) MAIN PIPE SYSTEM					
Pos.	WORKS DESCRIPTION	Unit	Quantity	Price per unit(EUR)	Total price (EUR)
1	HDPE pipe for transporting landfill gas to the gas flare Material PEHD Pipes pass after the closure of landfill body with multi-barrier layer before placing soil layer.				
	DN90 (Ø90x6,5, EN264, DIN8074)	m	280	8.00	2,240.00
	DN110 (Ø115x6,5, EN264, DIN8074)	m	90	10.50	945.00
2	Fitting PEHD Material PEHD Electro-Inductor junction				
	DN90 (Ø90x6,5, EN264, DIN8074)	pcs	16	64.00	1,024.00
	DN110 (Ø115x6,5; EN264, DIN8074)	pcs	12	52.00	624.00
3	T piece Material PEHD DN110 (Ø115x6,5; EN264, DIN8074) Electro-Inductor junction	pcs	1	125.00	125.00
4	T piece Material PEHD DN110/DN90 (Ø115x6,5/Ø90x6,5; EN264, DIN8074) Electro-Inductor junction	pcs	10	120.00	1,200.00
5	Flange Material PEHD DN110NP10	pcs	16	36.00	576.00
6	Flange Materijal PEHD DN90NP10	pcs	16	98.00	1,176.00
7	Set of screws with mainstream and pads				
	M16x65 8 screws	pcs	5	14.00	70.00
	M16x75 8 screws	pcs	8	14.00	112.00
8	Costs of testing and putting into operation including: - functional and security testing installation and regulation of parameters installation	lump sum	1	1,250.00	1,250.00
TOTAL (EUR):					**9,342.00**

C) GAS COLLECTING WELLS					
Pos	WORKS DESCRIPTION	Unit	Quantity	Price per unit(EUR)	Total price (EUR)
1	Regulative valve Material PEHD DN90NP10 Manuel regulative valve	pcs	8	126.00	1,008.00
2	Sealing threaded connector Material PEHD R3“, 30 mm With rubber gasket	set	8	25.00	200.00
3	Protective cap Material PEHD DN90NP10 Thread R3“	pcs	8	12.00	96.00
4	Pipe segment for gas collection Material PEHD DN110(Ø115x6,5; EN264, DIN8074) Perforated; l= 3000 mm; Both side thread R4“, 30 mm;	pcs	25	18.00	450.00
5	Threaded connector Material PEHD R4“; 30 mm;	pcs	24	12.00	288.00
6	Flange Material PEHD DN90NP10	pcs	8	36.00	288.00
7	Manhole with the cover Material PEHD Dimensions 1000x1000 mm	pcs	8	185.00	1,480.00
8	Gabion 1x1x1 m	pcs	8	56	448.00
	Gravel protection	m3	105	55	5,775.00
TOTAL (EUR):					**10,033.00**

TOTAL COSTS:

2. GAS COLLECTION SYSTEM

A) GAS FLARE	60,165.00
B) MAIN PIPE SYSTEM	9,342.00
C) GAS COLLECTING WELLS	10,033.00
TOTAL:	79,540.00

ESTIMATION OF WORKS AND EQUIPMENT
Facility: MUNICIPAL SOLID WASTE LANDFILL"VRTIJELJKA" Cetinje

3. ELECTRICITY SUPPLY

Pos.	WORKS DESCRIPTION	Unit	Quantity	Price per unit(EUR)	Total price (EUR)
1	ELECTRICAL CABLE WITH ASSOCIATED EQUPMENT Instalation of electrical cable of minimum capacity 10kW, approximate length 400m. All equipment is to be ex-proof and secured from any possible impact derived from dumpsite gas.	lump sum	1	12,000.00	12,000.00
TOTAL (EUR):					**12,000.00**

ESTIMATION OF WORKS AND EQUIPMENT

1) CIVIL WORKS	664,500.00 €
2) GAS COLLECTION SYSTEM	79,540.00 €
3) ELECTRICITY SUPPLY	12,000.00 €
TOTAL:	756,040.00 €
General Items	50,000.00 €
Grand Total:	806,040.00 €

Appendix 5 Technical Specifications

1 Rehabilitation and closure works of the dumpsite

The contractor shall perform the detailed design for the rehabilitation measures:

All necessary detailed designs shall be performed by the Contractor and submitted to the Engineer for approval. The Contractor shall further obtain all relevant approvals and permits from local authorities, owners, etc. All detailed designs shall comply with relevant Montenegrin legislation and regulations and EU Directives and shall be prepared according to the specifications and requirements given in this Appendix.

The contractor shall perform the works for the Rehabilitation including but not limited to the following:

1. Preliminary Works

2. Civil Works

3. Other works

4. Levelling, excavation, filling, spreading and compaction of waste and similar, according to the design, maximum slope (3H: 1V)

5. Waste and similar, levelling-excavation, filling, spreading, compaction according to the design.

6. Dumpsite Surface sealing system (Supplying, laying out and compaction)
   - Gas collection layer (landfills for non-hazardous waste), with minimum thickness of 0.3 m, composed of material with hydraulic conductivity of minimum 1 x 10^{-4} m/s (crashed stone),
   - Compacted mineral layer (clay), with a minimum thickness of 0.3 m, with hydraulic conductivity ≤ 1 x 10^{-9} m/s,
   - 1 mm thick HDPE liner impermeable synthetic material
   - Protective geotextile layer 500 g/m²
   - Drainage layer, with a minimum thickness of 0.3 m with hydraulic conductivity of minimum 1 x 10^{-4} m/s (crashed stone),
   - Soil layer with thickness of 1 m which include the top humus layer with minimum thickness 0.1 - 0.3 m or sewage sludge which meets conditions defined in regulation.

7. Gas Collection System

Gas Collection shall be active system, installed for the collection of gas generated from the waste and shall include the following:

- Gas collection wells
- Pipe network
- Blower and
- Gas flare.

Purpose of the gas collection wells is gas extraction from the waste body. Gas collection wells are vertical perforated HDPE pipes, coated with a protective

layer of gravel to prevent the closure of perforations with waste material. The active radius of gas collection wells is approximately 30m. For the gas collection from the "Vrtijeljka" dumpsite eight gas collection wells have to be installed. Anchoring of each gas collection well in the initial phase of installation is performed using gravel gabions.

Gas collection wells
- Eight drillings in waste material (diameter 600 mm)
- Supply and installation of the complete well, non-perforated extraction pipes (HDPE, DN100, PN10)

Pipe network
- Supply and laying of DN90 HDPE, PN10 non-perforated gas extraction pipes
- Supply and installation of perforated gas collection pipes (HDPE, DN110, PN10)
- Supply and laying of DN100, PN10 non-perforated gas transmission pipes
- Supply and installation of flange DN100NP10 and DN90NP10
- Supply and installation of gas separator condensate.

Blower
- Supply and installation of blower with engine power of 1.5kW

Gas flare
- Supply and installation of burner (min. capacity 10Nm3/h) with the connecting flange and electrical devise for firing with the transformer
- Supply and installation of radial gas fan capacity of 100 m3/h
- Supply and installation of flame arrestor with an automatic regulating valve, EN12784, DN100NP10
- Supply and installation of pipe vibration compensator
- Supply and installation of condensate separator
- Supply and installation of valves.

8. Landscaping
9. Monitoring during the defects notification period of 24 months as defined in Chapter 9
10. Storm Water Channel
11. Establishing of fence and Gate

2 Preparatory Works

Preparatory works include works described below.

2.1 Setting-out the Site

The Contractor shall in co-operation with the Engineer set out the total site to be used for marking the property lines shall be performed by a chartered surveyor hired by the Contractor. The points marking the property lines of the site shall be secured and kept intact during the construction period. Besides this Clause 4.7 (FIDIC Yellow Book.) applies.

The Boundary of the of the site is presented on drawing no. 003. and includes the following parcels: 2253/6, 2253/7, 2253/8, 2253/9 and 2253/10,. The footprint of the rehabilitation dumpsite shown on drawing no. 003 is the Consultant's proposal. However the Contractor is free to extend or reduce the area as long as the works including the fence is inside the mentioned parcels. The area not used for rehabilitation of the dumpsite inside the boundary can be used by the Contractor for workers camp, stockpiling of materials, interim roads etc. however the Contractor shall keep the working area as small as possible and all areas used by the Contractor shall be re-established to the level as it looked before commencement of the works.

Parcel 2201 is outside the boundary of the site however waste has been dumped on the area. All waste down to original ground level shall be removed from parcel 2201 and re-disposed at the rehabilitation dumpsite. The Contractor's working area on parcel 2201 is the area with waste plus a maximum 10 m zone from the edge of dumped waste. The working area shall be set-out by a surveyor (hired by the Contractor) and approved by the Engineer.

2.2 Supplementary Surveys

2.2.1 Geodetic Survey

An existing topographical survey of the site to be rehabilitated is given as an appendix to these Technical Specifications. The Contractor shall assess the existing topographical survey. If the Contractor finds it necessary to have additional topographical surveys, he will carry out these surveys at his own expanses. If the Contractor finds no additional surveys necessary as the result of his assessment of the existing topographical surveys, this shall mean that he takes and accepts all responsibilities regarding the accuracy, validity and all other aspects of the existing topographical surveys.

If additional topographical surveys are necessary as a result of his assessment of the existing surveys, the Contractor shall perform an overall topographical survey of the site. The topographic survey shall be carried out such that it covers the site and adjacent areas in coordination with the Engineer, once prior to commencement of the construction activities and once following completion, with a survey Grid of 10 m.

Cross sections shall also be prepared at a nominal spacing of 20 m.

The survey shall include the submission of drawings in hard copy (5 copies) and also in soft-copy AutoCAD 2010 Format. The points (3d) surveyed shall be delivered as an ASCII file.

2.2.2 Geotechnical survey

An existing geotechnical survey of the site to be rehabilitated is given as an appendix to this Technical Specifications. The Contractor shall assess and validate the existing geotechnical survey.

The interpretations and conclusions included in the geotechnical report are performed by "Geotehnika Montenegro d.o.o." and data included are only valid for the specific sample and date. The Employee does not take any

responsibility for the correctness of this interpretation and the Contractor shall make his own interpretation of the geological situation.

If the Contractor finds necessary to have additional geotechnical surveys, he will carry out these surveys. If the Contractor finds no additional surveys necessary as the result of his assessment of the existing geotechnical surveys, this shall mean that he takes and accepts all responsibilities on the accuracy, validity and other aspects of the existing geotechnical surveys. If additional geotechnical surveys are necessary as the result of Contractor's assessment of the existing surveys, the Contractor's survey shall comprise minimum one test pit or drilling per 1,000 m^2. The Contractor shall decide in co-operation with the Engineer what equipment to be used for the investigations and if deemed necessary to decide what action to be taken as well as which surveys to perform to verify and/or supplement the quality and correctness of the geotechnical data presented in the geotechnical survey report.

2.3 Office Container

An office container shall be supplied on the site for the Engineer's team complete with furniture, sanitary facilities (incl. toilet and washing facilities), and air conditioning for the exclusive use of the Engineer's staff for the duration of the contract and as defined under the General Technical Specifications.

The Contractor will be responsible for daily cleaning and maintenance of all facilities and cover the respective running cost.

All the equipment and furniture shall be the property of the Contractor after the handover.

2.4 Clearance of the Site

Existing structures, trees, tree stumps and bushes inside the site boundaries shall be uprooted and removed before commencement of the rehabilitation works.

