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Flooding case study along a specific sector of Timiș River lower course

Alina-Ioana POPESCU-BUSAN[1] Gheorghe I. LAZĂR[2] Marie-Alice GHITESCU[1] Albert Titus CONSTANTIN[3] Şerban-Vlad NICOARĂ[3]

Abstract: By considering the special natural hydrographer developed in-between the 4th and 8th of April 2000, and also employing feasible water volumes estimated to overspill the protection side embankments, the authors established the water flowing possibility along the Lugoj-Coșteiu braced sector on the lower course of Timiș River, West plain of Romania, in order to study the flooding phenomenon.

Keywords: river engineering, high-water flow, flooding, flow modeling.

1. LOCATION AND SPECIFIC DATA

Several socio-economic objectives, such as the *"Land Use Plan - logistic warehouse, administration building, parking area, and access ways"* owned by LIDL ROMANIA L.P.C. [5], are to be developed in the adjacent area of the considered river sector. The land is part of the administrative territory of Lugoj Municipality, the North-West part of the outside building area, with a vehicle access from the near E70 roadway. The flooding case study was performed at the special request of the mentioned company, its investment place (figure 1.1) being situated at about 1km from the right side protection embankment, northward bordered by the elevated belt road of Lugoj Town. The development place covers an area of about 180m^2 with a land level of about 115.30mSL.

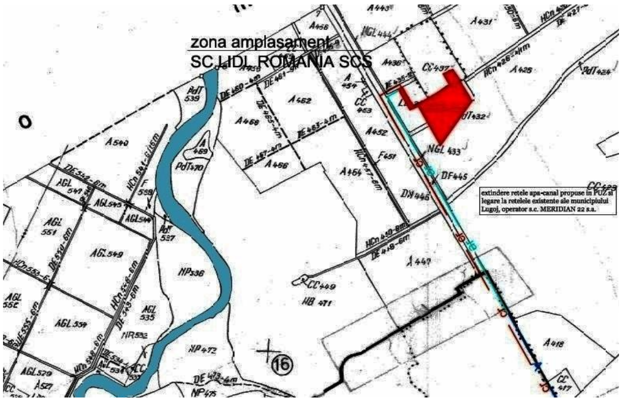

Figure 1.1 Site plan of the socio-economic development area with respect to the Timis watercourse

The Timiș River downstream of Lugoj Town, on the sector towards Coșteiu Hydrotechnical Arrangement (HA) and beyond, is both sides braced by embankments spaced at a variable span of 150m to 500m [3].

The unfavorable conditions of the natural environment are represented by the immediate areas of potential flooding risk on the river major valley, up to the level imposed by the side embankments. Following some rich precipitations that occurred in the years of 2000 and 2005, significant accidental flooding with severe social and economic impact happened along the main course of the river.

An extraordinary high water flow occurring in April 2000 (with the maximum flow of 1247m^3/s registered at Lugoj Hydrometric Station) produced an overspill on the left side embankment along the studied river sector Lugoj – Coșteiu HA. It is mentioned that the river embankments were designed for an Importance Class of level IV, to which the corresponding water flow on site was given at $Q_{2\%}$ = 1100m^3/s.

Later on, due to the remarkable high water flows that occurred in April 2005, the protection left side embankment on the same sector was superficially breached for a length of about 154m, down to the minimum level of about 115.90mSL (with respect to a dike top level ranging initially from 116.20 to 116.60mSL). There can be mentioned that a lateral discharge corresponding to a river water flow as low as of 5% overrun probability is to be produced for this level.

In the same time, one should keep in mind another flooding related aspect for the outside building area: heavy rainfalls determine the groundwater local rising which corroborates with overpassing the soil infiltration capacity, meaning a poor draining capacity towards a collecting canal proposed for relocation on the east side of the development space.

A flooding study case represents an evaluation of the flowing maximum parameters required in order to further on estimate the safety hazard under the lately specific conditions in this part of the country. The uncommon high-water of the last years proved of changed values for the standard parameters with respect to those considered by the nowadays technical codes or by the former design projects based on which the hydraulic arrangements were developed.

[1]assist.prof.dr.eng, [2]conf.dr.eng, [3]lect.dr.eng, POLITEHNICA University Timisoara, Department of Hydrotechnics, 1A George Enescu, 300022, Timisoara, Romania, e-mail: gheorghe.lazar@upt.ro

A stretch of about 1675m in length (figure 1.2) was considered in order to model the Timiș river course geometry on the Lugoj Town downstream sector towards Coșteiu HA. A specific data base, developed and supplied by MULTILINES Ltd. Company from Timisoara [5], consisting on a leveled plan view (“Stereo70” topographic measurements), 11 cross river profiles used to better distinguish the river bed and its major valley (floodplain), and 3 longitudinal profiles respectively (one along the thalweg and one along each embankment top) was employed. The cross river profiles, variably spaced, present the start (on the left bank) and the end (on the right bank) level points, and several intermediate points in the river course and on the side embankments respectively.

Figure 1.2 Aerial view (Google Maps) of the studied 1675m length and its left side adjacent area on the lower course of Timiș River in the West plain of Romania

Concurrently, the following specific data need to be considered in order to perform the hydraulics of flooding phenomenon [2], meaning to study the water flow transition along the Lugoj – Coșteiu HA sector (water levels and velocity regime development): maximum flows of several overrun probabilities ($Q_{0.5\%}$, $Q_{1\%}$, $Q_{2\%}$ and $Q_{5\%}$), the high water hydrographer development, the roughness ratios in the river bed and its major course, the watercourse hydrodynamic grade and the level-flow curve. Thus, hydrological data were supplied by “Romanian Waters” National Administration (RoWNA), the Banat Branch.

