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Bridge deck runoff control trough drainage, treatment and irrigation system: The case study of the bridge Ostruznica over the Sava river

Contrôle des eaux de ruissellement d'un tablier de pont par le drainage, traitement et système d'irrigation : étude de cas du pont Ostruznica au-dessus de la rivière Sava

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RÉSUMÉ

Cette communication présente le projet primaire du drainage des tabliers du pont d'Ostuznica et du traitement des eaux de ruissellement. Une solution intégrale de drainage et d'irrigation et/ou d'eau de décharge dans la rivière Sava des eaux de ruissellement, prétraitées entre l'autoroute Dobanovci - Bubanj Potok et le pont, non loin de Belgrade. L'eau traitée est récupérée pour l'irrigation, en représentant la recharge des eaux souterraines, le long de la série de puits pour l'eau potable de la zone de protection sanitaire du système d'alimentation en eau potable de Belgrade. Une telle solution est considérée comme une source additionnelle d'eau à l'aquifère par les rives. En outre, elle constitue une mesure d'amélioration du cycle de l'eau. « First flush » doit être prétraité en utilisant les barils Stormfilters. Le projet est complété par le système Swerm pour empêcher les situations accidentelles, telles que les fuites, les accidents de véhicules ou la pollution potentielle, et les risques de vulnérabilité des puits d'eau potable.

ABSTRACT

The paper presents main design project of the bridge Ostruznica deck drainage and runoff treatment. An integral solution of drainage and irrigation and/or discharge water into the Sava river of pre - treated runoff from the portion of highway Dobanovci – Bubanj Potok and the bridge The treated water is taken for irrigation into the groundwater as a recharge, along the series of wells for potable water within sanitary protection zone of the Belgrade Water supply system. The first flush of the criteria rainfall runoff volume is to be pre - treated using a Stormwater[R] barrels. Such a solution is considered as an additional water source at the aquifer by the rivers' banks. Also, it is a measure of water cycle improvement. The project is completed by a Swerm[R] preventing system for accidental situation, such as leakage or accidents of vehicles and potential pollution and risks of vulnerability for the potable water wells.

KEYWORDS

Bridge deck, rainfall runoff, drainage, Ostruznica, river Sava, banks, pre-treatment, irrigation, aquifer recharge, accident pollution prevention

1 INTRODUCTION

Natural water cycle is severely altered by human activities and consequently are the changes in some components (e.g. precipitation, evapotranspiration, infiltration), while certain artificial components, such as leakage from water supply and waste water systems, storm water drainage systems could become an artificial groundwater recharge sources. Those changes influence surface and groundwater regimes, including mentioned recharge (Lerner 2002, Garcia-Fresca 2005).

An urban drainage design procedure, in general, cannot be easily taken into analysis of collecting storm water from a bridge deck and access roads. A bridge drainage system have multiple protection functions considering the bridge structure (either steel or concrete), to protect it from water infiltration into construction, or seeping over the structure downward to the fundaments.

This project could be also promising in respect to improvement of water cycle safety planning accounting of climate change, particularly when seasonal distribution and rainfall extremes' occurrence is evident, along large rivers,i.e. paved areas such as bridges and highway loops etc. (Lerner 2002, Garcia-Fresca 2005).

The main design project of the bridge drainage upstream Belgrade over the Sava river, includes a complex bridge deck and a portion of highway storm water drainage system, and is combined of the systems for two bridges: the existing and new adjacent one.

The solution is in conformity with the National regulations and recommendations concerning environment protection and also with the conditions and terms for limited discharge and quality of runoff specified by the relevant institutions, in order to obtain approvals on the technical solutions and entire design project.

2 HYDROLOGY DATA

For design purposes were used short duration high rainfall intensities from the Vracar rain gauge station, of return periods of the 20 years, 10 years and 2 years. The criteria rainfall for dimensioning of the system are of the probability 10%, or return period of 10 years, in accordance with the National Highway standards. For a series of the elements of the drainage system the following rainfalls were taken:

- For dimensioning of inlets / gullies are used rainfall of 5 minute duration and intensity,
- For dimensioning of the pipe system the calculations introduced by usage of model EPA SWMM by applying the dynamic wave (USEPA, 2004).
- In parallel to design storms, also were taken historical rainfalls (Petrovic, Despotovic, 1998).

3 CONCEPT OF THE BRIDGE DEWATERING AND DRAINAGE

In the concept of drainage system of rainfall runoff have been defined the following phases and relevant installation and equipment, i. e. the structures:

- Interception by inlets/gullies of the rainfall runoff surface,
- „Collection“ – interception of water from certain number of inlets/gullies by longitudinal pipes – collectors housed/attached under the Bridge structures,
- Pre – treatment of the runoff water on certain structures with filtration which include separation – settling or solid particles, separation of greases, oils and other pollution before discharge to the retention at the left and the right bank, duct filtrating the rainfall runoff (Despotovic, et.al., 2011).