3 Earth Works and Transfer of Waste and Methodology

3.1 Transferring of Waste from the access road

The waste illegally dumped near the access road, beginning from the main road E80 Cetinje to Budva to the landfill, shall be collected, loaded, transferred to the site by trucks and shall be re-dumped to the designated filling areas. After collection and loading of waste, the contractor shall leave the road sites clean. The distance to the designated dumping site is approximately 500 meters.

3.2 Dumpsite profile, Earthworks

The rehabilitation of the dumpsite shall be re-graded to ensure long-term stability of the dumpsite body. Basically the future profile of the dumpsite will be a pyramid with slopes of max. 3H:1V. In order to establish this profile some of the waste has to be excavated, loaded, transported and re-tipped at the

appropriate dumpsite location and compacted with a minimum of 3 passes by a heavy steel wheel compactor (min 25 tonnes). During re-tipping each waste layer (maximum height 1.0 meter) shall be compacted before loading on the top of it.

All waste that needs to be re-disposed shall be unloaded and compacted in horizontal layers or with an inclination away from final slopes (to optimise stability). After final profiling of the surface (slopes) the waste shall be compacted with minimum 3 passes by a heavy steel wheel compactor.

The volume and gas calculations and the assessments were prepared in September 2012 and are given in this Report. The calculations were made to include 1 year (assumed period till commencement of the rehabilitation works) of waste quantities subsequently delivered to the dumpsites up to the commencement of works.

Any additional waste quantities subsequently delivered to the site up to this date will have to be considered.

The Earth works shall include but not be limited to:

- Excavation, loading, transportation and re-dumping of waste, debris and local soils
- Levelling, spreading, compacting and filling of waste, debris and local soils. The material shall be filled according to the profile given in the design (slopes up to 3H:1V)
- Establishment of surrounding storm water channel

Requirements, tolerances, and check:

The tolerance, requirements, and checks for fill material to the designed base for the geological barrier are:

Fill Requirements and Tolerances for final surface of waste after levelling and compaction

Parameter	**Requirements**		**Tests**
	Value	**Tolerance**	**Nos.**
Vertical alignment:			
- Level at slopes	at the test point	+/- 0.10 m	25 per 10,000 m^2
- Evenness (under a 4 m straight edge)	at the test point	0.05 m	25 per 10,000 m^2

All excavated surfaces and test results shall be inspected and approved by the Engineer before the next surface covering layer is installed.

4 Surface Sealing and Encapsulation System

An appropriate surface capping system for the rehabilitation of existing dumpsite shall be adapted to the local Cetinje conditions. Typical cross-sections of surface sealing systems and drawings are given in the conceptual design.

- Drawing no.1, Site map,
- Drawing no.2, Existing state,
- Drawing no.3, Elevation plan,
- Drawing no.4, Longitudinal profile cl1,
- Drawing no.5, Longitudinal profile cl2,
- Drawing no.6, Longitudinal profile cl3,
- Drawing no.7, Details.

4.1 Surface Sealing

The basic function of the cover layer is prevention of potential hazard to the environment, and it determines the nature of the final cover of the dumpsite. Final cover of the dumpsite shall be designed and constructed in order to:

- prevent storm water filtrating into the waste;
- prevent gas emissions by a controlled gas collection;
- prevent erosion;
- support vegetation.

The surface sealing shall be made in accordance with the provisions of the best known practice for rehabilitation of old landfills-dumpsites and in harmony with the EU Directive 1999/31/EC.

4.1.1 Surface Sealing with Active Gas System with Geo-synthetic Layer

A Landfill Surface sealing system shall be designed and constructed consisting of the following layers:

- Gas collection layer (landfills for non-hazardous waste),
- Compacted mineral layer (clay),
- 1 mm thick HDPE liner impermeable synthetic material
- Protective geotextile layer 500 g/m²
- Drainage layer,
- Soil layer with thickness of 1 m.

4.1.2 Gas Collection Layer

A gas collection layer with minimum thickness of 0.30 m with hydraulic conductivity of minimum 1 x 10^{-4} m/s, formed by crushed gravels with the grain size of 0-32 mm shall be installed and used as a levelling layer and to facilitate gas collection. This layer shall be mechanically spread and graded.

4.1.3 Mineral Clay Layer

General

As one of the components of surface sealing system, mineral clay shall be used. The mineral material shall satisfy permeability requirements such as hydraulic conductivity of kf$\leq 10^{-9}$ m/s.

The clay characteristics shall be documented by soil analysis (grain size distribution and hydrometer test) minimum one sample per 500 m³ of clay and by minimum one permeability test per 3,000 m³ clay.

Laying Out of Clay Liner

The 0.3 m clay shall be laid out in one layer and 95% standard proctor compaction shall be provided. The clay material shall be applied on proctor test and the optimum water content shall be determined accordingly.

One compaction test per minimum 1,000 m² (One test includes one proctor test and minimum 5 troxler tests)

Minimum height of the compacted clay layer shall be 0.3 m.

4.1.4 Geo-synthetic Liner (Geomembrane and Geotextile)

The mineral clay layer shall be covered with a flexible membrane liner consisting of 1 mm high density polyethylene (HDPE) to ensure protection of waste body from the storm water as well as to prevent gas release. To protect the flexible membrane from piercing and rupture, a layer of geotextile material (500 g/m2) shall be laid over the membrane. The selected manufacturer shall be required to provide certified data on the mechanical strength, chemical resistance and general durability of the material.

Installation of Geo-synthetic Liner

The synthetic membrane shall be installed, welded and tested according to relevant requirements to ensure integrity of the liner. The welds shall be subject to permeability testing. The density of the membrane shall be >0,94 kg/m2.
The Contractor shall submit a control program for delivery and installation of the HDPE liner for the approval of the Engineer. The program shall include as minimum:
- Type of liner (with spec.)
- Warranty
- Field Quality assurance plan (Testing, frequency, location etc.)
- Repair procedures

4.1.5 Water Drainage Layer

Water drainage layer with minimum thickness of 0.30 m, with hydraulic conductivity of minimum 1 x 10^{-4} m/s, made up of crushed gravels with grain size of 0-32 mm shall be installed to provide run-off water drainage on the geo-synthetic liner.

The purpose of installing this layer is to prevent water accumulation at the top layer that might cause surface erosion and to avoid water pressure on the liner system.

Outlet to the surface water drain shall be via an erosion protection layer of minimum 0.5 m thickness formed by crushed stones with a grain size of 32/64 mm.

4.1.6 Vegetative soil layer

The top layer shall be vegetative soil of 1m thickness, serving to prevent erosion and improve the landscape quality. The upper part (re-cultivation layer) can include the top humus layer with minimum thickness 0.1 - 0.3 m or sewage sludge which meets necessary conditions for vegetation to grow. Short-rooted, self-spreading plants capable of growing on poor and contaminated and reclaimed soil shall be selected from among local species subject to approval of the Engineer, to provide a vegetation cover. The remaining 0.9m to 0.7m will act as a protection layer.

The vegetative soil layer shall have a minimum 3 % slope to facilitate run-off, and any future settlements shall be repaired without delay.

Borrow pit

Material for the top soil layer shall be obtained from any source proposed by the Contractor and approved by the Engineer. The Contractor shall be responsible for all costs and permitting procedures necessary to obtain the required material from such source, including supply, loading, transportation, placing and testing.

Material specification

The 1.0 m thick top soil layer including the re-cultivation layer shall meet the requirements for materials, placement, testing and checking, as indicated in the following paragraph.

The soil layers must be of two categories, the uppermost layer must be of a higher quality. The Soil and the Vegetal Soil shall consist of a real rocky material to avoid any erosion. Collectively they must fulfil the following physical and chemical specifications:

Physical and Chemical Characteristics of the Soil

PHYSICAL CHARACTERISTICS				
TYPE	***Granulometry***		***Fine Soil***	
	Maximum size	*Coarse materials*	*Clay*	*Sands*
Vegetal Soil	0% > 25 cm	< 60%	< 25%	< 30%
Soil	0% > 25 cm	< 75%	< 15%	< 20%

CHEMICAL CHARACTERISTICS					
TYPE	***Fine Soil***		***N***	***P (ppm)***	***K (ppm)***
	Organic matter	*pH*			
Vegetal Soil	> 6%	6 – 7,5	>0.32 %	> 35	> 240
Soil	> 3.5%	> 6	> 0.2 %	> 25	> 180

The Contractor shall provide physical or chemical analysis (for approval by the Engineer) to demonstrate that the materials are compliant with the specifications requirements. Moreover, the Engineer will have the power to reject those soils that do not comply with these specifications. An analysis of all the above parameters will be carried out at intervals of 300 m^3.

5 Storm Water Control System

Depending on the topography it is necessary to drain the rain falling on the waste body as well as the storm water running from the catchment area outside the dumpsite boundary. In both cases, water needs to be drained in a controlled manner. Therefore the storm water falling to the Vrtijeljka dumpsite shall be drained using storm water channels.

5.1 Storm water channel

Storm water drainage channel shall be constructed in accordance with the drawings.

The storm water channels shall be concrete in trapezoidal shape and with a cross section area that comply with 1.5 m width at top and 0.5 m at the bottom and a depth of min. 0.5 m. The storm water channel will be installed

outside the perimeter embankment and where necessary on the landfill body itself. A minimum slope of 0.1% towards the surface water pond is required (depth of channel can locally be more than 0.5 m). Details of the storm drainage channel cross sections are given in the attached conceptual design drawings.

The storm water channel can either be an in-situ cast concrete structure or precast concrete elements. If precast elements are used they shall have a flexible and tight connection with tongue and groove (key and slot).

Concrete water channels shall be reinforced.

5.2 Storm water collection pond and drainage well

Collected storm water shall be drained to the pond to be constructed as shown on the attached drawings.

The Contractor shall remove topsoil, vegetation etc. for exposure of the karst conditions (optimise seepage capacity) in the lowest lying area downstream of the rehabilitated dumpsite at an area large enough to ensure future seepage of surface water from the entire catchment area. The surface area of the pond shall be minimum 600 m².

To ensure seepage for maximum daily rainfalls, a minimum of one drainage well shall be constructed. The Contractor shall excavate a well with diameter of 1m and depth of 10m, and deeper if necessary. Excavated material shall be crushed in place (grain size 100-200mm) and thrown back into the well.

The Contractor shall make his own calculations in order to find out the amount of rainfall and seepage capacity to calculate the surface area (minimum 600 m^2) and volume of the storm water drainage pond as well as number and volume of drainage well(s). The Contractor shall ensure that during heavy rainfalls water level will not rise up to the rehabilitated waste body. Before starting calculations the Contractor shall have approval of the Engineer on the rainfall intensity, duration and frequency that his calculations will be based on. As result of his calculations the Contractor will decide on dimensions of the storm drainage pond and number and volume of drainage wells he will construct, subject to the approval of the Engineer.

6 Landfill Gas Control System

In general all works associated with dumpsite gas are considered a specialist field, and shall be undertaken only by personnel with the appropriate level of technical knowledge and experience. The experience of the staff undertaking the task must be formally and fully demonstrated. Where the Contractor does not possess this experience in-house, it can usually be obtained from the equipment supplier.

6.1 Gas Extraction Wells

Within the active gas collection system, vertical gas collection wells shall be drilled and installed in the dumpsite body to extract the landfill gas. The wells

shall be installed, each with an effective radius of approximately 30 m. The construction of the gas extraction wells shall include but not limited to:

- Drilling of 8 wells with a diameter of 600 mm
- Filling the well d_{ia}= 600 mm with 16-32 mm, max. 20 % calcareous gravel
- Filling the well d_{ia}= 600 mm with mineral clay in the upper section (length 0.90 m) ($k \leq 10^{-9}$ m/s)
- Installation of a d_{ia}= 110 mm PN 10 vertical HDPE gas collection pipe in the centre of the borehole
- Installation of a well head and connection of the well head to the HDPE transmission pipe via a d_{ia}=90 mm butterfly valve and a flexible tube (stainless steel)
- Connection of the geo-membrane and protective geotextile in the gas extraction pipes to ensure 100% airtightness (To avoid intrusion of air into the gas extraction system).