The nowadays considered water flow values of several overrunning probabilities for the subjected sector on Timiș River are given by table no.1.1.

Table no.1.1

Crt. no.	River	Cross section	F [km^2]	Qmax [m^3/s]					
				0.1%	0.5%	1%	2%	5%	10%
1	Timiș	“Logistic warehouse Lugoj”	2827	2520	1540	1266	1100	860	695

We have to mention that these values are produced according to the present artificial geomorphological conditions for the flowing phenomenon on the entire Timiș River catchment basin, altered by all the hydrotechnical arrangements, side protection embankments mainly. The presented values do not yet include the safety ratios stipulated by the specific designing codes.

The high water hydrographer registered in April 2000 at Lugoj Hydrometric Station and supplied by RoWNA shows the phenomenon development and its peak flow value of 1247 m^3/s materialized on the evening of April 6th (at 20:00 – 21:00). The specific hourly values of the water level and flow, supplied by a spreadsheet, are synthesized by the hydrographer in figure 1.3. One can notice that the mentioned registered historical value gets very close to the value considered to match the 1% overrunning probability.

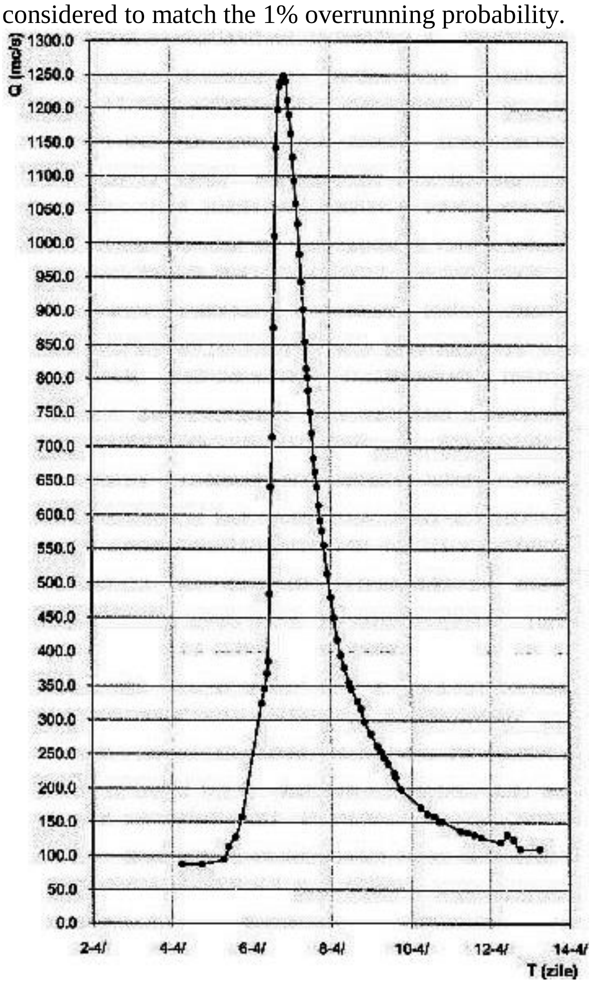

Figure 1.3 High water hydrographer, registered on April, 2000

In order to study the water flow regime either for the streambed and the river major valley and to estimate the discharge capacity respectively, a numerical modeling is to be developed by assuming different flow possibilities. For all performed numerical simulations, this graph shape was assimilated as it would similarly correspond to each of the maximum flow values given for the different overrunning probabilities.

As registered and supplied by RoWNA, the water flow at Lugoj Hydrometric Station on November 11th, 2014, was of 17.88m^3/s, to which the measured level of 110.80mSL at cross river profile S4 was corresponding. Several photos shot on late November, 2014, during a foot trip along the about one and a half river kilometers sector are presented here also.

2. IMPORTANCE CLASS AND CORRESPONDING FLOWS

The main hydrotechnical works developed on site are considered as corresponding to the importance class of III - middle, thus the dimensioning water flow of a 2% overrunning probability and the confirmation water flow of a 0.5% overrunning probability need to be consequently considered [2] (see previously presented values). In order to reach more conclusions about the water transport regime, the other two flow values of 1% and 5% overrunning probability had to be employed [5].

A high water hydrographer corresponding to the dimensioning flow of 2% overrunning probability ($Q_{2\%}$ = 1100m^3/s) was synthetically generated (HEC-RAS 4.1 software package) by considering the high waters configuration registered on April 2000 (of Q_{max} = 1247m^3/s) upon which a sizing ratio of 0.882 was enforced. As alike, the high water hydrographer corresponding to the verification flow of 0.5% overrunning probability ($Q_{0.5\%}$ = 1540m^3/s) was generated by enforcing a sizing ratio of 1.236 upon the same registered graph.

By the help of HEC-RAS 4.1 software package [4], one can develop a flow transition model either corresponding to a stationary regime (constant flow) or to a transitory regime (time developing flow – water hydrographer), both for natural site conditions of a river course or for artificial conditions as determined by specific arrangements. The numerical modeling employed by the present study looks to estimate both the maximum flooded area and the maximum flowing speed in the river streambed and across its major valley along the Lugoj – Coșteiu HA sector of Timiș River, and at the over spilling places.

