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NEW APPROACH ON ENVIRONMENTAL FLOW ASSESSMENT OF MOUNTAIN STREAMS IN THE REPUBLIC OF MACEDONIA

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Environmental flow is defined as the flow that is necessary to ensure the existence of habitats in a stream. According to the practice in Macedonia, environmental flow is 10% of mean annual flow but flow variation is significant and this approach could generate doubts for engineers. The final aim of this study was to be recommended the most appropriate method for this engineering purpose in Macedonia. This study consists of two parts: a) evaluation of the most used world methods in national conditions, and b) defining of environmental flow using previously selected method on case study. The proposed approach was tested for the "Dragor" water supply system. Using basically Tennant approach, and making modification according to the regional circumstance related to hydrological regime, environmental flow was calculated for 3 different periods of flow values that's follow the hydrogram.

Key words: environmental flow assessment; mountain stream

INTRODUCTION

With the enforcement of the new Water Law in the Republic of Macedonia (RM) that is in accordance with the European Water Frame Directive (WFD) (2000/60/EC), the Ministry of Environment and Physical Planning (MOEPP) is expecting a large number of applications for water usage permits. Since the legal instrument of water use permit is new in Macedonia and there is a lack of experience in enforcement, the MOEPP needs a precise support regarding law enforcement. In accordance with the WFD requirements, this also includes defining of environmental flow. Environmental flows describe the quantity, timing, and quality of water flows required to sustain freshwater and estuarine ecosystems and the human livelihoods and well-being that depend on these ecosystems [1].

Due to the natural conditions in the country, water flows significantly vary and the research by Škoklevski Ž. [2] showed significant variation even of the river of Vardar flow (Q_{min} = 6,2 m^3/s – year 1952; Q_{max} = 1310 m^3/s or 1595 m^3/s, year 1962). On the other hand, the small stream flow is more unstable. According to the practice in water sector in the Republic of Macedonia, minimal acceptable water flow (environmental flow) is defined as 10% of the mean annual flow. This is the simplest conservative approach that very often causes problems in practice because of the great variety of water flow. This approach should be improved or change with more pragmatic and precise method.

That was a reason for launching this study. The **general aim** of this study was the selecting/development of the most appropriate method for environmental flow assessment in the RM and the testing its applicability on a case study. The study consists of two parts: selecting of a most appropriate approach and testing of the selected method.

Objectives of the first part of the study were:

– Analyzing current methods in the world and needed data;

– Defining available data in the RM;

– Evaluation of the applicability of these methods in national conditions.

Subject of the second part is applicability of Tennant method in Macedonian conditions through case study.

Objectives of the second parts of the study were:

– Defining various flows using geospatial hydrology methods and approaches;

– Defining environmental flow using few/approaches;

– Comparative analysis between results obtained by other methods and proposed approach.

METHODOLOGY

Research methodology was adapted to the objective needs. Regarding the defining of the most appropriate method for environmental flow assessment (EFA), several criteria were set before starting the work. The new method/approach should satisfy the following needs: to be aimed for defining environmental flow of mountain streams; to be appropriate to water resource planning and practice; data to be easy available; to be simple without requirement for high scientific knowledge; assessment to be fast; to be cheap.

The qualitative method was used for analyzing the applicability of the most world used methods in national conditions. Evaluation of data availability for usage of various methods was done using qualitative method. For economic evaluation of the methods were used foreign experiences.

The case study region covers "Dragor" water supply system. Water received in filter station "Dihovo", originates from 3 sources: "Dragor" system (managed by PCE Bitola); surface water collector (managed by PE "Streževo" – Bitola); reservoir Streževo through main channel (managed by PE Streževo – Bitola). Maximal average daily water consumption in July and August is over 600 l/s although picks are near 900 l/s. The study area is located on the east slopes of the Baba Mountain, upstream from the village of Nižepole and fully belongs to the Nationla Park "Pelister". It consists of four stream catchments that form the Dragor river. Crvena Reka river catchment covers the north part of the study area. Ezerska Reka river (Lak Potok) is located in the mid part, while Sapundjica (including Stara Buka catchment) covers the south part of the area. Total catchment area is 37,2 km^2 and is distributed as follows: Crvena Reka (12,99 km^2), Ezerska Reka (3,85 km^2), Stara Buka (2,66 km^2) and Sapundjica (13,22 km^2). All natural conditions (topography elements, climate elements, geological and pedological structure, and vegetation cover) enable high values of flow, over 20 l /s km^2.