6.1.1 Drilling and Filling of Gas Wells

The wells with 600 mm diameter shall be drilled into the re-graded dumpsite body. In each well, an extraction pipe (HDPE, PN 10, DN 110) will be installed vertically. The extraction pipe shall be installed as perforated from the waste body until the levelling layer and as non-perforated in the upper section (length 3 m). The extraction pipe shall be centred in the well with special dedicated, centring device. The space between well and the pipe shall be filled with max 20 % calcareous gravel granular 16/32 mm, and sealed with mineral clay in the upper section (length 0.90 m). The upper section of the well will be fitted with a flanged well head. The wellhead shall be fitted with a 2.54cm (1") ball valve, flanged onto a butterfly valve (DN 90), and followed by a flexible stainless tube (length minimum 1.00 m).

The dumped waste is municipal household waste, as well as construction and demolition waste, chisel work might therefore be necessary. The Contractor shall be aware of the difficulties drilling in such material (reinforced demolition material, big stones etc.) as well as the necessary safety measures, particularly regarding the danger of explosions (Methane detection equipment).

Some of the wells are located in areas with slopes of maximum 3H:1V. All measures for reaching the drilling location and to secure the rehabilitation site shall be included. The contractor shall familiarise himself with the on-site conditions regarding the location of the wells and the other local conditions. The location of wells given in the attached drawings are indicative only and final locations of wells shall be defined in agreement with the Engineer (equally spread over the dumpsite area but mainly in areas with high waste thickness).

The depth of the drillings may reach up to 14 m in some locations. Nevertheless the former topography below the dumpsite is as yet unknown, and therefore the Contractor shall provide a reasonable estimation of the thickness of the dumped waste at the well location and the depth of the drilling. Based on these estimations, the depth of the drilling will be fixed in agreement with the

Engineer. As a result, the drilled material has to be monitored continuously for any indications that the natural ground has been reached where the drilling has to stop.

The depth of the wells shall be proven and full documentation of the drilling work shall be prepared.

All costs for the operation of the equipment, as well as all cost for the health and safety measures shall be included in Contractor's prices.

6.2 Gas flare

For the controlled burning of landfill gas a flare is designed with a closed chamber, high efficiency combustion. Burner must be equipped with the flame monitoring via UV photocell and inductor system for ignition. Inclusion of the pilot should be done using double electrode at high voltage. In the case of a missing pilot flame (which can be observed through the UV photocell) gas flow should be closed. Only after the confirmed presence of the pilot the main stream should be re-activated. The pilot line shall be equipped with on/off pneumatic and appropriate blocking flames. Main gas flow can be stopped with servo-command valve that is pneumatically connected with the designated alarm systems. In front of the burner flame arrestor should be installed. Burner consists of a combustion chamber that is heat resistant (with ceramic fibres or similar materials). Height of the burner must completely cover the flame. Automatic control of combustion has to be ensured. Air flow required for the combustion should be regulated with the sensor installed.

Gas flare, blower, switchboard and condensate trap shall be placed on a reinforced concrete platform.

6.3 Main pipe system

Main pipe system for gas collection from the waste consists of different non-perforated pipes i.e. gas extraction pipes HDPE DN90 PN10, gas collection pipes HDPE DN110 PN10 and gas transmission pipes DN100 PN10.

All pipe connections shall be welded using a butt-weld or electro-fitting welding techniques. Joints, butterfly valves and bends shall be connected with flanges. All fittings used for the main pipe system shall be produced and approved by the manufacturer of the rehabilitation pipe work.

Before delivery of pipes to the site, the Contractor shall submit information about the manufacturer, including a declaration and certificate for the pipe specifications and details of his quality assurance procedures for the approval by the Engineer.

Main pipe system shall be installed in an excavated trench in the soil layer of the top cover system. Pipes shall be laid in a sand bed and backfilled with sand.

The works shall include but are not limited to:

- Supply, and delivery of pipes

- Excavation of the trench for the pipes and levelling of the base with a minimum 0.10 m of sand or more if required by the pipe manufacturer, installed at a depth of up to 0.85 m.
- Installation of the pipes including gas tight proof assembling (welding).
- Back filling with sand surround to a depth of at least 0.30 m above the top of the pipes or more if required by pipe manufacturer.
- Manual compaction of the sand. Back filling and compaction of the rest of the trench with suitable soil materials or sand where necessary.
- Pressure tests of the installed pipes before backfilling of the trenches.
- Incidentals necessary to complete the work.

Before back-filling of the trenches the collection and transmission pipes shall be pressure tested, the protocol of the tests shall be submitted to the Engineer for approval.

Before delivery of HDPE pipes to the Site the Contractor shall submit information regarding the manufacturer and his respective processes and quality assurance, including a declaration and certificate for the pipe performance for the approval of the Engineer.

6.4 Gas Condensate Trap

The condensate trap shall be installed onto gas collection pipes prior the blower. The trap shall be used to prevent condensate water inside the gas transmission pipes. The collected water inside the trap shall be discharged via the drain holes of the trap.

6.5 Electrical connection to grid

The Contractor shall provide relevant conditions, design and construction works for the installation of electrical cable, 10kW capacity, with all following equipment (e.g. automatic lightening protection) to supply blower and gas flare with the electricity. Cable should be connected to the grid at closest substation, all according to existing conditions subject to approval of the Engineer.

Electrical equipment located in fire hazard areas „1" and „2" shall be ex-proof, in compliance with the requirements of standard IEC 60079.

The Contractor shall provide certificates to the Engineer to prove that purchased cable and equipment are ex-proof.

6.6 Operation and taken-over of gas collection and treatment pant

Prior taken-over by the Employer the contractor shall carry out a training session for the Employers staff and submission of documentation.

TRAINING PROGRAMME:

- The Contractor shall perform the necessary instruction during the installation of the gas collection and treatment system including maintenance of the mechanical parts
- The Contractor shall foresee at least 3 working days for training of staff during installation, calibration and commissioning of the gas collection and treatment plant

- Staff appointed by the Employer will participate during the whole installation, calibration and commissioning process as "on the job" training

SERVICE:

- The Contractor shall perform two service visits, one and two years after taken-over by Employer
- The service visit shall also include a 1-day "brush-up" course of the operators
- A total of 1 full working days are envisaged for the service visit
- The Contractor shall include this service visit in his quotation

DOCUMENTATION AND MANUAL INSTALLATION INSTRUCTIONS:

- The Contractor shall include all necessary manuals for operation and maintenance of the gas collection and treatment system
- 4 copies in Montenegrin language and 2 copies in English language shall be delivered

7 Landscaping

Landscape concepts shall be prepared by the Contractor and submitted to the Engineer for approval.

7.1 Plantation

The dumpsite area shall be planted with local species of shrubs. To prevent the top surface from erosion, a minimum of 20% of the rehabilitated dumpsite shall be covered with trees/shrubs and the rest by grass. The top layer shall be vegetative soil of 1m thickness, serving to improve the landscape quality. Short-rooted, self-spreading plants shall be selected from among local species to provide a vegetation cover. The vegetative soil layer shall be given as min. 3% slope to facilitate run-off, and any future settlements shall be repaired without delay.

7.1.1 Trees and Shrubs

Trees and shrubs shall be of the species proposed by the Contractor and approved by the Engineer and shall be of the best quality and free from disease. They shall be young stock or in the case of shrubs may be established seedlings or cuttings. All must be sufficiently mature to survive transplanting from the supply nursery. The root systems of all plants shall be maintained intact in the soil in which they have been grown and may be supplied in containers.

7.1.2 Irrigation

After planting of native tree and shrub species they shall be irrigated twice and thereafter only as required.

7.1.3 Maintenance

All new plants shall be maintained after planting. This shall take the form of irrigation, restacking, pruning, weeding, tilling, etc. to ensure sufficient growth is achieved by all plants up to handover to the satisfaction of the Engineer. All

new plants shall be protected to prevent damage from workers, builder's plant and equipment.

8 Fence and Gates

8.1 Fence

The entire rehabilitated site shall be fenced. The boundary fence shall be constructed according to the specifications given below and as shown in the drawing.

The fence shall consist of a galvanized steel mesh (standard 50 x 50 mm) and one row of barbed wire above the steel mesh. Height of steel mesh shall be 1.90 m, and the total height of the fence shall be 2.05 m.

Fence posts at 2.50 m intervals shall be pre-cast concrete, dimension 13 x 13 cm. The steel mesh shall be secured to the posts at convenient intervals along the height of the posts. Fence shall be supported by fixing to 3 wires strung between posts.

Furthermore the steel mesh and posts shall be embedded in the concrete foundation.

General grades of concrete foundation:
Concrete: BS16

8.2 Gates

Two-part wing gates are to be installed at the entrance to the dumpsite, giving an overall width 4 m.

The gates are to be manually operated and to be fixed into ground both in locked and open position. Height of the gates shall be 1.90 m and with barbed wire on top as for the fence.

Construction materials: Galvanized tubular steel frame and galvanized steel mesh as used for the fence. Gate posts shall be galvanized tubular steel. The gate shall be a standard type gate where spare parts easily can be procured.

The gate shall be equipped with an integrated lock and 4 sets of keys shall be delivered to the Employer at taken over.

General grades of concrete foundation:
Concrete: BS16

Contractor shall prepare workshop drawings subject to the approval of the Engineer.

9 Monitoring and Assessment

The Contractor shall monitor and maintain the rehabilitated site after completion of works, during the defects notification period of 24 months. Maintenance and monitoring shall in general cover the whole rehabilitated site.

Maintenance and monitoring of the site shall in minimum cover but not be limited to the following:

- Maintenance and monitoring of the gas system,
- Maintenance and monitoring of the slopes, repair of erosion ditches,
- Maintenance of the landscaping, including re-seeding as necessary,
- Maintenance and cleaning of surface water drainage channels including repairs as necessary,
- Maintenance and monitoring of the drainage pond, cleaning and repairs as necessary,
- Monitoring of leachate as per mitigation measures of the EIA,
- Monitoring of other measures that will be required as the result of the EIA.

9.1 Monitoring

Environmental Impact Assessment Study (EIA) shall define precise measures for the monitoring and shall define locations for the necessary sampling. These measures will be mandatory for the construction and aftercare works.

9.2 Health and Safety risk assessment

Before commencing the activities on site, a Health and Safety risk assessment shall to be submitted to the Engineer. The assessment including landfill gas evaluations shall be an on-going process throughout the whole duration of the activities.

9.3 Project Implementation

All design, facilities, materials and workmanship shall comply with the requirements of the latest revisions and with up to-date amendments of the appropriate standards of ISO, EN, DIN, IEC, BS, ASTX and CE marking; or alternatively, should none of these prove applicable, with the standards of best practice.

In the event that a Montenegrin national specification, technical standard, building, construction and environmental regulation is more restrictive than the specific standards listed in these specifications, the Montenegrin standard or regulation shall take precedence.

If the Contractor should wish to supply material or execute work in accordance with an alternative national standard or international specification, he shall give full details of his proposal in writing to the Engineer together with a certified English translation.

Any materials or workmanship not fully specified herein, or covered by the Standards, Codes or Manuals, shall be of a type and quality as to produce first class work. In such a circumstance the Engineer shall determine whether or not

all or any of the materials offered or delivered to site are suitable for use in the works. The Engineer's decision in this respect shall be final and conclusive.