3. GENERAL CONSIDERATIONS REGARDING NUMERICAL MODELING OF WATERCOURSE FLOW

3.1 DEVELOPMENT OF NUMERICAL MODEL

The given morphological situation centers on topographical measurements as materialized in a leveled plan view and several longitudinal and cross river profiles [5]. A section length of about 1675m was cut out from the known mentioned river route in order to develop the foreseen numerical model. This section was divided in 20 straight segments bordered up- and down-stream by the mentioned 11 cross river profiles and 10 other additional ones interpolated by the modeling software (figure 3.1).

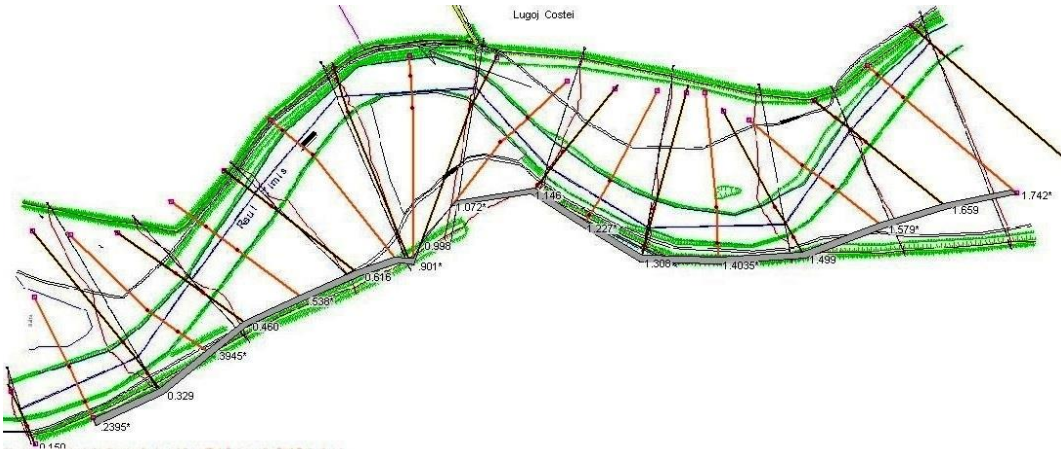

Figure 3.1 Site plan view indicating the cross river profiles and over spilling left side considered structure (“km 1.700”) – schematic presentation on HEC-RAS from “km 1.825” to “km 0.150” (model entrance / exit), topographic plan overlaid

As engaging the HEC-RAS 4.1 software, in order to properly identify the cross view profiles, a milestone type of numbering was employed [3], the denomination being a numerical value representing a real number. This is a useful method for generating new interlaced cross views (automatic interpolation profiles) between given topographic measurements in order to reach a thickened domain.

The left side embankment over spilling monitoring was prepared by considering a lateral fictitious structure as a wide step spillway with a discharge ratio md = 0.248. The plan configuration follows the points given by the topographical measurements as presented in the left bank longitudinal profile.

The following symbols were engaged in the model for the 21 consecutive cross river profiles with respect to their position, considering a decreasing sequence from the upstream start cross view toward the downstream ending one:

“1.825” (← corresponding to the topographic measured cross view S11), “1.742*”, “1.659” (←S10), “1.579*”, “1.499” (←S9), “1.403(.5)*”, “1.308” (←S8), “1.227*”, “1.146” (←S7), “1.072*”, “0.998” (←S6), “0.901*”, “0.804” (←S5), “0.710*”, “0.616” (←S4), “0.538*”, “0.460” (←S3), “0.394(.5)*”, “0.329” (←S2), “0.239(.5)*”, “0.150” (←S1); those labeled with an asterisk being the ones obtained by automatic linear interpolation by the software.

As the unit part of the labeling number represents the cross river related kilometer and the decimal part gives its specific position in meters, the difference between two labels shows their spacing distance measured along the river thalweg.

The over spilling side structure fictitiously considered on the Timiș River left bank is marked by “1.700” (figure 3.2).

The roughness coefficient was considered as variable for a cross river profile and also from one profile to another in-between the following limits: n = 0.065 … 0.085 for the major watercourse (depending on soil type and vegetation) and n = 0.035 for the minor riverbed. Four surface flowing scenarios were considered as to be performed in a computer simulation for the studied river sector.

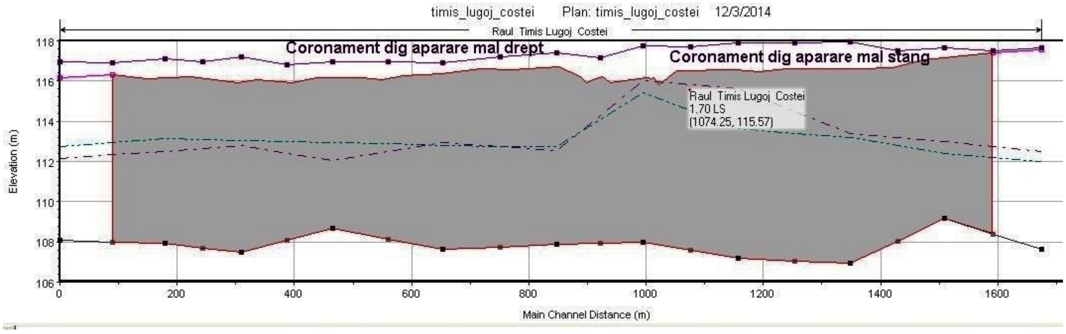

Figure 3.2 Longitudinal profile along the top of left side protection embankment, indicating the lateral over spilling considered structure "km 1.700" and the top levels development of both left and right embankments

3.2 INITIAL AND BOUNDARY CONDITIONS, NUMERICAL SIMULATION

As a common procedure [1], the boundary conditions on the river sector are given by the passing water flow of a specific overrunning probability (engaged by the help of the synthetic high-water hydrographer, values of which are attached to the upstream start cross river "km 1.825") and the water flow – surface level relationship curve (which is to be considered for the ending cross river "km 0.150"). As about the initial conditions, the starting water flow value is to be considered as known for the start cross river "km 1.825".

