Translation from Bulgarian language

EXPLANATORY NOTE

Subject: **Preventive clearing of the bed and reinforcement of the banks of the river Sandanska Bistritsa in the area of Lilyanovo village, Sandanski Municipality**

Part: Hydro engineering

1. Introduction

This project has been developed upon request by Sandanski Municipality. The goal is to provide a technical solution for the reinforcement of the riverbed in three locations endangered by erosion and overflow in case of high water level at the topmost bridge of the river in the area of v. Lilyanovo. The bridge has a support in the middle and two apertures, 6 m each.

Due to deposition of boulders and drift the left side aperture of the bridge has been completely obstructed and the river flows only through the right side aperture. Due to high water level in 2010, water flew over the bridge, and in case of another overflow event, the bridge will be completely destroyed. In order to ensure passability of the river flow in this section, upstream and downstream the bridge, we have made provisions for corrective concrete walls enclosing the transverse profile of the river, width 12 meters. Following onsite inspection to study the condition of the riverbed using geotechnical survey methods, four different challenging sections finding have been identified and measures have been proposed to improve the riverbed and banks condition, via corrective walls and facilities comprised of gabions.

2. Technical solutions

The project is category III as per the Territories Development Act.

For the most endangered section of the banks, on both sides of the bridge, plans include corrective walls, clearing in the progress of work of the obstructed bridge pass to ensure capacity for high water level.

The walls differ in length, but have identical cross sectional area and foundation depth, H= 1, 5 m – substrate – gravel mixed with large boulders.

Wall No.1 – left bank (along the river course) – 35 m long

Wall No.2 – right bank (along the river course) – 47 m long

Wall No.3 – right bank (along the river course) – 45 m long

Deposits at the left bridge mainstay will be cleared under the travel slab. Walls have been designed for ground pressure excluding live load, since there is no existing road adjacent to the walls and plans do not include any new access road to the river. The norms as specified in article 41 of the Rules for load bearing walls, H = 4.0 m max , require no seismicity calculations.

Static design data have been shown in the basic details as used for wall design. The dimensions have been shown on the formwork arrangement drawings. The wall base B =1.10 m wide with foundation om gravel and rock base following water removal from the excavation, using no substrate concrete. The wall will be made using lamellas of 20 m with construction joints in between.

The water flow capacity in the first section of the riverbed has been obstructed and there is a bank erosion potential downstream the small bridge at the hydro- metering point HMS No.51540. Only the left side bank is endangered by erosion and we have planned reinforcement of this bank via a single line of gabions 2x1x1 m extending a 37 m distance.

Gabions will be made of structural steel Φ 8 mm, dimensions 2x1x1 m, covered with hot dipped steel mesh, 3,00 mm wire thickness and 6x6 cm mesh eye. This type of gabion structure will be filled with river stones to be collected from the riverbed.

The second section potentially affected by erosion is at the right side bank, 400 m downstream the bridge and is 20 m long. We plan reinforcement via gabions, 2x1x1 m.

The third section endangered by erosion is also located on the right side bank and is 53 m long; it will be reinforced using gabions 2x1x1 m.

From the onsite inspection of the riverbed and banks, we found further minor deposits and partial erosion effects, as well as small bushes and single trees covering the banks, which represent a favorable condition for new depositions. These must be cleared, roots and branches will be transferred to wider areas beyond the riverbed.

3. Engineering geology conditions

The riverbed of S.Bistritsa within the territory of v. Lilyanovo is covered with natural river boulders and coarse gravel being a good substrate for foundation works for the intended new support systems. Foundation works will be at 1,5 m maximum depth on solid riverbed with large boulders with gravel filler. Water shall be removed from the excavations prior to concrete works for the foundations.