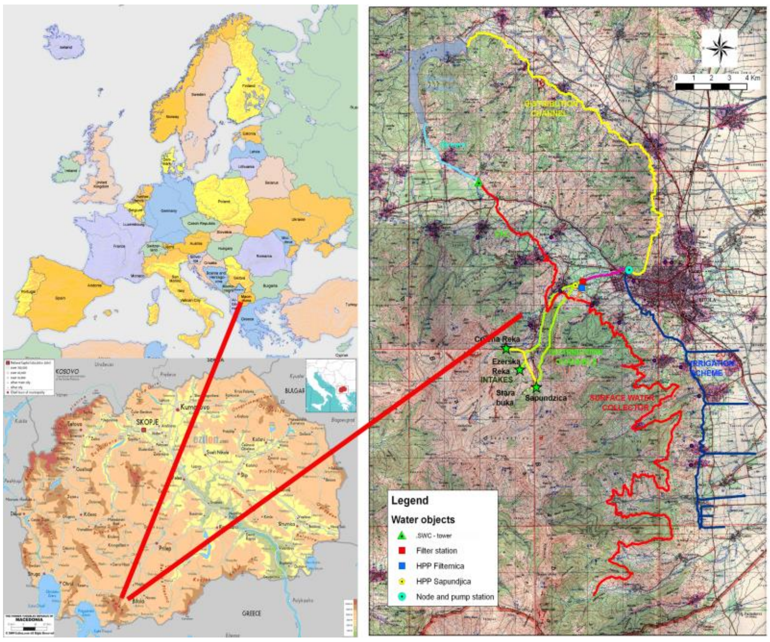

Figure 1. Study area location

Measuring data from the study area do not exist. A long-term hydrologic prediction in ungauged basins is one of the critical issues in the field of hydrologic calculations. Wang et al. [10] states that hydrologic analogy is an important method for long-term hydrologic prediction and hydrologic calculation in ungauged basins. There is a gauge station on the Dragor river (downstream from the village of Nižepole) but this data was not useful because significant amount of water has already been used. In the vicinity, there are measuring stations on the rivers of Semnica and Brajčinska Reka. Brajčinska Reka is adjacent and was selected as a referent basin. The flow module was defined on the basis of a deep comparative analysis of factors affecting the flow between the study region and the selected reference catchment was defined flow module. This value was later used for calculation of minimal average and maximal flow using correction based on the comparative analyze.

Environmental flow was firstly calculated using original Tenant method. Results were compared with real hydrogram. Because of significant deviations was developed a new approach that follows the hydrogram variation more precisely then using Tennant method. This new approach was tested per month.

THEORETICAL BACKGROUND

There are a lot of methods for calculating the minimum (environmental) flow that is required for water habitats. Each method takes different properties of water habitat into account. That is why these methods depend on different assumptions. Different methods are used in different countries.

According to Tharme [3] there are more then 200 environmental flow assessment (EFA) methods. Pyrce [4] classified all methods in 4 groups: a) hydrological methods; b) hydraulic rate methods; c) habitat simulation methods; d) holistic methods.

Using hydrological or so-called historical flow methods, environmental flow is calculated by using daily and monthly measurement values or using flow measuring data.

Hydraulic methods relate various parameters of the hydraulic geometry of a watercourse channel to discharge. The most commonly used hydraulic method is the wetted perimeter. The wetted perimeter method is the simplest of the field survey-based, site-specific techniques that allows the minimum instream flow of a watercourse to be calculated, it should be noted that the wetted perimeter technique includes no explicit representation of the aquatic habitat, The wetted perimeter of a watercourse is defined as the length of the line of intersection of the channel wetted surface with a cross sectional plane normal to the direction of the flow [5].