The initial starting conditions together with the boundary ones, as engaged for the four running scenarios, are as follows [5]:

Scenario I. Water flow simulation on Timiș River as an unsteady regime for the existing embankment conditions and considering the synthetic hydrographer corresponding to the flow of 5% overrunning probability → $Q_{5\%}$ = 860m^3/s, employed for setting the model:

• initial flow imposed to the start upstream cross river "km 1.825" $Q_{\text{Nov.10,2014}}$ = 17.88m^3/s,

• the estimated hydrodynamic grade J corresponding to the downstream ending cross river "km 0.150" varies in-between 0.000285 and 0.00095,

• the water level established by topographic means at cross river "km 0.616" (←S4 topographic profile) of 110.80 mSL,

• the obtained (and further on imposed) water flow – surface level relationship at the ending cross river "km 0.150", graphic presented by figure 3.3-I (water level expressed in mSL);

Successive running of the numerical model for several values of the riverbed and floodplain roughness coefficient and of the hydrodynamic grade downstream of cross river "km 0.150" were performed. The obtained values of the water surface elevation at cross river "km 0.616" were compared with corresponding elevation (topographic measured at cross view S4 on November 10, 2014) until a match to 110.81mSL was reached. For these values of the varied parameters the numerical model was considered as set up and the water flow – surface elevation relationship was saved as input data for the next flowing scenarios.

Scenario II. Water flow simulation as an unsteady regime for the existing embankment conditions and considering the synthetic hydrographer corresponding to the flow of 2% overrunning probability → $Q_{2\%}$ = 1100m^3/s, as requested for a dimensioning design phase:

• the synthetic hydrographer attached to the start upstream cross river "km 1.825",

• the flow – level relationship imposed at the ending cross river, as presented by the graphic in fig. 3.3-II;

Scenario III. Water flow simulation as an unsteady regime for the existing embankment conditions and considering the synthetic hydrographer corresponding to the flow of 1% overrunning probability → $Q_{1\%}$ = 1266m^3/s:

• the synthetic hydrographer attached to the start cross river,

• the flow – level relationship imposed at the ending cross river, (figure 3.3-III);

Scenario IV. Water flow simulation as an unsteady regime for the existing embankment conditions and considering the synthetic hydrographer corresponding to the flow of 0.5% overrunning probability → $Q_{0.5\%}$ = 1540m^3/s, as requested for a verification design phase:

• the synthetic hydrographer attached to the start cross river,

• the flow – level relationship imposed at the ending cross river, (figure 3.3-IV).

The numerical modeling of the synthetic generated high water hydrographers (Scenarios I to IV) was performed for a given significant time interval, specifically starting on April 1st, 01:00 hours, and ending on April 8th, 21:00 hours, 2000. Even if a time step Δt = 1min was adopted for running the numerical analysis, there was considered as rather adequate to save the output data at the end of every hour

3.3 OUTPUT DATA

All specific steady and time depending parameters, concerning the water level and flow or velocity, were reached by running the numerical simulated model considered for the four mentioned flow transit scenarios. The software output was post processed and digitally stored in order to be studied by analyzing table values or by graphic visualizing the phenomenon development.

[1]assist.prof.dr.eng, [2]conf.dr.eng, [3]lect.dr.eng, POLITEHNICA University Timisoara, Department of Hydrotechnics, 1A George Enescu, 300022, Timisoara, Romania, e-mail: gheorghe.lazar@upt.ro