Pollution of runoff from the bridge surfaces until certain moment is increasing than commence falling. The time sequence from the rainfall commence to the moment of concentration of pollution is diluted enough and acceptable for release into recipient without purification is the time of so called "first flush". There are many theories regarding this phenomenon (J. Despotovic, 2009).

The flushing time depends on the surface distance to the structure for pre-treatment and from intensity of rainfall. In this case the way is very short measurable in minutes, the intensities are of the short duration, such as 5 minute, and the washing time is dependent of the 15 mm of precipitation fulfilled by the condition for flushing of pollution from the Bridge. The criteria rainfall for the entire system is of 60 minute.

Drained rainfall runoff from the existing and designed bridge deck before discharge to the channels or to the Sava river have to be pre - treated what is aiming at deposition, separation and collection of sediment, oil, grease and other pollution. The chambers for pre – treatment consinsting of the numbers of Stormfilters, already tested at the bridge Gazela drainage system in Belgrade, (Despotovic, et.al, 2013). In this order is designed the treatment vault - deposit part and group of barells, the each of 2 l/s, the product of StormwaterItalia.

Gully choice / selection varies of the structure – concrete or steel and from the number of parameters and conditions (Despotovic, et.al, 2005). Based on laboratory experiment were chosen specific bridge deck inlets (Despotovic et al,2011).

The bridge structure was calculated based on temperature range $\pm$ 35^{o}C, and for compensation purposes were designed expansion compensators. Apart of those, for sagging dynamic load the compensators considerably decrease also damp vibrations what is important concerning fatigue of the pipelines. In vertical direction have been foreseen the flexibile receiving sagging of the pavement structure.

In general, the thorough system of the bridge dewatering and adjacent portions of the Highway drainage concept, consisting of:

- From the highest bridge deck point are designed 4 drainage pipes, for the each side and for the left and right banks, on the existing and new designed bridge, i. e. pipes 1, 2, 3, 4.
- The "Pipe 1" and "Pipe 3" connecting in the revision manhole R3-47 from where it is conducted together with the rain water from the Highway (Sections 1 & 2) on pre-treatment, than discharge into the retention pond. From the pond, treated water flow to the pump station close the Sava river. Immediately before retention was established an irrigation channel behind a series of the Ranney wells (W50 to W50) of the BWS (Fig. 1).
- The pipe along the support M5 joins the “Pipe 2” and “Pipe 4”, the lenght of 340 m conwey water to the structure for treatment for further discharge into the near-by channel.
- With regard to the quality of the collected water since such water is to be discharge to the irrigation channel, pre - treatment of oil, grease and other polluters should not be overlooked. This is important in particular due to the Belgrade water source protection zones on both Sava river banks. Concerning possible risks of vulnerability to the wells.

The calculation of the rainfall runoff from the relevant areas between two neighboring inlets / gullies based on Rational theory, according the formula, as follows: $Q(l/s) = B_m * L * i \times K_o$; while L (m) = inlet/gully distances, I = criteria 5 minute rainfall is of 449 l/s.ha, K_o = Runoff coefficient equal to 1, and the bridge width B_m = 14.3 m. The inlets are set at distances from 8.5 m, 10 m, 12 m, depending on longitudinal and cross slope of the pavement, and other parameters (Despotovic, 2009, 2014).

The technical solution was created under the preposition that the surface runoff spreading (directly upstream from the each inlet/gully) should not exceed the width of service lane, which is a space between the bridge edge and the fence at the bridge.

4 PREVENTION OF ACCIDENTAL TRAFFIC POLLUTION OF THE BANKS AND THE RENNY WELLS

The Ostruznica Bridge location being set at a vulnerable distance and within the protected zone for potable water wells and by all means it requires prevention of possible pollution due to the traffic. The subject of protection is the aquifer / bank of the river Sava area and Rennay wells on both banks of the Sava rivers, and also an instant pollution prevention and other road and drainage infrastructure. Otherwise, it is solved partially i. e. bit by design of collecting, evacuation and purification of the rainfall runoff in conformity to the European Directives in this area what was already constructed at the Gazela Bridge in Belgrade (Despotovic, et al., 2013)

For this purpose was proposed the system SW-ERM 03®, i. e. SW Environmental Risk Management 03®, presented in Fif 1 as Accident unknit. The solution consists of a concrete. structure furnished by equipment and sensors with relevant program (software) and other modern attachments as a local info system what allows among others also urgent traffic stoppage. This way with automatic closure of the outlet valve or action of the pump station as it is here the case, preventing splitting of the collected splash of liquid polluting matters into the drainage system, including support of radio connection and automatic equipment fulfils its function. It is also energetically efficient due to usage of the solar energy.