Habitat rating methodologies use changes in simple hydraulic variables, such as wetted perimeter or maximum depth, usually measured across single, flow-limited river cross-sections (commonly riffles), as a surrogate for habitat factors known or assumed to be limiting to target biota [6]. According to Hatfield, T. et al [7] habitat rating methods provide the most complex and the most flexible approach to environmental flow assessments. These methods provide information on how habitats change with flow for instream uses, either biological or recreational. The most exposed habitat-rating method is Instream Flow Incremental Methodology

Holistic methodologies aim to address the water requirements of the "riverine ecosystem" rather than the needs of only a few taxa. They share a common objective – to maintain or restore the flow-related biophysical components and ecological processes of in-stream and groundwater systems, floodplains and downstream receiving waters (e.g. terminal lakes and wetlands, estuaries and near-shore marine ecosystems). There are numerous methods that belong to this group as follow: Holistic Approach, Building Block Methodology, Scientific Panel Assessment Method, Habitat Analysis Method, Benchmarking Methodology etc.

Each method has it own advantages or disadvantages. Some methods are based only on hydrological data, some methods are based only on hydraulic data. On the other hand, there are methods that encompass hydrological, hydraulic and biological data. Accuracy level is inversely proportional with needed work time and costs of works for defining environmental flow.

RESULTS AND DISCUSSION

Defining the most appropriate environmental flow assessment approach

According to Stojov [8], State Hydrometeorological Service of the Republic of Macedonia has been performing regular hydrological monitoring on 110 Surface Stations since 1947. These stations are located on the biggest stream and usually in the lower part of the catchments. Data about flow in upstream/mountain parts of the streams are missing. However, there are various methods for defining values based on data from measuring in any similar referent point, in this case referent stream catchment. Biological data (data about fishes, macrozoobenthos and florae taxa) generally are very limited.

Generally, hydrological methods characterized as: simple, rapid, inexpensive desktop approaches, low data needs – primarily flow data, suitable for water resource planning purposes, enable potential for regionalization for different river ecotypes, suitable for low controversy situations but inflexible, with low resolution output, without direct ecological links that’s usually absent or are limited.

Habitat-ratio methods characterize as: high resolution habitat-flow relationships for target species; generate alternative e-flow scenarios for different species; advanced technical support, but focus on target species, not whole ecosystem; are not applicable for some ecosystem components; limited links with characteristics of flow regime; output restricted to flow-hydraulic habitat relationships; resource intensive relative to output and poor links with biological responses to flow change

Holistic methodologies characterize with: whole-ecosystem focus; generates alternative environmental flow scenarios for different ecological and social conditions; use of interdisciplinary expert judgment in structured, consistent process; usable in data rich and data poor contexts (use of available techniques and understanding); explicit links with characteristics of flow regime and with biological and social responses to flow change.

De Fretas [9] presents approximate needed time and finances for defining environmental flow using various groups of methods. According to his research, hydrological methods need 1–5 months and 10 000 USD; holistic expert-panel methods need 6–12 months and 100 000 USD, while holistic – field studies and monitoring need 2–5 years and over 1 000 000 USD.

Table 1. Evaluation of analyzed methods/approaches for environmental flow assessment

	Needed data	Data availability	Field work	Needed knowledge	Costs	Precision
Tennant – Montana	low	high	no	mid	low	low
Q_{90}	mid	mid	no	mid	low-mid	mid
Hydraulic methods	mid	mid	yes	mid	mid	mid
Habitat rating methods	high	low	yes	mid-high	high	mid
Holistic – expert panel driven	high	low	no	high	high	high
Holistic – measuring and modeling	high	low	yes	high	ext. high	ext. high

Taking into consideration all mentioned above, only group of hydrological methods satisfied all set requirements.

There are 2 subgroups of hydrological methods:

a) using directly daily/monthly measurement values (the most used is Tennant or Tennant–Montana method and its modifications);

b) using various low flow duration exceedance percentiles (e.g. Q95, Q75 – these known flows, known, are the average flow for any one day expected to be greater for 95 days or 75 in any 100 days or single low flow indices e.g. 7Q10, 7Q2, i.e. seven-day, consecutive low flow with a ten year return frequency; the lowest stream flow for seven consecutive days that would be expected to occur once in ten years).

The second group of methods needs daily flow data and the results are more reliable then results obtained by the first subgroup. All these methods depend on the availability of hydrological data.

According to the official price list of State Hydrometeorological service, there is a big difference between long-term daily data and long-term monthly data. Greater part of daily data in Macedonia is still in paper format and it increases the price.