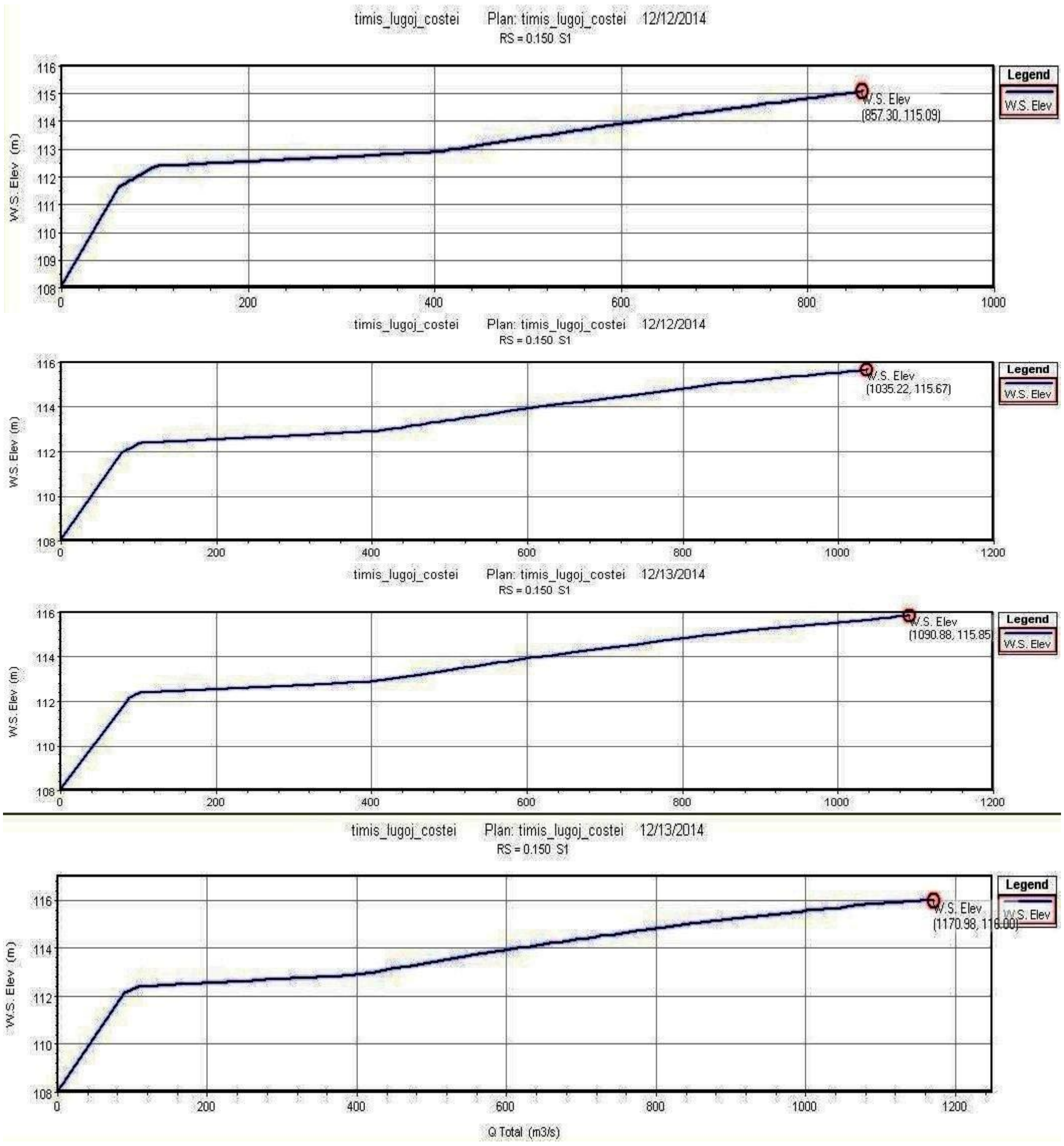

Figure 3.3 -I, -II, -III, -IV Water flow (mSL) – surface level relationship at "km 0.150" (←S1), Scenario I (model setting) and Scenarios II, III and IV (imposed)

The meaning of the specific parameters, considered as significant to be mentioned in this paper, is as follows [5]:

PF1 = the cross river profile attached to a cross section where the existing geometry and water level are registered; **Q Total** = the whole water flow in m3/s transiting the studied sector of Timiș River watercourse at a given moment; **Min Ch El** = the minimum level in mSL for the riverbed – thalweg; **WS Elev** = the water surface elevation in mSL in a cross river profile associated to a given cross section; **Crit WS** = the water surface elevation in mSL corresponding to the critical flowing regime in a given cross section; **EG Elev** = the hydrodynamic elevation in mSL, meaning WS Elev + velocity head ($\alpha v^2/2g$), in a cross river profile associated to a given cross section; **EG Slope** = the hydrodynamic grade associated to the length between two cross river profiles; **Vel Chnl** = the mean water velocity in m/s for a given cross section on the river course; **Flow Area** = cross section flowing area in m^2 for a given profile; **Top Wdth** = the total opening in m at the water surface for a given cross section; **Froude #Chl** = the Froude number of the river course.

The following figures look to show, as for a medium level scenario between those corresponding to the dimensioning and the verification design phases, some of the main specific output post processed as graphic developments:

• maximum water surface elevations (mSL) and consequent velocity spectrums (m/s) for several cross sections, corresponding to conditions considered in Scenario III (figures 3.4);

• maximum water surface elevation development with respect to the left and right embankments top levels along the considered 1675m length in the Lugoj – Coșteiu HA river sector, due to the synthetic high-water hydrographer corresponding to Scenario III, 1% overrunning probability (→ $Q_{1\%}$ = 1266m^3/s, fig. 3.5);

• water flow and water surface elevation development with time at profile "1.700" attached to the considered left side over spilling structure, corresponding to Scenario III (figure 3.6);

• water surface elevation and flow development

[1]assist.prof.dr.eng, [2]conf.dr.eng, [3]lect.dr.eng, POLITEHNICA University Timisoara, Department of Hydrotechnics, 1A George Enescu, 300022, Timisoara, Romania, e-mail: gheorghe.lazar@upt.ro

with time at profiles “1.825” and “0.150” (figure 3.7), corresponding to Scenario III;

• water flow – surface level relationship at “km 0.150” (←S1) obtained by considering Scenario I (as model setting), and then imposed with the same pattern for running Scenarios II, III and IV (figure 3.3-I…IV).