4. Technology of works

Construction of corrective walls can be subdivided in the following types of works:

- Construction of temporary deviator dyke from the foundation excavation
- Water removal for foundations
- Foundation formwork
- Foundation concrete works
- Formwork, rein bars and formwork removal for the walls
- Backfill behind the walls

Water catchment will be made of:

- Concrete grade B20W04 (C16/20)
- Steel AI No.12 – structural and Φ 8 distribution type

Gabions will be made on flat levelled riverbed, excavated at 30 cm down. Gabions on top will have concrete cover, 20 cm to extend the mesh life and to ensure protection of steel bars of gabion skeleton against robbery.

HYDRAULIC CALCULATIONS

Passability of riverbed for S. Bistritsa

Basic data:

High water level @ 5% reserve Q=67 m3/sec.

High water level @ 1% reserve Q=102 m3/sec.

Water catchment width -> 12.00 m

Bottom inclination -> i=7, 5‰.

Roughness coefficient of gravel bottom π=0.0225

Design calculation formula

Chézy's formula -> Q= F.c.√R.i [m/sec]

F=12.0 x 1.4 = 16.8 m2 cross sectional area, for water flow height H=1, 4 m

R = F/p = 16.8/14.8 = 1.13 m -> hydraulic radius in meters

P = 12.0 + 2 x 1.4 =14.8 m wet perimeter for water flow height H=1, 4 m

Readings as per Pavlovski： c = 45.1

Q = 16.8 x 45.6 x V1.13 x 0.0075 = 65 m3/sec. – secured for high water level and reserve assumed as 40 cm for the walls over the high water level – wall height H = 1.4 +0.4 = 1.8 m.

Hydrological report

1. Introduction

The hydrologic parameters of the S. Bistritsa River have been determined for the area of HMS No.51540 at the start of the section intended for emergency clearing and banks reinforcement.

This development demonstrates details for the water catchment area and general parameters of river flow with details included for minimum water quantity and high water level, being of key importance of the design calculations of the corrective walls.

The hydrologic development has been based on the use of:

- Maps Scale M 1: 25 000 for determination of orohydrographical elements of the river at HMS No.51540.
- Details from the inspection of the section and the riverbed, and details of eyewitnesses of high water level in the river during pouring rains in the past.
- Data from hydrogeology handbooks for the flow of the S. Bistritsa River

At the point of HMS.

At the subject point of the river flow has been obstructed by the previously built, to years ago, Sandanska Bistritsa cascade with 3-off water power plants with rated flow 4.0 m3/sec. and water take off for water supply to Sandanski municipality –of max 150 l/sec.

The orohydrographical components of the water catchment basins and the details for surface water runoff for a medium to dry year at the point of HMS No.51540 for Sandanska Bistritsa River have been shown below:

	Natural pattern	Disturbed pattern
- Water catchment basin area	118.6 sq.km	118.6 sq.km
- Surface runoff module	22.7 l/sec/km2	10.5 l/sec/km2
- Average annual water amount for a medium dry year	2,7m3/sec	1,24m3/sec
-Water amount for a medium dry year	85 mio.m3	39 mio.m3
-average annual water quantity for a 85% dry year	1.90 m3/sec	0,7 m3/sec
-water amount for a 85% dry year	60 mio.m3	22 mio.m3
-high water level with 5% reserve	67 m3/sec	67 m3/sec

2. Summary of orohydrographical characteristics of the water catchment basin

Location and general information.

The S. Bistritsa River draws its water from the southwestern slopes of northern Pirin. The water catchment basin relief is high mountainous and mountainous in nature; at altitude above the sea level over 2000 m, the peaks have the nature of bare rocks, lakes and steep river of alpine character.

A dominating factor that is determining for the relief to the subject point at the S. Bistritsa river is the northern part of the Pirin mountain with high peaks in the water catchment - over 2 500 m, where the highest is Banderishki chukar point (2 732 m). there are several high mountain lakes in this water catchment with small volume – Polenishki, Malokamenishi, Glavniski and others.