9.4 Wear and tear and spare parts kit

Spare parts, sufficient for a 12 months period operating of all equipment installed shall be handed over by the Contractor immediately before Taking-Over. The Contractor shall, based on the manufacturer's recommendation, determine the required spare parts for all equipment and prepare a list of spare parts.

9.5 Documentation

9.5.1 Test Certificates

All test certificates and inspection records (including records from suppliers or external testing laboratories) shall be clearly identified with the part of the works to which they refer to and shall include information required by the appropriate Reference Standard or Specification.

Test certificates shall as a minimum include the following:

- Date of test,
- Tested installation/equipment,
- Description of test,
- Result of the test,
- Comments and Name of person executing the test.

The timing for submission of such certificates is as follows:

- Manufacturer's and supplier's test certificates shall be submitted not less than seven (7) days prior to the time that the material, or equipment are to be factory tested or are ready for shipment,
- Certificates of tests carried out during the installation works or on completed parts of the permanent installation shall be submitted within fourteen (14) days of the completion of the test.

Three (3) copies (in English and Montenegrin) of the Test Report with documentation of all tests carried out shall be submitted to the Engineer as soon as possible after the Tests on Completion.

9.5.2 Contractor's Drawings

The Contractor shall prepare and submit to the Engineer for approval within 45 days of the Commencement Date 4 copies of drawings prepared. The drawings shall be fully dimensioned to illustrate the proposed final rehabilitation of the dumpsite, i.e. to show the following:

- All equipment.
- All pipe connections,
- All construction works in detail.

9.5.3 Operation and Maintenance Manuals

Operating and maintenance instructions as well as Technical documentation shall be submitted in English and Montenegrin.

9.6 Inspection, Testing and Commissioning

9.6.1 Inspection and Testing during Manufacture

The plant (gas collection system with all equipment installed) shall be subject to inspection, examination and testing during manufacture in accordance with the Conditions of Contract, to demonstrate that it complies with the Specifications and that the performance is suitable for the intended purpose. Plant shall not be dispatched from the manufacturer's works until notification has been received from the Engineer.

9.6.2 Works Tests

Major equipment (E.g. flare, blower, switchboard) shall prior to shipping be tested in the factory and/or in the Contractor's workshop for function, performance and faults. The Engineer shall be notified about all the planned tests, so he can attend the tests if he should desire so.

The Engineer may require works test of other equipment in addition.

9.6.3 Check before Shipping

The Contractor shall check all equipment delivered under the Contract before packing and shipping. All components shall be checked as follows:

- Correct amount of components.
- Correct manufacture and type number.
- Components appear new and with no visible defects.
- All control panels are tested with voltage applied and circuits control measured. All electronic parts are tested.
- Numbers of packages are recorded.
- Packing lists contain all equipment.

9.6.4 Inspection and test after installation

All the costs related for the testing will be borne by the Contractor.

The equipment and installations will be inspected for compliance with standards and specifications. The visual inspection will cover all works and equipment including, but not limited to, the following:

- Fixing of all mechanical and electrical equipment.
- Electrical cable routing.
- Alignment of pipes.
- Protective guards.
- Workmanship.
- Overall finish of works, including welding, surface treatment, cleanliness etc.
- Check of quality of materials.

9.6.5 Test on completion

Site testing shall demonstrate the satisfactory operation of each part of the system, before testing of the complete system as a whole during commissioning.

All tests must be carried out in the presence of the Engineer, or such other person appointed for this purpose, unless the Engineer states otherwise in writing. Tests shall be carried out to the satisfaction of the Engineer.

Certificates shall mention shortcomings to be corrected by the Contractor in a List of Defects.

The Engineer may require additional tests to prove compliance with the specifications. All such tests shall be at the Contractor's expense.

The tests shall include all procedures and functions, safety, emergency as well as normal procedures such as:

- Testing of automatic operation.
- Testing of manual operation.
- Testing of capacity of all machines individually and as part of the entire plant.
- Testing of alarm systems.
- Testing of the emergency switch system.
- Testing of all interlocking systems.
- Testing of indications
- Testing of all panel functions.
- Testing of safety systems.

9.6.6 Running-in

Running in of the plant is part of the services under the Contract. The Engineer shall have the opportunity to witness the running-in activities.

The running in shall take place after all individual main equipment have been tested successfully.

9.6.7 Commissioning

The Contractor shall give the Engineer not less than twenty-one (21) days' notice of his intention to commission the entire plant.

Before commissioning the entire plant shall be in stable operation. Commissioning and performance tests shall be carried out using trained, experienced engineers.

If considered necessary by the Engineer, re-testing of parts of the plant previously tested on completion shall be carried out at the expense of the Contractor until such time as the entire plant performs satisfactorily.

All tests shall be carried out in the presence of the Engineer or such other person appointed for this purpose unless the Engineer states otherwise in writing.

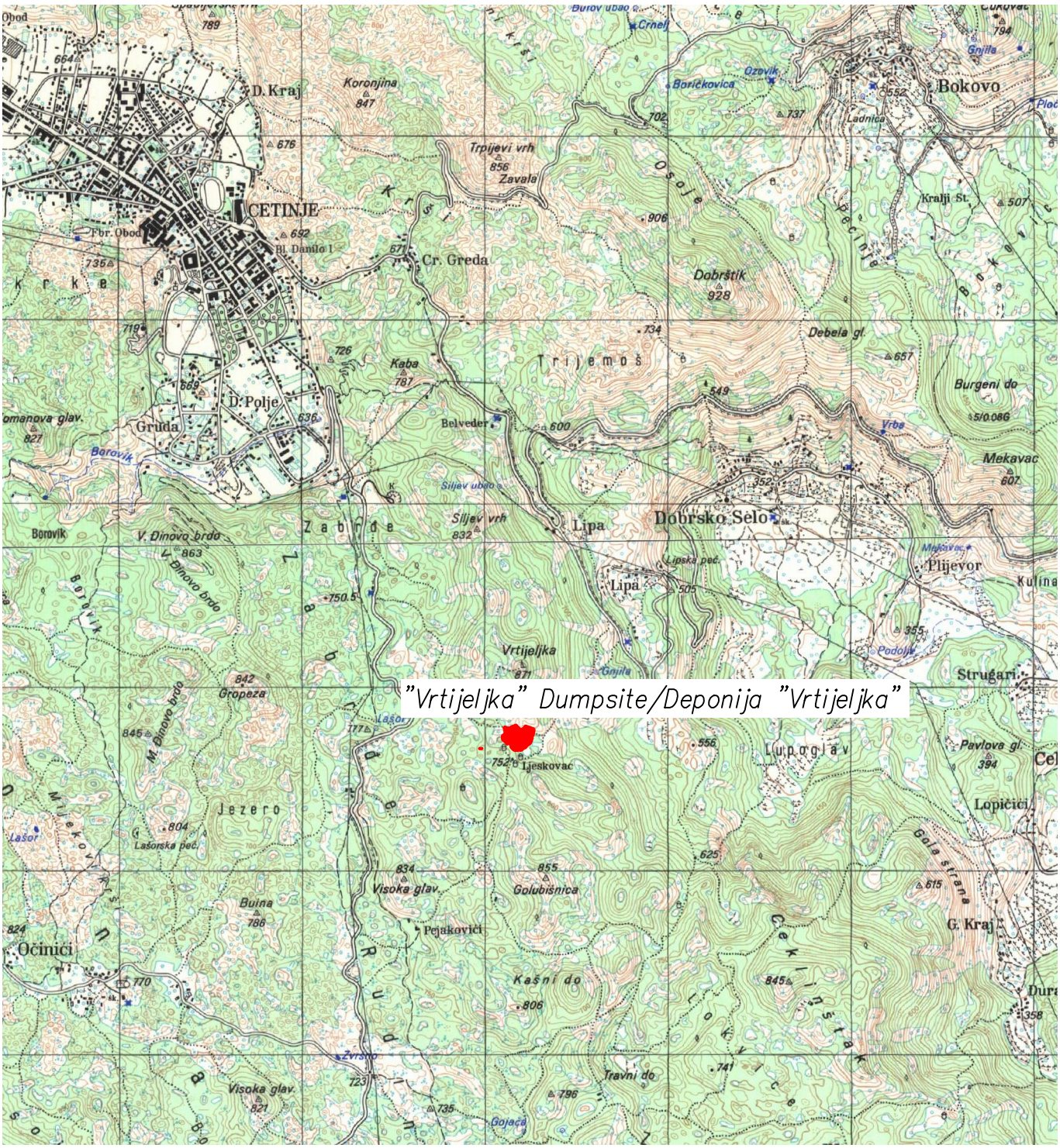
9.6.8 Taking-Over

The issuing of the Taking-Over Certificate by the Engineer will take place after the following demands have been fulfilled to the satisfaction of the Engineer:

- The Operation and Maintenance Manual has been handed over to the Recipient in its final version.
- The As-Built Drawings have been handed over to the Engineer.
- All works have been tested on site for all functions and performance by the Contractor to the satisfaction of the Engineer, and documented in the Quality Assurance and Test Report.
- The Quality Assurance and Test Report have been handed over to the Engineer.
- No defects or deficiencies found such as damaged surfaces, rust on stainless steel, dirty not cleaned equipment, wrong materials installed, etc.
- The stock of spare parts and consumables has be refilled (if any parts have been used) and handed-over to the Employer.

The Taking-Over Certificate shall be signed by the Engineer, and countersigned by the Employer.