Finally taking into account all mentioned above the only appropriate approaches for environmental flow assessment of mountain streams that fulfill all set criteria should be those based on Tennant method. This method was developed for mid-western USA and has regional character. There are several modifications for use in other regions. The only needed data for usage of this method is long-term monthly flow. This type of data is available and cheap. The only disadvantages are that data are of limited use, and for some EFA should be used referent catchment where hydrological measuring exist.

The next step was the testing of the applicability of Tennant method on a case study.

Case study: "Dragor" system – geospatial hydrology analyses

Because measuring data for the study area do not exist, the method of hydrological analogy was used. For this purpose the data from Brajcinska Reka were used.

Hydrological station on Brajčinska Reka is located near the village of Nakolec and represents almost the whole catchment of Brajčinska Reka.

According to WFD needs and rules, within the project Prespa Lake Watershed Management Plan (PLWMP) Brajčinska Reka was delineated in 2 water bodies as follows: Brajčinska 1 that represents the upper part of Brajčinska Reka catchment on the altitude from 1120 m up to 2329 m asl. and Brajčinska 2. The flow in the upper part – Brajčinska 1 is significantly higher.

Table 2. Monthly flow [m^3/s] – Brajčinska Reka for period 1951–2004

Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual
Nro	44	44	44	44	44	44	44	44	44	44	44	44	44
Min	0.2	0.2	0.3	0.7	0.6	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.3
Max	3.2	3.5	3.5	5.7	5.0	2.6	1.2	0.4	1.9	1.6	3.9	2.4	1.7
Mean	0.7	0.8	1.2	2.4	2.4	0.9	0.4	0.2	0.3	0.3	0.7	0.8	1.9
Std/Dev	0.5	0.6	0.6	1.0	1.2	0.6	0.2	0.1	0.3	0.3	0.7	0.5	0.3
Variations	0.8	0.8	0.5	0.4	0.5	0.6	0.6	0.4	1.1	0.8	1.0	0.7	0.2

Source: KfW – [11]

Table 3. Mean monthly flow of Brajčinska Reka 1 – period 1951–2004

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	avg.
0.621	0.703	1.067	2.111	2.162	0.797	0.349	0.183	0.217	0.271	0.595	0.686	0.813

Source: Prespa Lake Watershed Management Plan [12]

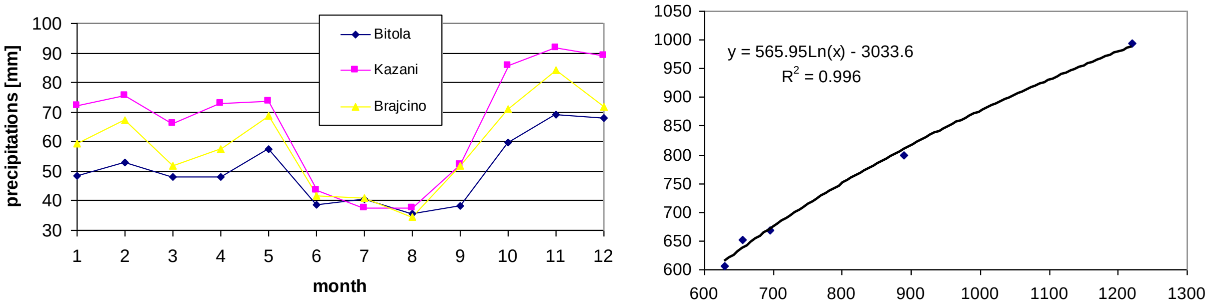

Figure 2. Correlation between altitude and rainfalls

With an aim to define the flow module of study catchments and the referent catchment, a deep analysis of site factor affecting flow was launched.

For defining of the correlation between rainfalls and altitude, a mathematical analysis was made. For this estimation data from gauge stations: Bitola, Kazani, Graešnica and Lopatica were used.

Estimated equation is $y = 565{,}95\ Ln(x) - 3033{,}6$, where y is annual sum of rainfall and x is altitude. Coefficient of determination is $R^2 = 0{,}996$. It shows almost functional correlation. Mean precipitation on the catchment was defined using the following formula and the mean catchment altitude.

The next step was the developing of basic geospatial dataset and geospatial analysis.

Generally, relief type is mountainous and dissected with various streams. It also enables high values of flow module. Catchment shape of Brajčinska Reka is significantly positive to high flow then the other. Altitude difference is similar. Mean catchment slopes are almost the same, while stream bed slopes are similar. Calculated mean precipitation values are also almost the same.