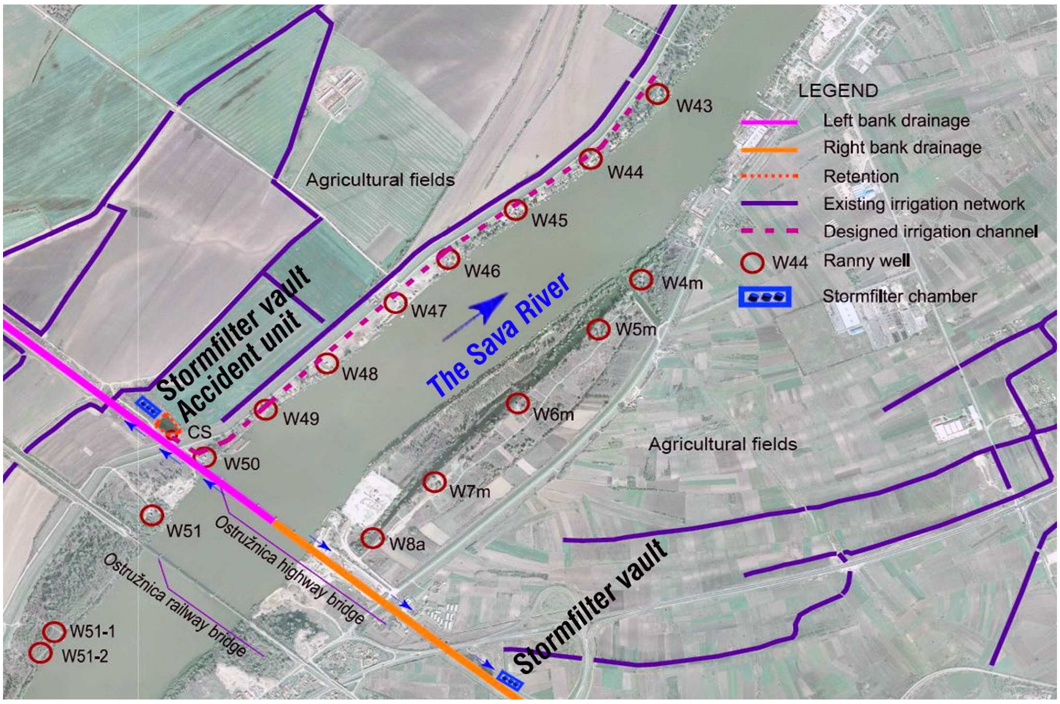

Figure 1. Layout of the Ostruznica bridge, and a series of Ranny wells and Stormfilter vault including an accident unit SWErm, at the left bank of the river Sava

The groundwater recharge by collected and pre-treated runoff from the Ostruznica bridge will be continually monitored using existing piezometers that will be completed with additional ones around the open retention pond, irrigation channel and the existing wells. Continual observation of groundwater level is designed, including water quality sampling on the two weeks frequency basis. The extended list of water quality parameters will be monitored in accordance with Serbian National legislation for drinking water quality.

5 CONCLUSIONS

The design project was not done traditionally nor bridge decks in urban conditions are frequently completed with a complex drainage and treatment systems like the one at the Ostruznica bridge over the Sava river. The compound drainage system included measures and devices concerning increase of the traffic safety and reliability of transport. In addition, to the drainage pipes are added pre - treatment and retention of the deck and incident loops' runoff. The part of the treated runoff is infiltrating into the potable water aquifer of the Belgrade wellhead, at the river left bank. Because of potential vulnerability, the overall assessment of the drainage and infiltration system should be evaluated upon a due and meticulous procedure including monitoring. On top of those is added an accidental alarm and pre caution system SWErm

Lots of usual polluters and several unusual, such as high iron - Fe and other metals' concentrations were found within the preliminary analysis of soil under the bridge at the banks. The drainage system also protected to a high degree the lower levels' loops pavements and also numerous city infrastructures, such as water supply systems, ground water drainage systems, electro-power channels, telephone chambers, etc. Proposed monitoring and improved modelling of the complex drainage, pre – treatment and infiltration system are expected to shape next design projects for ground water capacity increasing along the series of bridges and paved areas close and along the Sava and other rivers as the potable water sources in a wider area in Belgrade (Garcia-Fresca B., 2005).

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