- *Relief :*

The water catchment basin of the S. Bistritsa River covers a part of the southern slopes of Northern Pirin at the foot of Sini vrah point. The water catchment basin of the river to the point of water intake is characterized by a fan-shaped form, oriented south-north, same as the river flow direction. The relief of the water catchment is mountainous, alpine in nature in the highest parts. Due to the existence of high mountainous relief shapes in this basin, the average elevation above the sea level and average slope of the river are high. The river banks are steep, well defined and covered with rocks. For the greater part, they are covered with coniferous wood and high mountain pastures, at the foot of the highest rocky peaks juniper and mountain herbaceous species can be found.

In the high part of this water catchment, there are several rivers springing: Mozgovitsa, Kozya reka, Raslankovitsa, Snapolska reka, and Tremoshnitsa. The high elevation above sea level, the rocky terrain of the catchment, presence of lakes and geographical location are favorable conditions for the formation of significant amount of precipitations-both snow and rain, and steady run-off. Soil cover for this altitude of more than 500 m, of leached cinnamon forest soils on top of rocky base; in some places, the rocky base is uncovered at the surface, especially at the slopes along the riverbed.

3. *Climatic characteristics*

The geographical location of the S. Bistritsa river generally predetermines the climate here. The water catchment basin is situated in an area with combined climatic influences – moderate continental, and in the zone higher than 1 500 m - mountainous.

Climate parameters have been identified based on the observations of meteorological and rain stations in the area of Sandanski town. The climate of Northern Pirin is influenced both by the high altitude above the sea level, and orographic effects on the overall atmospheric circulation. Typical features are medium duration of period with snow, low temperatures, heavy clouds, strong winds. Average annual precipitation amount in the higher part of the basin exceed 1 000 mm. Mediterranean climate influence along the valley of the Struma river in winter is associated with abundant snowfall; snow melting begins as early as February.

- *Temperature*:

Average annual temperature of the region of Sandanski is 11,2 deg. C. Days with average 24-hour temperature of ambient air below 0 deg. C (the so-called freezing days) represent 100% of all days in January. The warmest months are July and August with t = 21,5 deg. C. The temperature amplitude is in the range of max 11,2 deg. C. Temperature transition via 0 deg. C occurs in the period December – February. This fact eases snow-melting process that in turn plays an important part in the formation of run-off pattern. Active snow melting here starts in March and April. Because of the variety of orographic conditions of the valley of R. Bistritsa river, and concurrent snow melting process in the higher water catchment, there are conditions for extended period of full river flow (for 2 to 3 months) , however happening a month earlier compared to the peaks of Northern Pirin in the direction of Bansko and Razlog.

- *Precipitation*:

Precipitation is a key factor acting upon formation of run-off. The nature of this component has been clarified considering details from rain metering stations in the area. Precipitation has uniform distribution in both multi-annual profile and within separate years. Distribution of precipitation is closely related to atmospheric circulation, and in some places, it has tremendous effect of hydrographic parameters.

Average annual amount of precipitation obtained from the said stations vary from 575 mm to 1 050 mm for the area Popina Laka. The amount of average annual precipitation for the subject section of the river is in the range of 770 mm, i.e. approx. equal to the average value for the country.

Looking at the precipitation distribution in an year, it is obvious that maximum occurs in November- December, and minimum – in summer months, this being a confirmation of the transitory climate feature.

Intensive precipitation in the river valley was recorded at various moments of time in an year, mainly these constitute the reason for catastrophic river flow.

Maximum 24-hour precipitation with varying probable occurrence (certainty) play an important role for the calculation of maximum water amount and determination of the relevant features.

For the purposes of determination of the values for maximum 24-hour precipitation amount with varying probability of occurrence, annual maximum data has been processed from the stations used during the entire period under study.

The maximum 24-hour precipitation amount with varying probability of occurrence, (certainty), has been determined based on a theoretical curve of certainty for each single rain metering station. It contains the parameters of maximum 24-hour precipitation amount for each station with the relevant coefficient of variation of annual lines and the maximum 24-hour precipitation amount with the associated certainty, calculated using a theoretical curve of certainty for $C_S=4.C_V$.