Soil type distribution (cambisols and rankers) is similar. Cambisols occur in region with rainfall surplus but in terrains that permit surgical discharge of excess water. Cambisols have good structural stability, high porosity, good water holding capacity and good internal drainage. Rankers are skeletous and shallow with lower water capacity then cambisols. Within Brajčinska 1 catchment, semi-porous rocks (Sse – quartz-quartz-sericite schists) dominate. Similar distribution is within the Stara Buka catchment. On the other hand non-porous rocks (γ–alkaline granites) dominate within other catchments. Appearance of porous Quertenary deposits (gl/fgl – glacial, fluvuioglacial) is almost the same but is not significant.

According to land cover distribution (reclassified for hydrological needs), there is a significant difference. Water resistant land cover type dominates in Brajčinska 1, while semiresistant and low resistant land cover dominates within other catchments.

Taking into consideration all above, it can be concluded that catchments used for water abstraction are very similar to the referent site – Brajčinska 1. It means that runoff module of Brajčinska 1, q = 21,5 l/s·km^2, can be used as relevant to all other catchments.

Total catchment area of the study area is 3272 ha or 32,72 km^2. Calculations were done using catchment area and the runoff module. Results are presented per and the whole area.

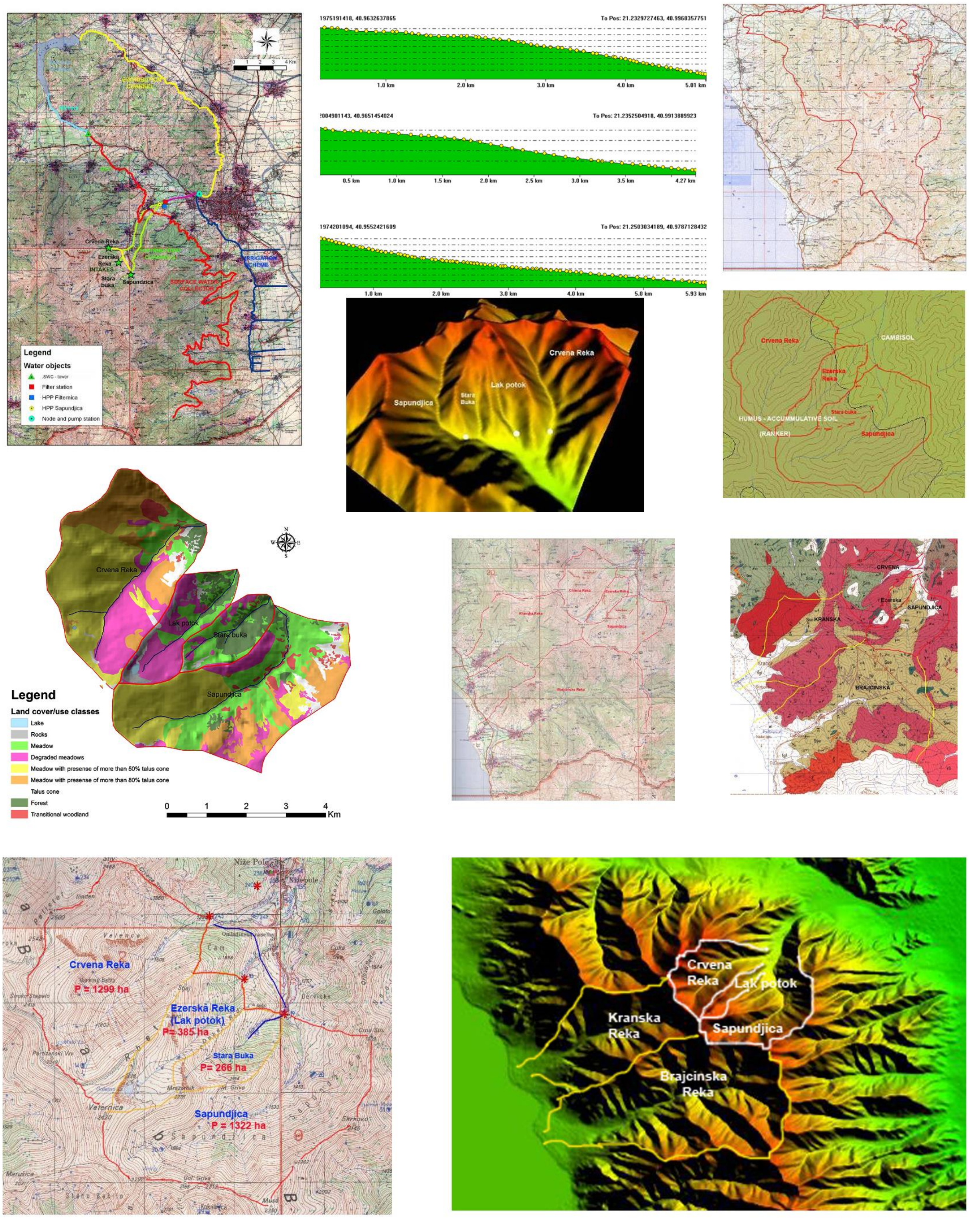

Figure 3. Basic geospatial database

Table 4. Comparison of site factors affecting flow

	Element	Brajčinska 1	Crvena Reka	Lak Potok	Sapundjica	Stara Buka
A [km^2]	Catchment area	37.75	12.89	3.85	13.22	2.66
	Catchment shape	trapeze	squatty	elongated	elong-squar	elongated
N_{min} [m]	Minimal altitude	1120	1296	1289	1276	1276
N_{max} [m]	Maximal altitude	2329	2600	2420	2420	2235
N_{avg} [m]	Mean altitude	1785	1986	1902	1852	1642
ΔN [m]	Altitude difference	1191	1303	1129	1144	1059
I [%]	Mean slope	42.12	45.12	38,05	40.26	42.86