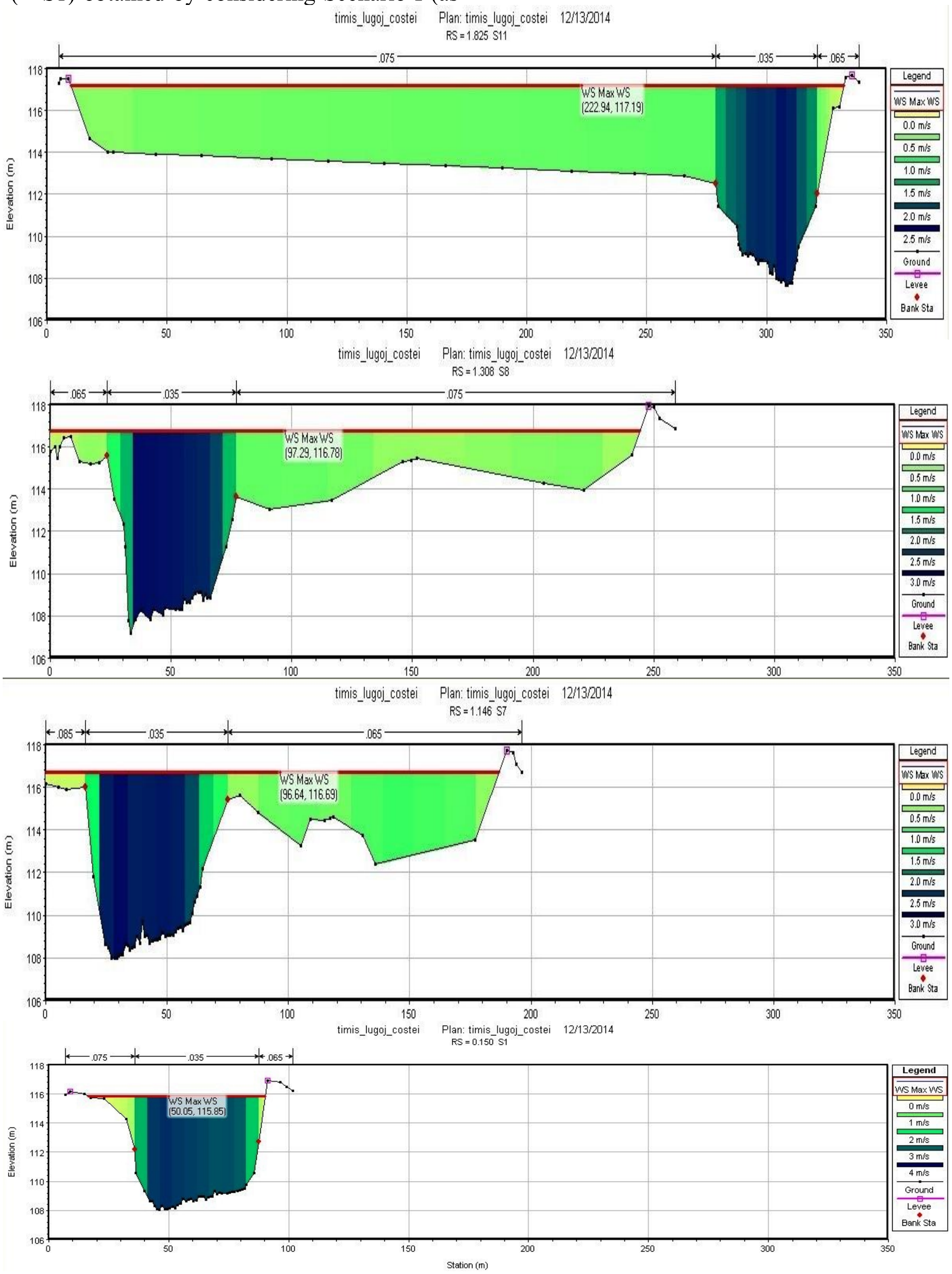

Figure 3.4 Water levels and consequent velocity spectrum at “km 1.825” (←S11), “km 1.308” (←S8), “km 1.146” (←S7) and “km 0.150” (←S1), Scenario III

As shown by output graphs, the water surface maximum elevations are presented in table no.3.1 alongside other related geometrical and flowing parameters corresponding to Scenario III. Thus, one can consider the water elevation values calculated in the 11 cross river profiles (given by topographic measures) with respect to the top of the side embankments. There is consequently obtained that the left side embankment was over spilled in the area of cross profile S7 with a maximum water elevation of 116.69mSL, meaning with a head of Δh = 116.69-115.84 = 0.85m. The correspondingly maximum discharge reaches at 174.47m^3/s and so the total volume of water that spread through the gap over the near plain was estimated as 6384.27x103 m^3.

4. CONCLUSIONS OF THE FLOODING CASE STUDY

The conclusions drawn from the performed flooding case study along the specific Lugoj – Coșteiu sector on Timiș River lower watercourse are based on the output supplied by HEC-RAS 4.1 specialized software which was engaged for running four numerical modeled scenarios [5].

As shown by the output of Scenario III (unsteady flow regime for the existing embankment conditions, the synthetic hydrographer of 1% overrunning probability, $Q_{1\%}$ = 1266m^3/s), one can conclude that these specific conditions determine a complex water flow covering both the riverbed and major valley and also over spilling the left side protection embankment.