- *Snow cover*:

Development is based on details for altitude and duration during the period with available records (approx. 40 years).

The period of snow cover melting starts usually in the second decade of March and is shorter than the period of snow cover accumulation.

The maximum average monthly height of snow cover exceeds 50 cm in 70% of the winter periods for this region; and in January and February, it exceeds 80 cm. Snow cover maximum height varies from 70 to 120 cm for the river valley elevation 1 500 m and mountain peaks.

4. Run-off characteristics

4.1 Hydrological information from studies

The subject region from hydrographic point of view falls within the basins of the left-side tributaries of the Struma River in its lower run. The water catchment of S. Bistritsa River starts from Northern Pirin, with some lakes contributing, and the river run-off in summer months is higher. Such increased aquifer activity in the mountain part of the basin is determined by significant amount of precipitation, and significant run-off effects of the latter, especially in the higher parts, due to steep slopes and limited evaporation rate under lower temperatures.

The pattern of superficial run-off can be explained via data collected at the HMS point No.51540 at v. Lilyanovo.

4.2 *Parameters of average multi-annual run-off*

In the subject point of the river, run-off has been disturbed by the construction of Sandanska Bistritsa Cascade built 40 years ago with 3-off water power plants, with design flow rate of 4.0 m3/sec and water intake for water supply for Sandanski of max. 150 l/sec.

Determination of high water level is based on empirical formulae of Alekssev, Sokolovski et al.

High water level has been determined with 5% reserve as per the design norms for this wall class – IV, H=15 m max.

The orohydrographic components of the water catchment basins and data for surface run-off for a medium dry and a dry year at the HMS No.51540 point for S. Bistritsa have been demonstrated below:

	Natural pattern	Disturbed pattern
- Area of the water catchment basin	118,6 sq.m	118,6 sq.m
- Surface run-off module	22,7 l/sec/km2	10,5 l/sec/km2
- Average annual amount of water for a medium dry year	2,7 m3/sec	1,24 m3/sec
- Water mass for a medium dry year	85 mio.m3	39 mio.m3
- Average annual water amount for a 85% dry year	1,90 m3/sec	0,7 m3/sec
- Water mass for 85% dry year	60 mio.m3	22 mio.m3
- High water level, 5% reserve	67 m3/sec	67 3/sec

4.4 Yearly distribution of runoff by month:

Yearly distribution of runoff means natural laws of variation within a single hydrological year. Annual distribution of river runoff is irregular, just these three months – March, April and May, contribute approx. 50% of annual runoff to S. Bistritsa. Runoff distribution is based on data lines at HMS No.51540 of S. Bistritsa River. The runoff pattern valid for the period of study there is maximum peak in March and April, and a minimum for August and September.

For the purposes of the Project – emergency clearing of the riverbed of S. Bistritsa, this study of yearly runoff distribution has no major relevance.

4.5 Maximum water amount

High water level has been determined with a reserve of 5%, a norm used for design calculations for this wall class IV, H= 15 max.

Maximum water amount constitutes a significant part of this development. It is a characteristic component of runoff pattern. Knowledge of origin and nature of high water level is highly important.

Typical for the subject region is the fact that, high water level in most cases follow the distribution pattern of precipitation. Equally important for the formation of high water level are orohydrographic features of the water catchment basin of S. Bistritsa river. Typical for the said mountainous feature is high peaks and extended duration of occurrence of high water level.

Two methods have been employed to determine the parameters of maximum water amount and associated values with different reserves:

- Using data from direct observations and measurements at the existing hydro metering station and using the mathematical statistics method and graphical methods;

The parameters of high water level with the required reserves have been determined based on details from direct observations and measurements made by the Hydro metering station No.51540 at S. Bistritsa River – v. Lilyanovo.

Detailed analysis was made of high water passing at the HMS point for the entire period of study using official published details for high water. Because, a great number of peaks of former high water events occurring at the stations have been missed for various reasons, the result obtained has shown reduced maximum values at the point of HMS. Therefore those had be recovered. The resultant line of annual hydrological maximums is representative enough, since the line covers a period of 50 years.

