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Strengthening the Capacities for Implementation of the Water Framework Directive in Montenegro

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Adriatic River Basin Plan

Annex 1: Groundwater bodies – Characterisation and status

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Appendices I-XIII

Tables of characterisation and status assessment of the delineated Groundwater bodies and Group of groundwater bodies

Appendix I Description of the groundwater body “ ***Southern Rim of the Skadar Lake*** *“*

River basin	Sub-basin	Name of GGWB	Code	Type of GWBs
Bojana River	Skadar Lake	Southern Rim of the Skadar Lake	ME_A_GGW_K_1	C
Area (km^2)	**Autogenous (km^2)**	**238.5**	**Allogenic (km^2)**	**4.8**

Topography and geographical description		Group of groundwater bodies is distributed from the border with Albania (SE) to Crmnica (NW), and from the top of Rumija Mountain (SW) to Skadar Lake (NE). Elevation ranges from 5 to 1,594 m asl.
Geology of GW bodies	**Geology**	Mesozoic limestone and dolomite (T, J, K); Flysch: conglomerate, sandstone and marl (T_2^1, Pg),); Andesite (α); Alluvium (al); Deluvium (d)
	Hydrogeological units (K, I, F, C)	Limestone and dolomite (K), Alluvium (I); Hydrodynamic conditions –UC and CF (just for alluvial aquifer of Crmničko polje)
	Depth to GW level (assessed)	Up to 400 m (confidence level: RA)
	Hydrogeological parameters	$K = 1 \times 10^{-4}–1 \times 10^{-1}$ m/s (confidence level: RA)
	Tracer tests	Hydraulic connections between swallow holes and springs: Ostros-Van I Šitarit Spring(v=0.42 cm/s); Swallow hole in Bijelo Polje - VeljeOko, Malo Oko, Okruglica Spring (v=0.11 cm/s) ; Swallow hole in Ljevačko (Sozina) - Pod Kapom Spring (v=0.82 cm/s)
	GW flow directions	General groundwater flow direction is NE-SW
Overlaying strata	**Lithology**	Soil in autogenous area; Flysch sediments in allogenic area
	Thickness	Soil: 0-5 m; Flysch sediments 200 m
	Outcrop of GW body (%)	98%
Recharge	**Sources of recharge**	P (2,461 mm/a)
	Infiltration of atmospheric water (assessed)	68%P or 407 x 10^6 m^3/year of 599 x 10^6 m^3/year (confidence level: RA)
Outflow	**Main springs Q_{min}/Q/Q_{max}(l/s)**	Raduš Spring (Q_{min}=0.06 m^3/s; Q=1.24 m^3/s; Q_{max}=50 m^3/s), Krnjice Spring (Q=0.7 m^3/s); Velje Oko (Q=1m^3/s); Malo Oko (Q=0.3 m^3/s); Okruglica Spring (Q=0.2 m^3/s)
	Average abstraction (m^3/s)	Q=0.04 m^3/s (Malo Oko Spring) **Q_{tot}=0.04m^3/s**
	GW resources (Q, Total recharge)	Q = 11.5 m^3/s; $\sum I_{ef}$= 12.9 m^3/s
Surface water–Groundwater interaction		Poor interaction within catchment areas of springs, and good interaction along Crmnica River.
Water quality	**Chemical composition**	HCO_3 – Ca – Mg
	Protection zones	Delineated for the water-source “Velje Oko”

Vulnerability and risk	**Vulnerability**	Very high and High = 0% (on Vulnerability Map), while low vulnerability covers 77% of the terrain	
	Assessment of pressure	**Point**	Not registered significant point pollutants
		Diffuse	Wastewater of small settlements (few houses) which are not connected to sewage system; Local landfills; Agriculture; Main road Podgorica-Bar with tunnel “Sozina”
	Risk assessment	Not at risk	
GW status	**Quality**	Good status	
	Quantity	Good status	
Monitoring	**Quality**	Existing: Continual for water-source “Velje Oko” / Proposed: Surveillance monitoring on few more water points	
	Quantity	Existing: Continual for water-source “Velje Oko” / Proposed: Surveillance monitoring	
Dependent ecosystems		Skadar Lake, Crmnička River	