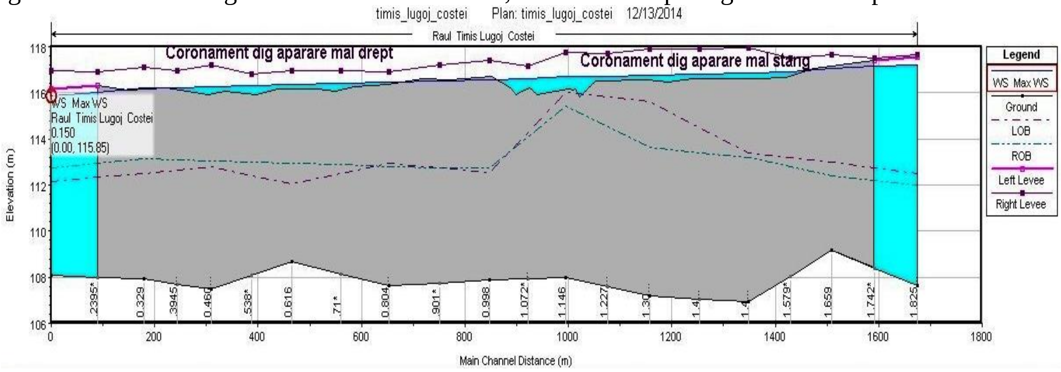

Figure 3.5 Maximum water level development from “km 1.825” (←S11) to “km 0.150” (←S1), Scenario III

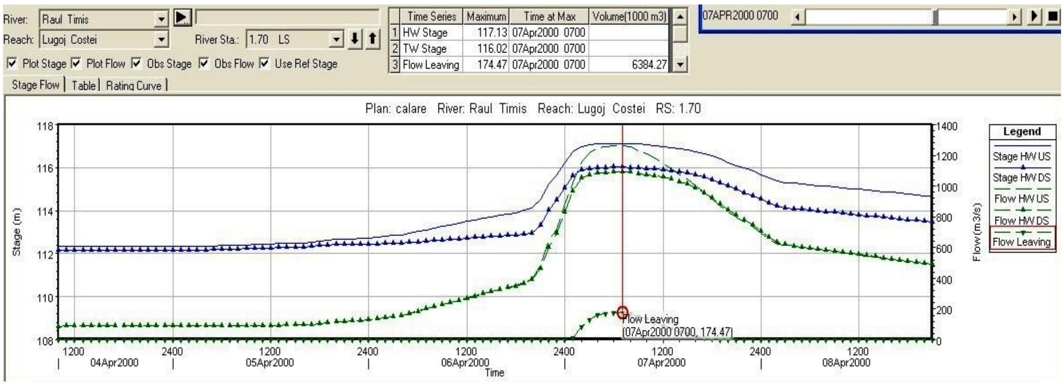

Figure 3.6 Water flow and surface elevation (mSL) time development at “km 1.700” (left side over spilling structure)

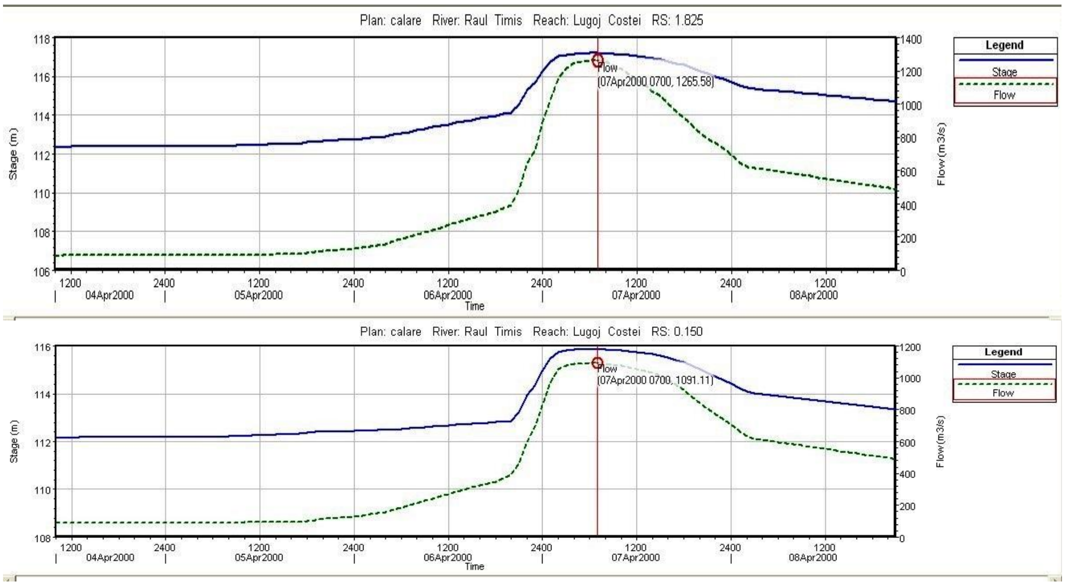

Figure 3.7 Water level (mSL) and flow time development with time at “km 1.825” (←S11) and “km 0.150” (←S1)

We have to mention that the original design of the entire water arrangement, meaning mainly the river framing by the side protection embankments, considered an overrunning probability of 5% for the dimensioning stage and of 1% for the confirmation stage, respectively.

It can be noticed from the graphic output that the maximum water flow through the end cross view (S1) is 1171.19m3/s, meaning below the 1% overrunning probability flow ($Q_{1\%}$ = 1266m^3/s), while the left side embankment is over spilled at a discharge of 370.28m^3/s. As about the right side embankment, there was obtained that it won’t be over spilled not even for the exceptional flow corresponding to the 0.5% overrunning probability ($Q_{0.5\%}$ = 1540m^3/s).

The flooding safety margin can be established by interpreting the maximum water surface elevations with respect to the side protection embankments top level at each cross river profile. Table 4.1 present such margin values as obtained for the exceptional flow considered by Scenario IV. One can notice the negative values indicating an almost general over spilling of the left side embankment.

We need to highlight here that the numerical model considered only the possible over spilling of a given enduring structure, without breaching the side embankments which would be very like to happen (and harshly develop) in a real life high-water situation.