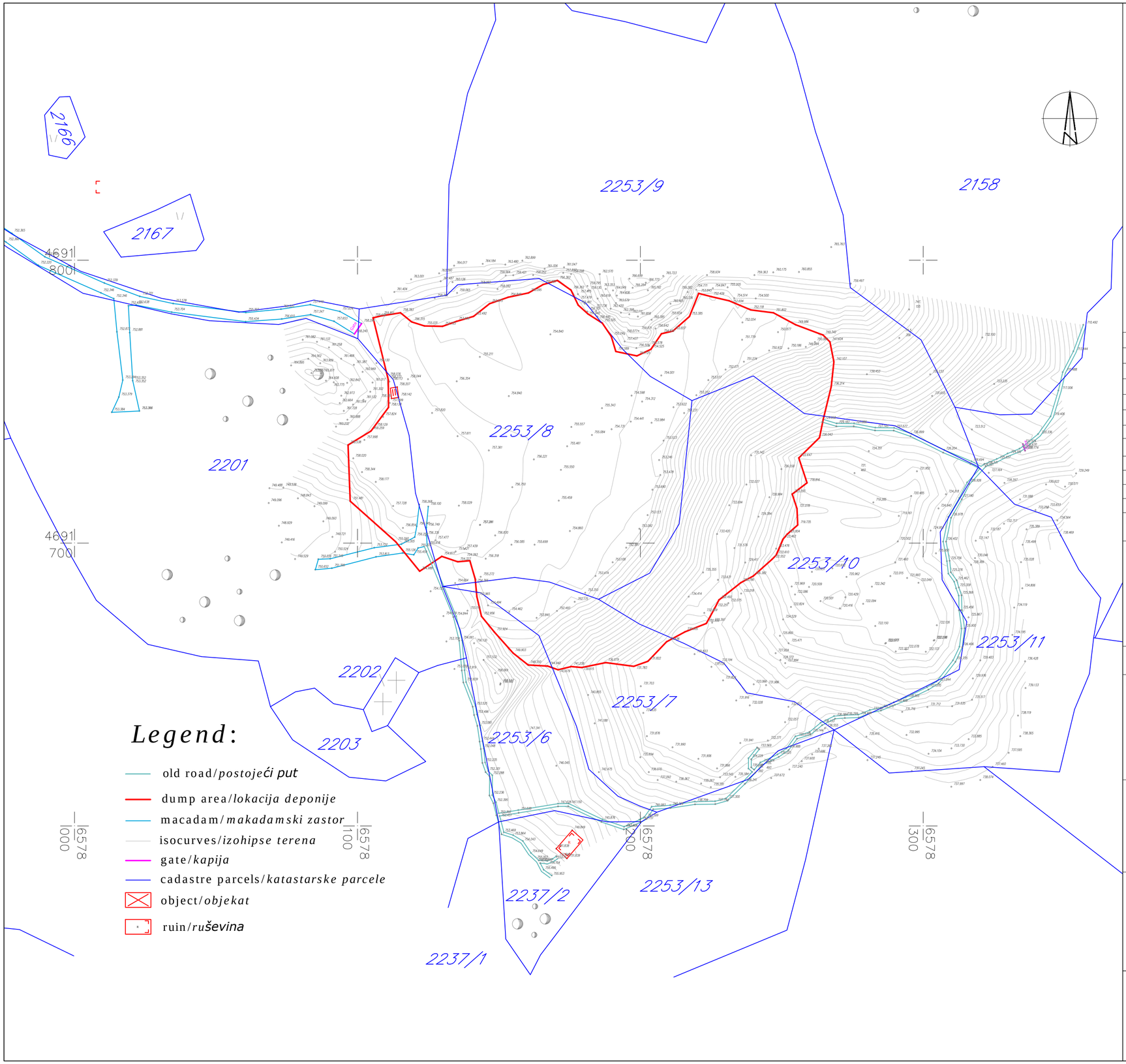
Appendix 6 Drawings



DESIGNED BY	Ivana Stevanović	NOTES	REVISIONS
CHECKED BY	Vladanka Presburger Ulniković		
APPROVED BY	Enver Kiyik		
DATE 2013/09	ISSUE 1		

ISSUE	DATE	MADE BY	CHECKED BY	APPROVED BY	DESCRIPTION

BENEFICIARY PROCON Municipality of Cetinje	PROJECT CODE WB4-MNE-ENV-12 PROJECT TITLE Analysis of the way of Collection, Transport and Treatment of Waste from the Old Royal Capital of Cetinje and Preparation of Conceptual Design and Tender Documents for the Rehabilitation of "Vrtijeljka" Dumpsite	DRAWING NUMBER 001 DRAWING TITLE SITE MAP *PREGLEDNI PLAN*
This project is implemented by COWI • IPF CONSORTIUM	This project is designed by COWI • IPF	This project is funded by European Union EuropeAid/128073/C/SER/MULTI Infrastructure Project Facility Technical Assistance Window (IPF - TA) Western Balkan



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DRAWING NO 002

DRAWING TITLE

EXISTING STATE
POSTOJEĆE STANJE

PROJECT CODE WB4-MNE-ENV-12

PROJECT TITLE

Analysis of the way of Collection, Transport and Treatment of Waste from the Old Royal Capital of Cetinje and Preparation of Conceptual Design and Tender Documents for the Rehabilitation of “Vrtijeljka” Dumpsite

BENEFICIARY

PROCON

Municipality of Cetinje

This project is funded by European Union

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Infrastructure Project Facility

Technical Assistance Window (IPF - TA)

Western Balkan

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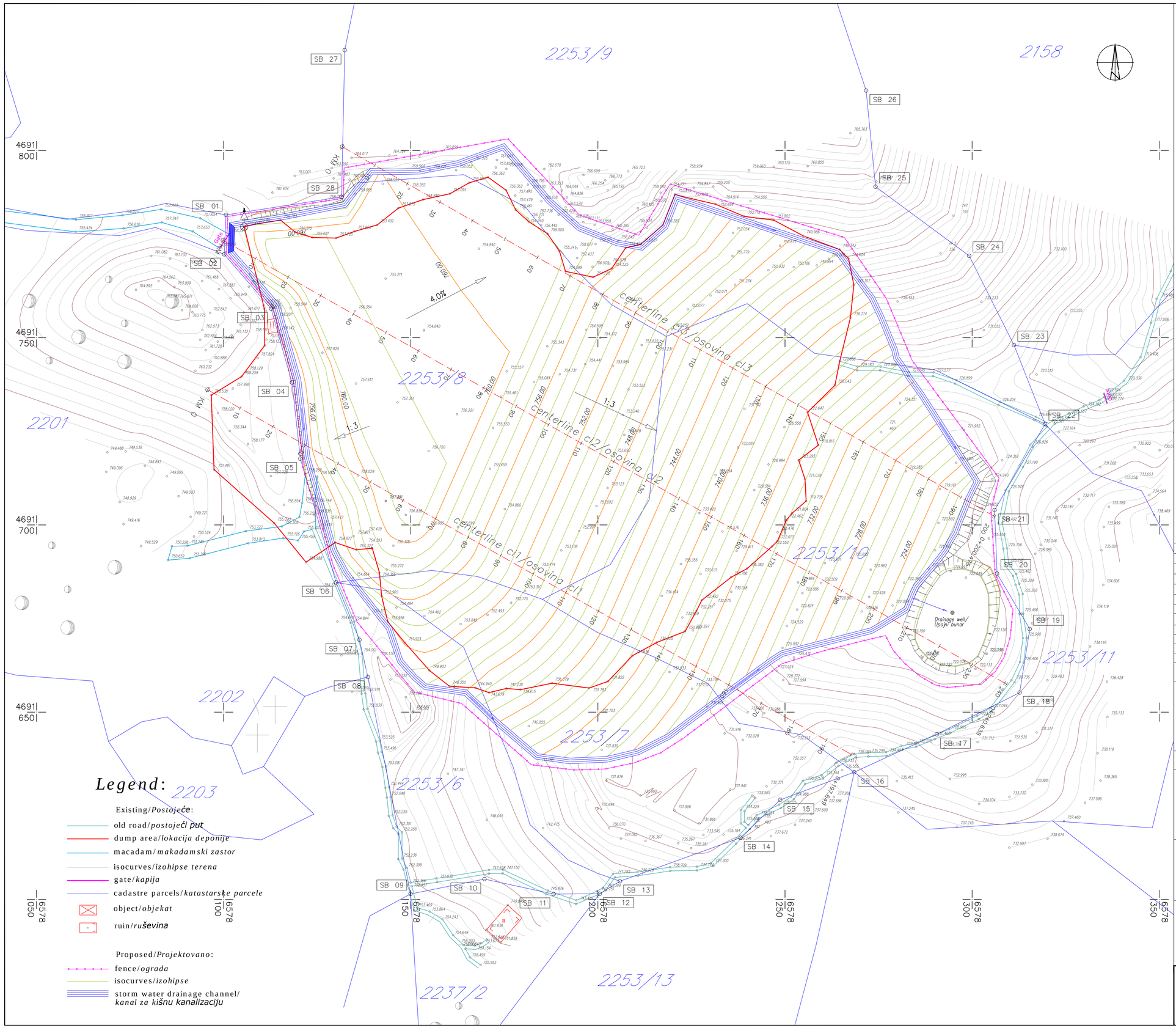

Notes: The point numbers included in the table Site boundary - SB below is the area designated for rehabilitation of the dumpsite.

Site boundary – SB		
Point No	Easting	Northing
01	6578100.620	4691782.780
02	6578100.160	4691772.270
03	6578112.690	4691757.730
04	6578118.260	4691738.040
05	6578120.510	4691717.700
06	6578130.060	4691684.660
07	6578136.290	4691669.320
08	6578138.540	4691659.390
09	6578149.940	4691601.450
10	6578169.700	4691605.420
11	6578188.180	4691601.420
12	6578200.490	4691601.510
13	6578205.890	4691604.860
14	6578238.110	4691616.470
15	6578248.710	4691626.570
16	6578268.500	4691633.970
17	6578290.570	4691644.100
18	6578312.700	4691655.240
19	6578315.410	4691672.190
20	6578306.680	4691687.000
21	6578306.020	4691703.950
22	6578319.520	4691726.930
23	6578311.200	4691748.030
24	6578299.220	4691771.860
25	6578274.210	4691790.320
26	6578271.680	4691815.990
27	6578132.360	4691826.790
28	6578131.510	4691787.610

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DRAWING NO 003

DRAWING TITLE

ELEVATION PLAN, e=1m
NIVELACIONI PLAN, e=1m

SUB-PROJECT CODE WB4-MNE-ENV-12

SUB-PROJECT TITLE

Analysis of the way of Collection, Transport and Treatment of Waste from the Old Royal Capital of Cetinje and Preparation of Conceptual Design and Tender Documents for the Rehabilitation of "Vrtijeljka" Dumpsite

BENEFICIARY

PROCON

Municipality of Cetinje

This project is funded by European Union

Infrastructure Project Facility
Technical Assistance Window (IPF - TA)
Western Balkan
EuropeAid/128073/C/SER/MULTI

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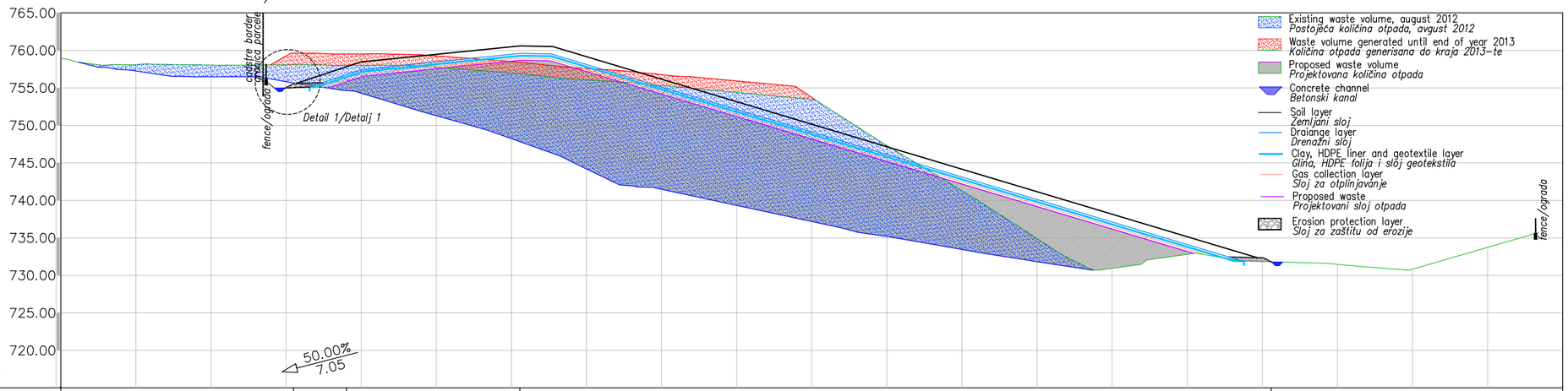
Centerline cl1/Osovina cl1



Proposed Projektovane	Top Grades Nagibi gornjeg sloja				30.99 755.64	38.04 759.17	10.10 23.10	61.14 761.50					30.00% 100.05					61.19 732.75					
Proposed Projektovane	Levels Kote: Top Gornji sloj					759.37	760.38	761.39	760.10	757.10	754.10	751.10	748.10	745.10	742.10	739.10	736.10	733.10				
Existing Postojeće	Levels Kote: Top Gornji sloj	758.11	758.05	758.09	758.01	757.75	756.98	756.06	755.30	754.40	753.47	747.34	741.30	734.92	730.94	732.81	731.83	731.47	730.83	733.74		
Existing Postojeće	Levels Kote: Bottom Donji sloj	757.25	756.49	755.83	754.30	751.29	748.24	744.20	741.48	739.34	737.19	735.19	733.45									
Station Stacionaža	KM	0	10	20	30	40	50	60	70	80	90	1	10	20	30	40	50	60	70	80	90	97.65	2	