General assessment of data (confidence level): Rough assessment (RA)
Sources of data: Existing hydrogeological maps, reports, books, etc.
Legend: K–karst aquifer ; I–intergranular aquifer; F–fissured aquifer; C–complex aquifer; UC–unconfined conditions; CF–confined conditions; RA–rough assessment

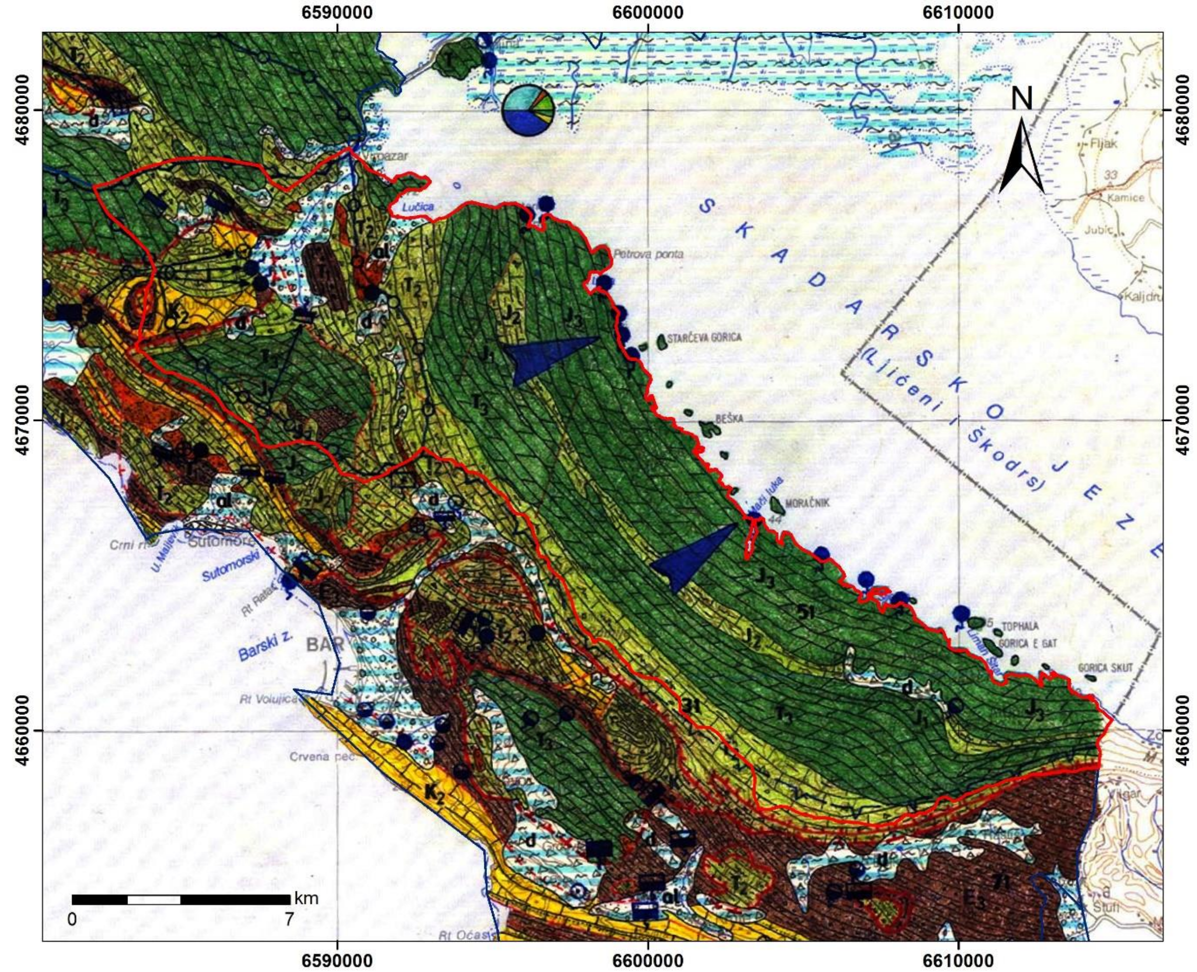

Fig. 1 Boundaries of the group of groundwater bodies“Southern Rim of the Skadar Lake” (red line) on the hydrogeological map (Source of background map: Radulović M. and Radulović V., 2004)