Table no.3.1

HEC-RAS Plan: calare River: Raul Timis Reach: Lugoj Costei Profile: Max WS — Reload Data

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
Lugoj Costei	1.825	Max WS	1265.58	107.65	117.19		117.31	0.000358	2.03	1338.98	322.20	0.23
Lugoj Costei	1.742*	Max WS	1265.58	108.40	117.14		117.28	0.000413	2.13	1148.21	270.67	0.25
Lugoj Costei	1.70		Lat Struct									
Lugoj Costei	1.659	Max WS	1265.58	109.15	117.07		117.25	0.000506	2.27	954.69	229.21	0.28
Lugoj Costei	1.579*	Max WS	1264.08	108.04	116.93		117.25	0.000699	2.75	742.04	239.77	0.33
Lugoj Costei	1.499	Max WS	1253.99	106.94	116.85		117.21	0.000763	2.89	702.56	233.89	0.34
Lugoj Costei	1.4035*	Max WS	1243.55	107.07	116.81		117.14	0.000761	2.79	740.07	239.12	0.33
Lugoj Costei	1.308	Max WS	1231.09	107.19	116.78		117.05	0.000663	2.55	809.07	244.36	0.30
Lugoj Costei	1.227*	Max WS	1222.39	107.58	116.73		117.00	0.000692	2.55	755.93	215.54	0.31
Lugoj Costei	1.146	Max WS	1193.06	107.97	116.69		116.94	0.000715	2.48	701.33	186.76	0.31
Lugoj Costei	1.072*	Max WS	1157.54	107.92	116.59		116.93	0.000779	2.77	654.32	235.56	0.34
Lugoj Costei	0.998	Max WS	1142.56	107.87	116.56		116.88	0.000699	2.79	766.54	275.95	0.32
Lugoj Costei	.901*	Max WS	1142.56	107.75	116.51		116.80	0.000702	2.72	799.17	285.54	0.33
Lugoj Costei	0.804	Max WS	1142.25	107.63	116.47		116.72	0.000688	2.57	845.28	289.54	0.32
Lugoj Costei	.71*	Max WS	1136.18	108.15	116.41		116.65	0.000602	2.44	815.81	268.91	0.30
Lugoj Costei	0.616	Max WS	1123.72	108.67	116.38		116.60	0.000529	2.29	788.25	238.85	0.28
Lugoj Costei	.538*	Max WS	1111.98	108.08	116.32		116.57	0.000565	2.42	747.27	226.01	0.29
Lugoj Costei	0.460	Max WS	1099.84	107.48	116.24		116.54	0.000667	2.63	676.81	221.50	0.31
Lugoj Costei	.3945*	Max WS	1092.37	107.70	116.21		116.49	0.000645	2.55	698.61	254.42	0.31
Lugoj Costei	0.329	Max WS	1091.64	107.92	116.22		116.44	0.000514	2.29	798.39	291.75	0.28
Lugoj Costei	.2395*	Max WS	1091.11	107.99	116.02		116.42	0.000817	2.85	478.23	185.80	0.35
Lugoj Costei	0.150	Max WS	1091.11	108.07	115.85	112.68	116.34	0.001001	3.10	370.81	73.61	0.38

Table no.4.1

Crossview	Thalweg level [mSL]	Water level model [mSL]	Left side bank embankment level [mSL]	Left side „safety" height [m]	Right side bank embankment level [mSL]	Right side „safety" height [m]
0	1	2	3	5	4	
S11	***107.65***	117.46	***117.54***	+0.08	***117.66***	0.20
S10	***109.15***	117.31	***117.08***	-0.23	***117.66***	0.35
S9	***106.94***	117.04	***116.66***	-0.38	***117.86***	0.82
S8	***107.19***	116.98	***116.48***	-0.50	***117.92***	0.94
S7	***107.97***	116.87	***116.18***	-0.69	***117.73***	0.86
S6	***107.87***	116.74	***116.59***	-0.15	***117.44***	0.70
S5	***107.63***	116.64	***116.53***	-0.11	***116.93***	0.29
S4	***108.67***	116.54	***116.38***	-0.16	***116.98***	0.44
S3	***107.48***	116.41	***116.16***	-0.25	***117.19***	0.78
S2	***107.92***	116.40	***116.08***	-0.32	***117.09***	0.69
S1	***108.07***	116.00	***116.17***	+0.17	***116.95***	0.95

In conclusion, based on the four scenarios considered for the river flow numerical model, we can say that the water transit along the studied sector of the river course also produces a side over spilling for a length spreading from about 470 to 1300m when the water flow goes above the dimensioning value given by the overrunning probability of 2% ($Q_{2\%}$ = 1100m^3/s). While the right side flooding protection (for the investment place inclusively [5]) resulted to be covered by the existing embankment, the left side embankment does not meet the current requirements.

Still, until some extend, the superficial breach that occurred in the spring of 2005 and the general lower top of the left side embankment (erosions due to previous over spilling) seem to work in favor for the transition of the dimensioning / confirmation water flows (2% / 1% overrunning probability) as long as the left floodplain can be employed for now as a natural attenuation polder.

In case of exceptional situations with water flows coming close to the value corresponding to the 0.5% overrunning probability ($Q_{0.5\%}$ = 1540m^3/s), special measures should be considered for the right side embankment for those sections with low safety margins (cross river profiles S11, S5, S10 and S4 at least).

5. REFERENCES

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