REVISIONS

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DRAWING NUMBER
004

DRAWING TITLE
LONGITUDINAL PROFILE
Centerline cl1
PODUŽNI PROFIL
Osovina cl1

SUB-PROJECT CODE
WB4-MNE-ENV-12

SUB-PROJECT TITLE
Analysis of the way of Collection, Transport and Treatment of Waste from the Old Royal Capital of Cetinje and Preparation of Conceptual Design and Tender Documents for the Rehabilitation of "Vrtijeljka" Dumpsite

BENEFICIARY
PROCON
Municipality of Cetinje

Infrastructure Project Facility
Technical Assistance Window (IPF - TA)
Western Balkan
EuropeAid/128073/C/SER/MULTI
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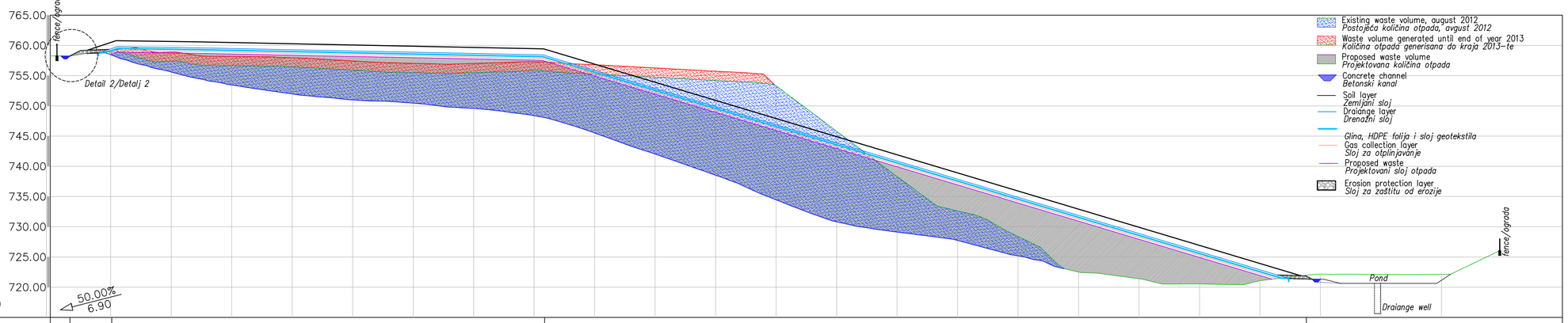
Centerline cl2/Osovina cl2



Top Grades / *Nagibi gornjeg sloja*

3.26 | 758.26
10.16 | 761.71
2.00% 71.57
81.72 | 760.34
30.00% 125.95
7.67 | 722.55

Station / *Stacionaža* KM	0	10	20	30	40	50	60	70	80	90	1	10
Proposed / *Projektovane* Levels / *Kote* Top / *Gornji sloj*		761.63	761.56	761.39	761.18	760.98	760.78	760.57	760.37	757.85	754.85	751.85
Existing / *Postojeće* Levels / *Kote* Top / *Gornji sloj*		759.00	757.35	756.65	756.45	755.91	755.51	755.49	755.81	755.27	754.74	754.20
Existing / *Postojeće* Levels / *Kote* Bottom / *Donji sloj*		758.47	755.60	753.47	752.00	750.99	750.46	749.59	748.38	745.51	742.04	738.53

Station / *Stacionaža* KM	20	30	40	50	60	70	80	90	2	10	20	30	40.64	50
Proposed / *Projektovane* Levels / *Kote* Top / *Gornji sloj*	748.85	745.85	742.85	739.85	736.85	733.85	730.85	727.85	724.85	721.51	720.80	721.15		
Existing / *Postojeće* Levels / *Kote* Top / *Gornji sloj*	753.33	745.82	738.32	732.63	728.39	722.52	721.40	720.55	721.09	722.16	722.12	722.14		
Existing / *Postojeće* Levels / *Kote* Bottom / *Donji sloj*	734.47	730.83	729.13	727.73	725.20									

REVISIONS

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DRAWING NUMBER
005

DRAWING TITLE
LONGITUDINAL PROFILE
Centerline cl2
PODUŽNI PROFIL
Osovina cl2

SUB-PROJECT CODE
WB4-MNE-ENV-12

SUB-PROJECT TITLE

Analysis of the way of Collection, Transport and Treatment of Waste from the Old Royal Capital of Cetinje and Preparation of Conceptual Design and Tender Documents for the Rehabilitation of “Vrtijeljka” Dumpsite

BENEFICIARY

PROCON
Municipality of Cetinje

Infrastructure Project Facility
Technical Assistance Window (IPF - TA)
Western Balkan
EuropeAid/128073/C/SER/MULTI

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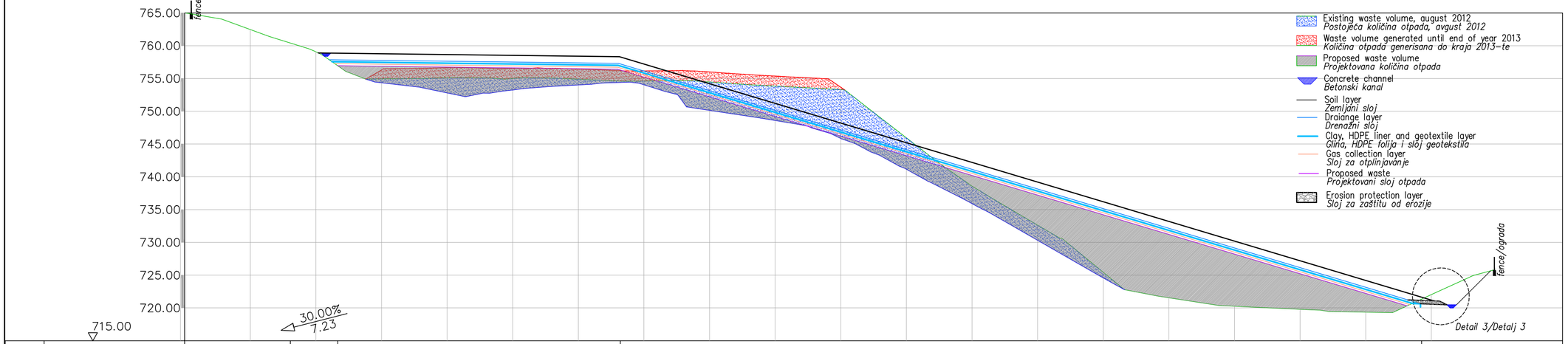
Centerline cl3/Osovina cl3



Proposed Projektovane	Top Grades Nagibi gornjeg sloja		16.11 757.59	23.34 759.75	1.25% 43.06			66.40 759.21					30.00% 122.13								88.53 722.58				
Proposed Projektovane	Levels Kote: Top Gornji sloj		758.75	759.67	759.54	759.42	759.29	758.13	755.13	752.13	749.13	746.13	743.13	740.13	737.13	734.13	731.13	728.13	725.13						
Existing Postojeće	Levels Kote: Top Gornji sloj	762.46	759.08	754.95	755.12	755.00	754.90	754.61	754.47	753.83	753.30	745.94	738.60	732.64	725.44	721.54	720.26	719.79	719.37	722.03					
Existing Postojeće	Levels Kote: Bottom Donji sloj			754.36	752.81	753.25	754.03	754.05	750.14	748.59	745.85	741.15	735.92	730.32	724.60										
Station Stacionaža	KM	0	10	20	30	40	50	60	70	80	90	1	10	20	30	40	50	60	70	80	90	0.47			10

REVISIONS

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DRAWING NUMBER
006

DRAWING TITLE
LONGITUDINAL PROFILE
Centerline cl3
PODUŽNI PROFIL
Osovina cl3

SUB-PROJECT CODE
WB4-MNE-ENV-12

SUB-PROJECT TITLE
Analysis of the way of Collection, Transport and Treatment of Waste from the Old Royal Capital of Cetinje and Preparation of Conceptual Design and Tender Documents for the Rehabilitation of "Vrtijeljka" Dumpsite

BENEFICIARY
PROCON
Municipality of Cetinje

Infrastructure Project Facility
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Western Balkan
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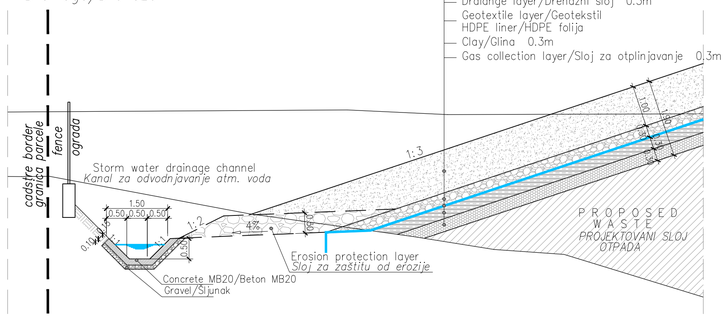
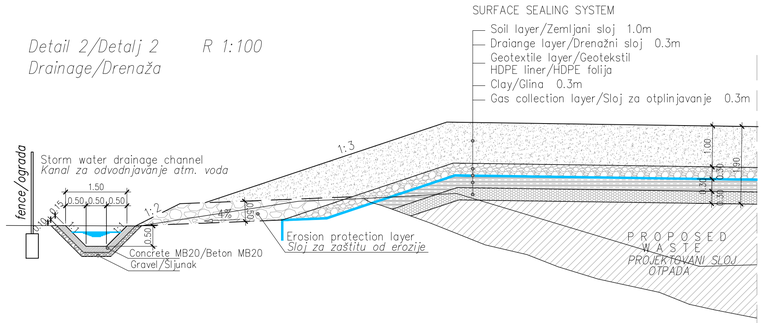
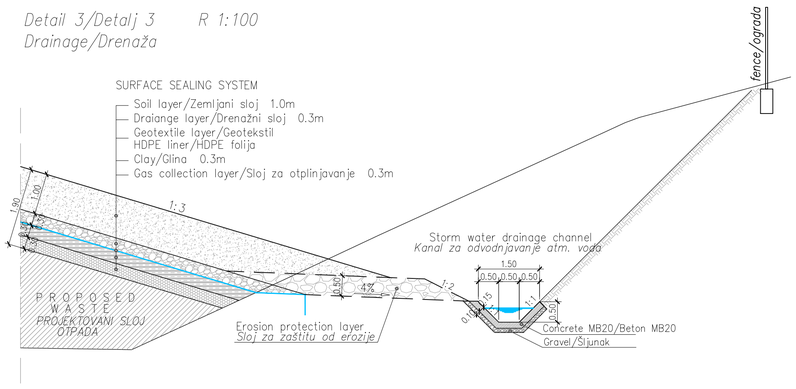
Detail 1/Detalj 1 R 1:100
Drainage/Drenaža



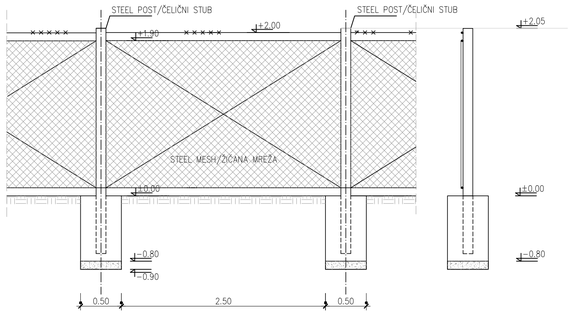
Detail 2/Detalj 2 R 1:100
Drainage/Drenaža