The trend of the study is to determine the most probable parameters for high water for the selected HMS (Q max. average, Cv and Cs). The method of determination of statistical parameters will depend on the choice of theoretical law of distribution. For such purpose, based on the lines of data from actual observations of extreme yearly values, choice was made of the most relevant parameters. Determination of these parameters became possible after the empirical curve of certainty was plotted, as well as various theoretical curves of certainty at the HMS point. Best coincidence of those theoretical curves and the empirical curve was studied for the HMS.

Following a detailed review of all cases of coincidence between the theoretical curves and the empirical curve of certainty for the area of the subject HMS, the best coincidence of the distribution curves occurs most frequently at the theoretical curve of Pearson type III and normal distribution.

Based on Pearson's type III distribution study is made of various values of the of the asymmetry coefficient Cs=k.Cv. It has been found that, most frequently best coincidence of the empirical and theoretical curves is for Cs = 4.Cv.

- Besides using the empirical and theoretical method, statistic parameters can be calculated also via the graphic - analytical support quantitative method. The results obtained by the two methods fall within the allowable range.

Unavailability of sufficient number of direct observations for water condition and measurements from previous events of high water of the studied ranges has necessitated validation of the determination of maximum high water using the empirical formulae:

SOKOLOVSKI's formula:

$$Q = B\sqrt{F} \quad (\mathrm{m^3/sek}),$$

Where: B = coefficient depending on water catchment, F= water catchment area

Determination of design reserve values for the peaks of high water level had to be done also using indirect methods.

For comparison in determining high water, empirical methods were employed, as well as the limit intensity method.

The main formula in this limit intensity method invented by the Russian hydrologist G. A. Alekseev, with yearly potential of increase p % has two forms:

$$Qpi_{\max} = 0.0116 \times Npi_{\max} \times \eta_m \times kpi \times m \times F,$$, m3/sec.

River runoff time is determined using serial approximations by the formula:

$$Qpi_{\max} = 0.0116 \times Npi_{\max} \times \eta_m \times kpi \times m \times F,$$

The denominator in this formula is the Chézy's formula for water velocity in open water currents.

Runoff coefficients for maximum water amount have been calculated considering filtration and concurrence of maximum precipitations.

And Gerasimov's formula:

$$Qp_{\%} = Si.Fp$$ (m3/sec)

Also based on maximum precipitation amount, orohydrographic, soil and geology, and climate factors that are characteristic of the specific water catchment basin.

As required for problem solving, data provided refer to p=1%, 3%, 5% and 10%; the theoretical curve for distribution of reserves of Kritski–Menkelnwas used, handled by the method of moments. The results have been shown in Table No.4.

4.6 Determination of water amount for makeup

For environmental demands, the said river site shall be provided with a minimum water amount with p=95%. In view of the goal of this study, the issue of makeup quantity is not relevant, since plans do not provided for water take-off from the riverbed during emergency clearing and reinforcing of the banks.

For makeup:

$Q\ min^{95\%} = 18$ l/sec.

The analysis and validation of data has been completed subject to compliance with the criterion for makeup river flow in case of water takeoff for various demands, as developed by the Ministry of Environment (refer to the Instruction for development of project part Environmental protection dated August 1993).

For makeup: Q min. environmental 0.1 Q av.=0,1 x 2,7 m3/sec = 270 l/sec.

For comparison – as per Ordinance No.RD-1385/year 2003 -> Q min 95%=120 l/sec.

Identified environmental minimum: 270 l/sec

Signature and stamp of eng. K. Gotsev

I, the undersigned Blaga Hadzhieva, Personal ID # 7105310010, do hereby certify that the foregoing translation from Bulgarian into English of the attached document, and namely: Explanatory note, is true and correct to the best of my knowledge. The translation comprises 11 (eleven) pages.

Translator: *Blaga Hadzhieva*

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