Jb [%]	Bed slope	18	22	24	19	19
P [mm]	Precipitations	1204	1264	1240	1225	1157
Impervious - ness	Soil type	C, R	C, R	C, R	C, R	C, R
	Rock type	Sse,γ,	γ,Sco, fgl,	Sse,γ, fgl,	Sse,γ, fgl	Sse,γ, fgl
	Catchment Distribution per porosity classes	NP – 0.15 SP – 0.75 P – 0.1	NP – 0.6 SP – 0.3 P – 0.1	NP – 0.65 SP – 0.25 P – 0.1	NP – 0.5 SP – 0.4 P – 0.1	NP – 0.1 SP – 0.7 P – 0.2
Catchment distribution per land cover	Forests	55.05	2.23	12.59	2.91	39.13
	Grassland/woodland	44.95	69.98	72.46	74.86	57.12
	Bareland	0.00	27.78	13.81	22.21	3.74
	Other (lakes)	0.00	0.05	1.13	0.02	0.00

Table 5. Calculated average monthly flow on the whole system area

Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Q_{avg} [l/s]	537	608	923	1826	1871	690	302	158	188	235	515	594

Table 6. Calculated monthly minimal, average and maximal flow (discharge) per catchment [l/s]

	Crvena Reka			Lak Potok			Stara Buka			Sapundjica		
	Q_{min} [l/s]	Q_{avg} [l/s]	Q_{max} [l/s]	Q_{min} [l/s]	Q_{avg} [l/s]	Q_{max} [l/s]	Q_{min} [l/s]	Q_{avg} [l/s]	Q_{max} [l/s]	Q_{min} [l/s]	Q_{avg} [l/s]	Q_{max} [l/s]
I	48	215	768	14	65	230	10	43	154	48	215	768
II	48	244	840	14	73	252	10	49	168	48	244	840
III	67	370	840	20	111	252	13	74	168	67	370	840
IV	168	730	1368	50	219	410	34	146	274	168	730	1368
V	144	748	1200	43	225	360	29	150	240	144	748	1200
VI	50	276	624	15	83	187	10	55	125	50	276	624
VII	24	121	288	7	36	86	5	24	58	24	121	288
VIII	24	63	96	7	19	29	5	13	19	24	63	96
IX	26	75	456	8	23	137	5	15	91	26	75	456
X	24	94	384	7	28	115	5	19	77	24	94	384
XI	31	206	936	9	62	281	6	41	187	31	206	936
XII	38	238	576	12	71	173	8	48	115	38	238	576
Avg.	58	282	698	17	84	209	12	56	140	58	282	698

Case study: "Dragor" system – Environmental flow assessment

According to the current Macedonian practice, environmental flow represents 10% of mean annual flow. Calculated values using previous approach are as follows: Crvena Reka: 28 l/s, Lak Potok 9 l/s, Stara Buka: 6 l/s, Sapundjica: 28 l/s, and total (from the whole area) – 71 l/s.