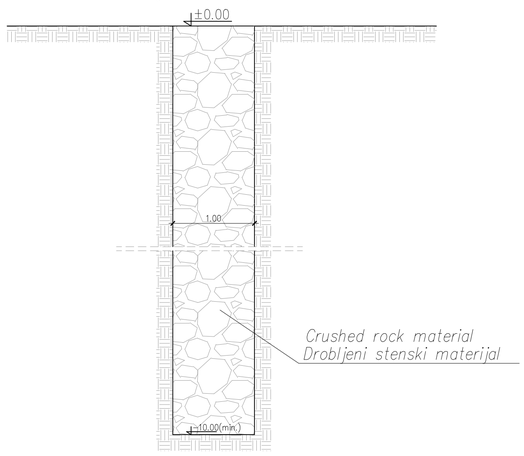
Detail 3/Detalj 3 R 1:100
Drainage/Drenaža



Detail 4/Detalj 4 R 1:50
FENCE/OGRADA



Detail 5/Detalj 5 R 1:50
Drainage well/Upojni bunar



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DRAWING NO 007

DRAWING TITLE

DETAILS
DETALJI

PROJECT CODE WB4-MNE-ENV-12

PROJECT TITLE

Analysis of the way of Collection, Transport and Treatment of Waste from the Old Royal Capital of Cetinje and Preparation of Conceptual Design and Tender Documents for the Rehabilitation of “Vrtijeljka” Dumpsite

BENEFICIARY

PROCON

Municipality of Cetinje

This project is funded by European Union

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Western Balkan

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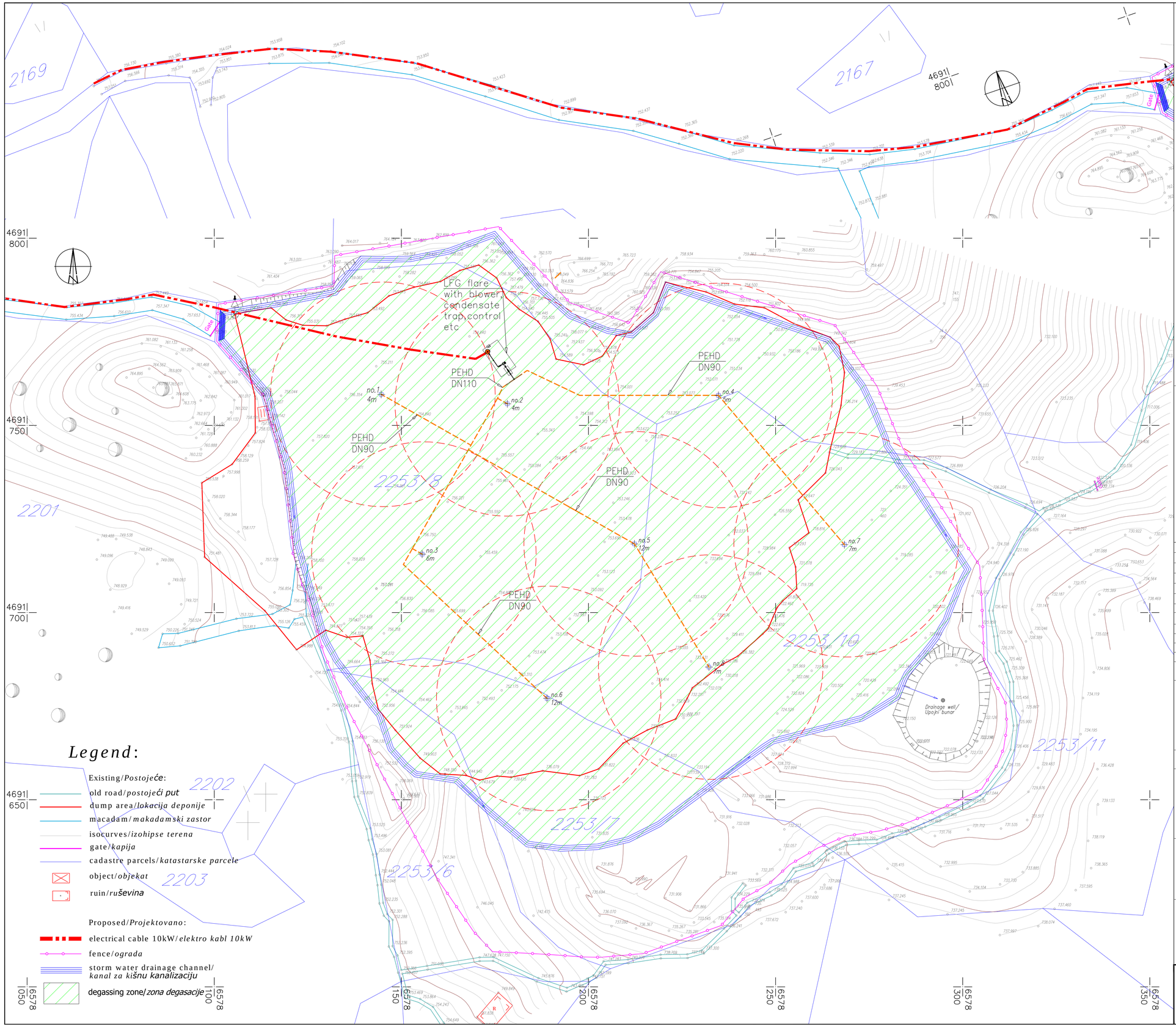

ID	ITEM/STAVKA	X	Y	DEPTH/DUBINA
1	BIOWELL/BIOTRN	6 578 144	4 691 758	4m
2	BIOWELL/BIOTRN	6 578 178	4 691 755	4m
3	BIOWELL/BIOTRN	6 578 155	4 691 715	6m
4	BIOWELL/BIOTRN	6 578 234	4 691 758	5m
5	BIOWELL/BIOTRN	6 578 212	4 691 718	12m
6	BIOWELL/BIOTRN	6 578 188	4 691 677	12m
7	BIOWELL/BIOTRN	6 578 268	4 691 718	7m
8	BIOWELL/BIOTRN	6 578 232	4 691 685	7m

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1	1:500	2013/09

DRAWING NO 008

DRAWING TITLE

GAS COLLECTION SYSTEM
LAYOUT
SITUACIONI PLAN
SISTEMA ZA PRIKUPLJANJE GASA

SUB-PROJECT CODE WB4-MNE-ENV-12

SUB-PROJECT TITLE

Analysis of the way of Collection, Transport and Treatment of Waste from the Old Royal Capital of Cetinje and Preparation of Conceptual Design and Tender Documents for the Rehabilitation of "Vrtijeljka" Dumpsite

BENEFICIARY

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Western Balkan
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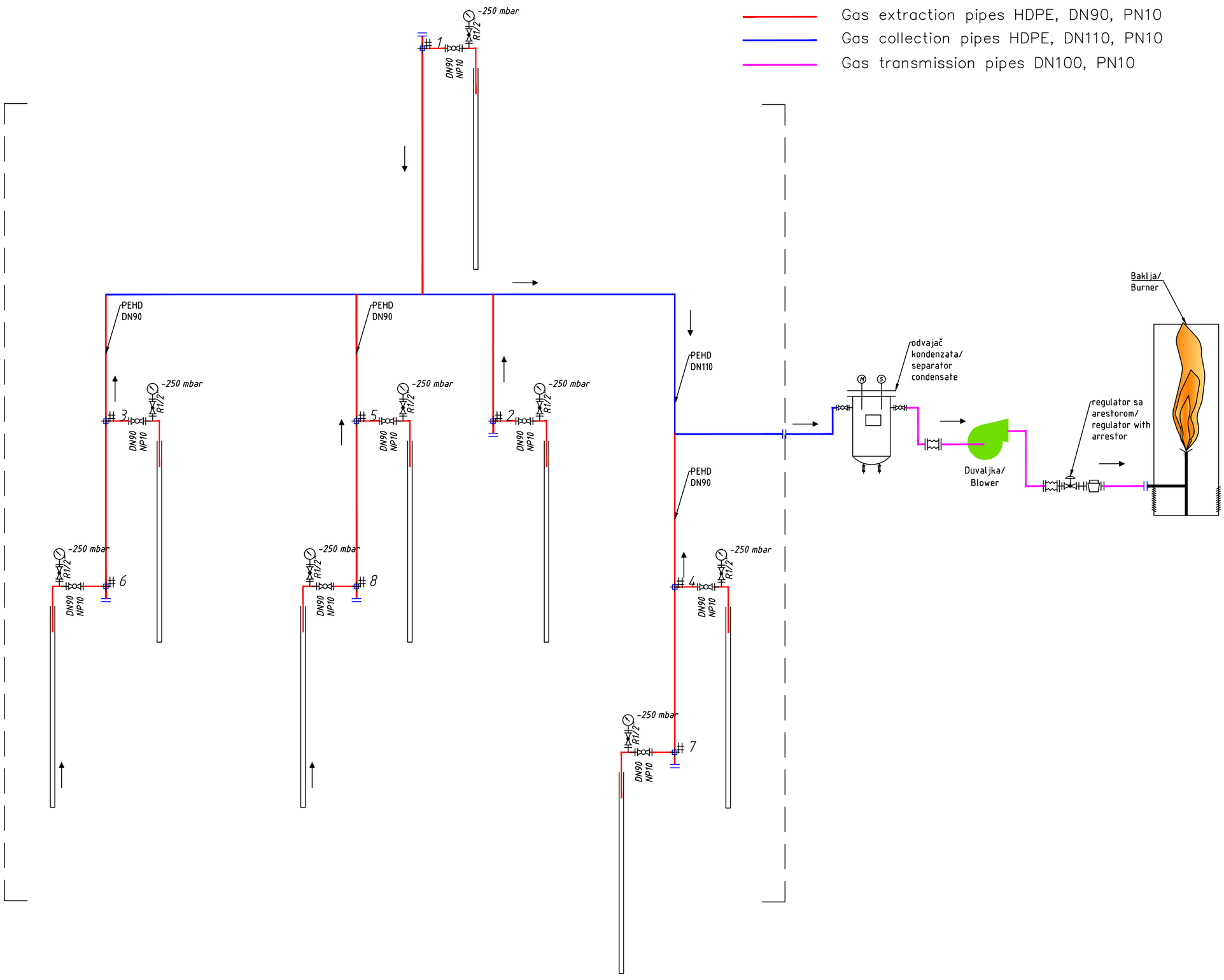
LEGEND:

- Gas extraction pipes HDPE, DN90, PN10
- Gas collection pipes HDPE, DN110, PN10
- Gas transmission pipes DN100, PN10



NOTES

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Dragan Tadic	Ivana Stevanovic	Enver Kiyik
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1	-	2013/09

DRAWING NUMBER
009

DRAWING TITLE
GAS DISPOSAL SYSTEM
Technological scheme
SISTEM ZA PRIKUPLJANJE I TRETMAN GASA
Tehnološka šema

SUB-PROJECT CODE
WB4-MNE-ENV-12

SUB-PROJECT TITLE
Analysis of the way of Collection, Transport and Treatment of Waste from the Old Royal Capital of Cetinje and Preparation of Conceptual Design and Tender Documents for the Rehabilitation of "Vrtijeljka" Dumpsite