Tennant (or Montana) method appeal is in its simplicity easy to of use. Tennant method uses a percentage of the mean annual flow for two different six month periods to define conditions of flow related to fishery, wildlife, recreation and environmental resources [13].

Table 7. Calculated minimal ecological flow according to the original Tennant method [l/s]

	October – March						April – September					
	%	Total	CR	LP	SB	SAP	%	Total	CR	LP	SB	SAP
	Q_{avg}	568.70	225.78	66.92	46.24	229.78	Q_{avg}	839.13	333.14	98.74	68.22	339.04
Flushing or maximum	200	1137	452	134	92	460	200	1678	666	197	136	678
Optimum range	60–100	341	135	40	28	138	60–100	503	200	59	41	203
Outstanding	40	227	90	27	18	92	60	503	200	59	41	203
Excellent	30	171	68	20	14	69	50	420	167	49	34	170
Good	20	114	45	13	9	46	40	336	133	39	27	136
Fair or degrading	10	57	23	7	5	23	30	252	100	30	20	102
Poor or minimum	10	57	23	7	5	23	10	84	33	10	7	34
Sever degradation	<10	57	23	7	5	23	<10	84	33	10	7	34

CR – Crvena Reka, LP – Lak Potok, SB – Stara Buka, SAP – Sapundjica

According to the practice in the country, calculated flow of 71 l/s is lower then average minimal flow in four months (July, August, September and October). According to original Tennant method, not only 10% even 20 %, and 30 % calculated environmental flow is lower than the measured flow in July, August and September. During the summer quartile, some streams and rivers have no or very little water in their bed. In a case of extreme dry period the flow value is lower then the calculated minimum flow.

New approach for environmental flow assessment

This approach belongs to hydrological methods and is based on Tennant (Tennant–Montana) method. The original Tennant method accepts "hydrological year" and divides it into two parts: October – March and April – September. According to the precipitation regime in the region and mostly in the Republic of Macedonia dominant values appear in May and somewhere additionally in November.

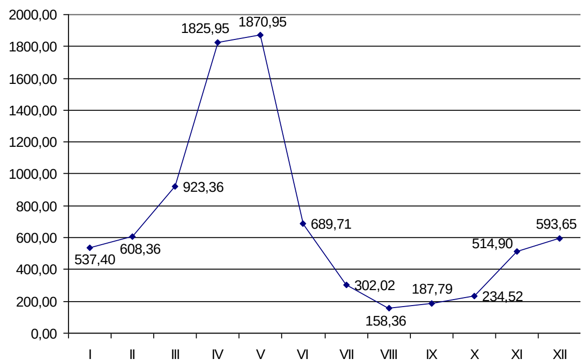

Figure 4. Variation of month flow of whole "Dragor" system

The hydrogram above shows three clearly separated groups of flow values:

Period 1 (P1) – mid values – November, December, January, February, March and June.

Period 2 (P2) – high values – April and May.

Period 3 (P3) – low values – July, August, September, October.

This leads to the conclusion that environmental flow should be defined according to the hydrological regime. Taking into consideration the above, environmental flows of study catchments were calculated for 3 different periods.

Using basically Tennant approach, and making modifications according to the regional circumstances related to hydrological regime, environmental flow was calculated as:

– for the low values period (P3), environmental flow is calculated as 30% (fair to good) of the mean period flow,

– for the mid values period (P1) calculated environmental flow was 15% (fair–good) of mean period flow or equal to month flow,

– for the high values period (P2), environmental flow is calculated as 10% (minimum) of mean period flow or equal to month flow.

Comparison of minimal flow (Q_{min}) in the study area (whole 3 catchments) and calculated minimal ecological flow (biological minimum) per month according to the practice in Macedonia, Tennant method and new approach, show that this new approach follows the hydrogram appropriately. If we compare absolute month minimum flow Q_{min} and calculated environmental flow Q_{env} per month, only in excess cases in November the difference is higher then expected. However, in a case of extreme excess, then environmental flow is equal to the current measured flow. If we compare calculated environmental flow using new approach with Tennant descriptions then, for the period 1 (mid flow values) and period 2 (high flow values), it is evaluated between fair and good, while for the dry summer period (period 3) is evaluated as minimum. Comparison of calculated Q_{env} using different approaches is presented on the Figure 5.