BENEFICIARY
PROCON
Municipality of Cetinje

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Western Balkan
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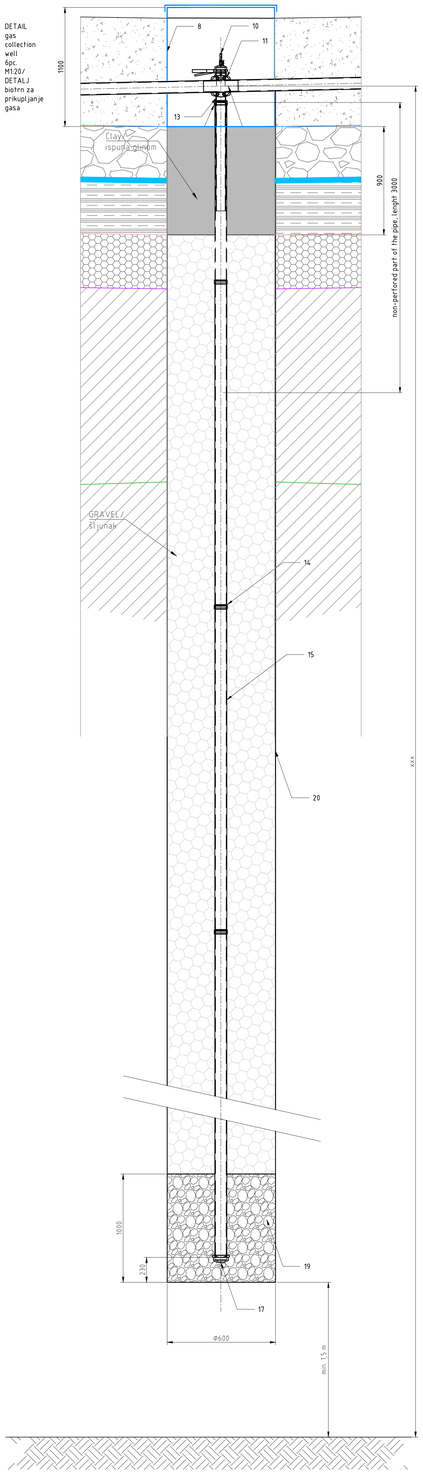

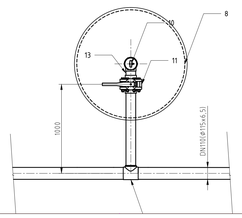

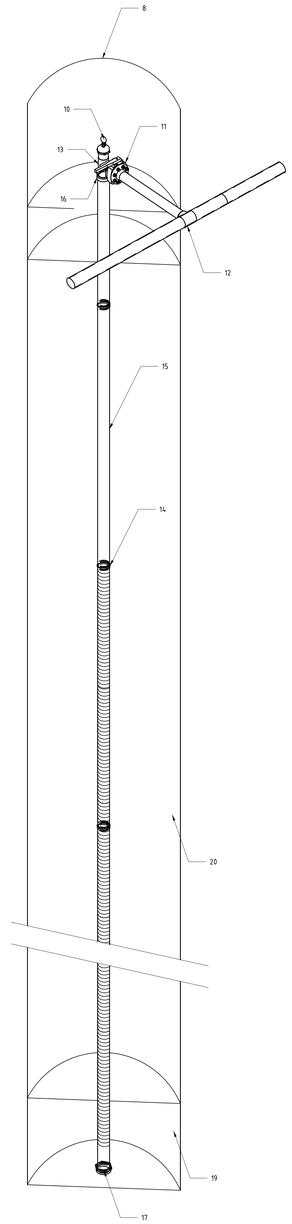

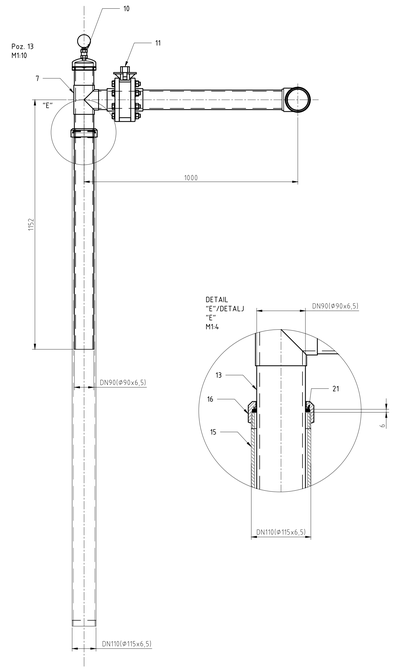

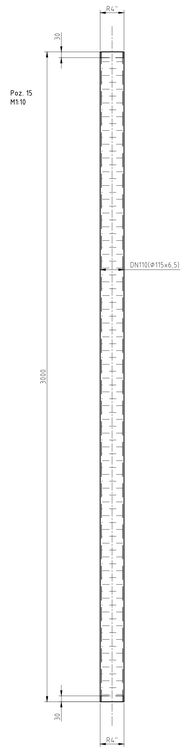

Notes

LEGEND
9 - Housing shaft
10 - Connection with valve control and sampling
11 - Control valve
12 - T pcs
13 - Telescopic jack
14 - Threaded joints
15 - Pipe segment of degassing
16 - Sealing threaded joints
17 - Cap
18 - Gabion
19 - Gravel protection
20 - The rubber gasket compound telescope

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REVISIONS

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DRAWING NO 010

DRAWING TITLE

DEGASSING SYSTEM
GAS COLLECTION WELL
SISTEM ZA DEGAZACIJU
BIOTRN ZA PRIKUPLJANJE GASA

SUB-PROJECT CODE WB4-MNE-ENV-12

SUB-PROJECT TITLE

Analysis of the way of Collection, Transport and Treatment of Waste from the Old Royal Capital of Cetinje and Preparation of Conceptual Design and Tender Documents for the Rehabilitation of "Vrtiljeljka" Dumpsite

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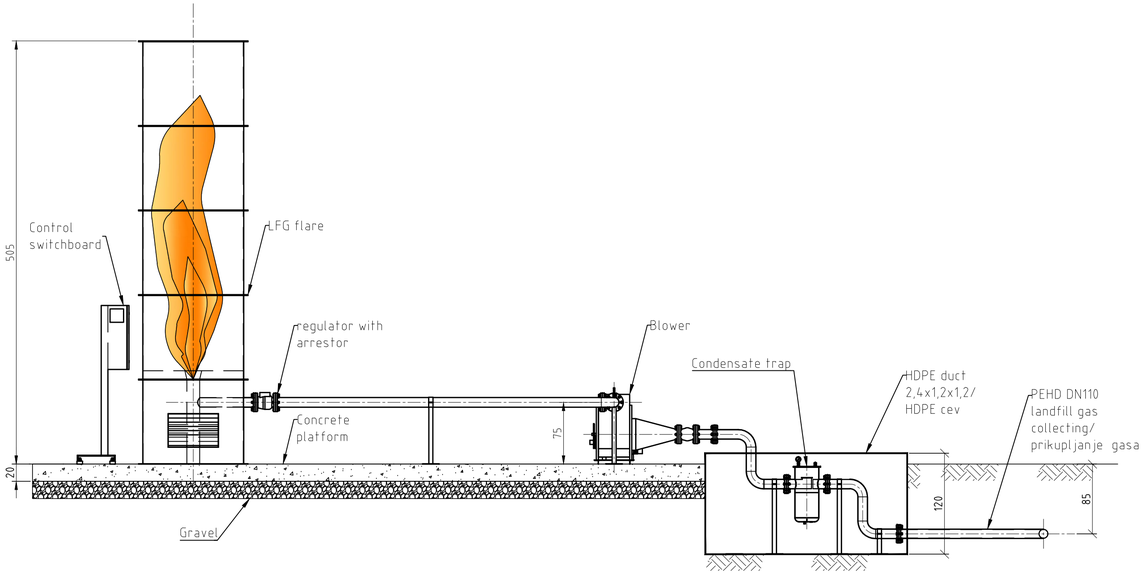

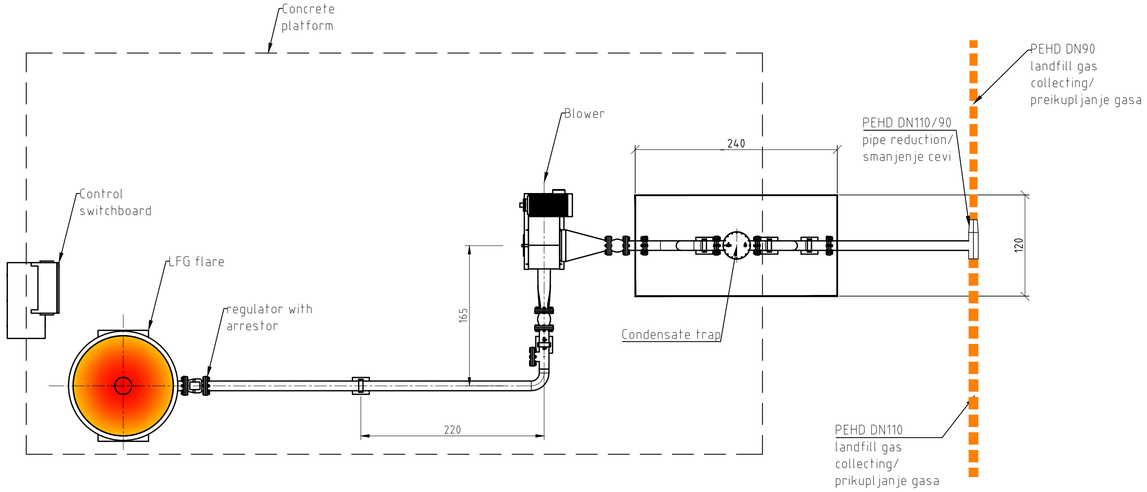

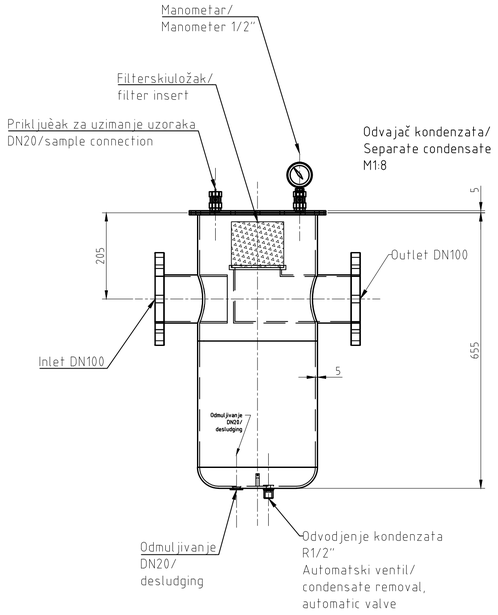

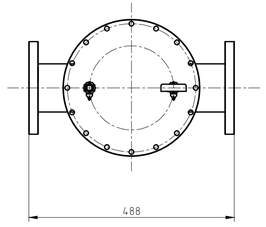

ISSUE	DATE	DESIGNED BY	CHECKED BY	APPROVED BY	DESCRIPTION

REVISIONS

DESIGNED BY	CHECKED BY	APPROVED BY
Dragan Tadić	Ivana Stevanović	Enver Kiyik
ISSUE	SCALE	DATE
1	1:40	2013/09

DRAWING NO 011

DRAWING TITLE

DEGASSING SYSTEM
GAS FLARE
SISTEM ZA DEGAZACIJU
SPALIONICA DEPONIJSKOG GASA

PROJECT CODE WB4-MNE-ENV-12

PROJECT TITLE

Analysis of the way of Collection, Transport and Treatment of Waste from the Old Royal Capital of Cetinje and Preparation of Conceptual Design and Tender Documents for the Rehabilitation of "Vrtijeljka" Dumpsite

BENEFICIARY

PROCON

Municipality of Cetinje

This project is funded by European Union

EuropeAid/128073/C/SER/MULTI
Infrastructure Project Facility
Technical Assistance Window (IPF - TA)
Western Balkan

This project is implemented within the framework of IPF TA which is managed by
COWI • IPF CONSORTIUM

This project is designed by
COWI • IPF