Table 8. Calculated environmental flow Q_{env}, according to new approach

Stream	Crvena Reka			Lak Potok			Stara Buka			Sapundjica		
Period	P1	P2	P3	P1	P2	P3	P1	P2	P3	P1	P2	P3
% of Q_{avg}	15	10	30	15	10	30	15	10	30	15	10	30
Q_{avg} [l/s]	258	739	88	78	222	27	52	148	18	258	739	88
Q_{min} [l/s]	*47*	*156*	*25*	*14*	*47*	*7*	*9*	*31*	*5*	*47*	*156*	*25*
Q_{env} [l/s]	39	74	26	12	22	8	8	15	5	39	74	26

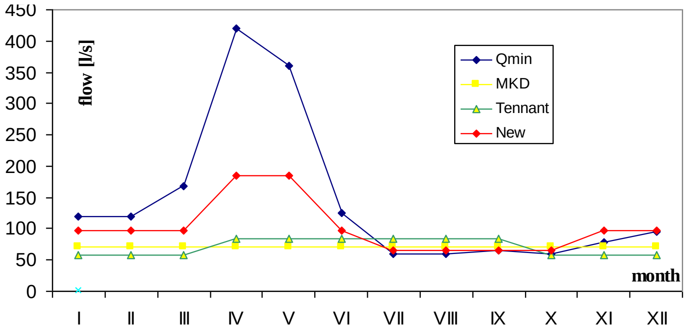

Figure 5. Comparison of Q_{env} calculated by different approaches for the whole "Dragor" system

CONCLUSIONS

According to the available data, knowledge, needed time and financial resources, Tennant–Montana method is the most appropriate method for environmental flow assessment. Because of absence of measured hydrological data, calculation of average flow should be carried using hydrological analogy using deeper analysis of factors affecting flow on a study area and possible referent catchments.

Case study Dragor shows that direct usage of Tennant method is not fully in accordance to hydrological regime of studied mountain streams. For this purpose it is necessary firstly to analyze in details the hydrological regime and to define periods with various flow (low, mid, high) on the hydrogram. Using basically Tennant approach and making modifications according to the regional circumstance related to hydrological regime, environmental flow was calculated as:

– for the low values period (P3), environmental flow was calculated as 30% (excellent) of the mean period flow,

– for the mid values period (P1) calculated environmental flow was 15% (fair–good) of mean period flow or equal to month flow and

– for the high values period (P2), environmental flow was calculated as 10% (minimum) of mean period flow or equal to month flow.

This new approach should be used for environmental flow assessment of all mountain streams in the Republic of Macedonia.

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НОВ ПРИСТАП ЗА ПРОЦЕНА НА МИНИМАЛНИОТ ПРОТОК НА ВОДА КАЈ ПЛАНИНСКИ ВОДОТЕЦИ ВО РЕПУБЛИКА МАКЕДОНИЈА

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Минимален прифатлив проток на вода (биолошки минимум) се дефинира како проток што е потребно да се обезбеди заради постоење на живеалиштата во водотеците. Во практиката во Македонија, минимален прифатлив проток на вода се дефинира како 10% од просечниот годишен проток, но варијациите на протокот се значителни и овој пристап може да генерира сомнежи за инженерите. Крајната цел на оваа студија беше да се препорача најсоодветен метод/пристап за инженерска намена во Македонија. Оваа студија се состои од 2 дела: а) процена на употребилвост на најчесто користени светски методи во националните услови; и б) да се дефинира минималниот проток на вода според новиот пристап на студија на случај. Новопредложениот приод беше тестиран на системот за водоснабдување „Драгор“. Со користењето на основниот пристап на Тенант и негова модификација според регионалните услови поврзани со хидролошкиот режим, минималниот прифатлив проток е пресметан за 3 различни периоди согласно со вредностите на минималниот и просечниот проток кои го следат хидрограмот.

Клучни зборови: процена на минимален прифатлив проток; Тенант; планински водотек