*Appendix II Description of the groundwater body "**Ulcinjsko polje**"*

River basin	Sub-basin	Name of GWB	Code	Type of GWB
Bojana River/Adriatic Sea	Bojana River/Adriatic Sea	Ulcinjsko polje	ME_A_GW_I_2	I
Area (km²)	**Autogenous (km²)**	**111.1**	**Allogenic (km²)**	**0**
Topography and geographical description	The groundwater body is distributed from Adriatic Sea (S) to Fuša Kravari (N), and from Bojana River (E) to Ulcinj (W). Elevation ranges from 0 to 26 m asl.			

Geology of GW bodies	**Geology**	Alluvial sediments (al) represented by sand, gravel, silt and clay (thickness: 30 m)
	Hydrogeological units (K, I, F, C)	I (alluvium); Hydrodynamic conditions – UC and C
	Depth to GW level (assessed)	2 m in average (confidence level: RA)
	Hydrogeological parameters	$K_f = 5.8 \times 10^{-5}$ m/s(confidence level: RA)
	Tracer tests	N/A
	GW flow directions	General groundwater flow direction is N-S
Overlaying strata	**Lithology**	Soil cover
	Thickness	Up to 2 m
	Outcrop of GW body (%)	100%
Recharge	**Sources of recharge**	P (1,253 mm/a); Infiltration from Bojana River; Subterranean inflow from the surrounding karst aquifer
	Infiltration of atmospheric water (assessed)	30%P or 42 x 10^6 m³/year of 139 x 10^6 m³/year (confidence level: RA)
Outflow	**Main springs Q_{min}/Q/Q_{max}(l/s)**	N/A
	Average abstraction (m³/s)	Q = 0.25 m³/s (water source "LisnaBori") **Q_{tot}= 0.25m³/s**
	GW resources (Q, Total recharge)	Q = 0.9 m³/s (there is diffuse discharge to Adriatic Sea and Bojana River); $\sum I_{ef}$ = 1.33 m³/s
Surface water–Groundwater interaction	Good interaction along Bojana River	
Water quality	**Chemical composition**	HCO_3 – Ca
	Protection zones	Delineated for the water source "Lisna Bori"

Vulnerability and risk	**Vulnerability**	The class „Very High" vulnerability occupies 39% while „High" vulnerability around 4% of GWB area	
	Assessment of pressure	**Point**	PE Load: 10 707
		Diffuse	Sea water intrusion; Wastewater of settlements which are not connected to sewage system; local improper landfills; beaches; agriculture; road network
	Risk assessment	Potentially at risk, PE vs Vulnerability is 11.77	
GW status	**Quality**	Poor status due to natural quality / Potentially at risk	
	Quantity	At risk	
Monitoring	**Quality**	Existing: Continual for water-source "Lisna Bori"and coastal area / Proposed: Operational monitoring	
	Quantity	Existing: Continual for water-source "Lisna Bori" and coastal area / Proposed: Operational monitoring	
Dependent ecosystems		Bojana River, Šasko Lake, Porta Milena, Kodra Wetland, Adriatic Sea	

General assessment of data (confidence level): Rough assessment (RA)
Sources of data: Existing hydrogeological maps, reports, books, etc.
Legend: K–karst aquifer ; I–intergranular aquifer; F–fissured aquifer; C–complex aquifer; UC–unconfined conditions; CF–confined conditions; RA–rough assessment

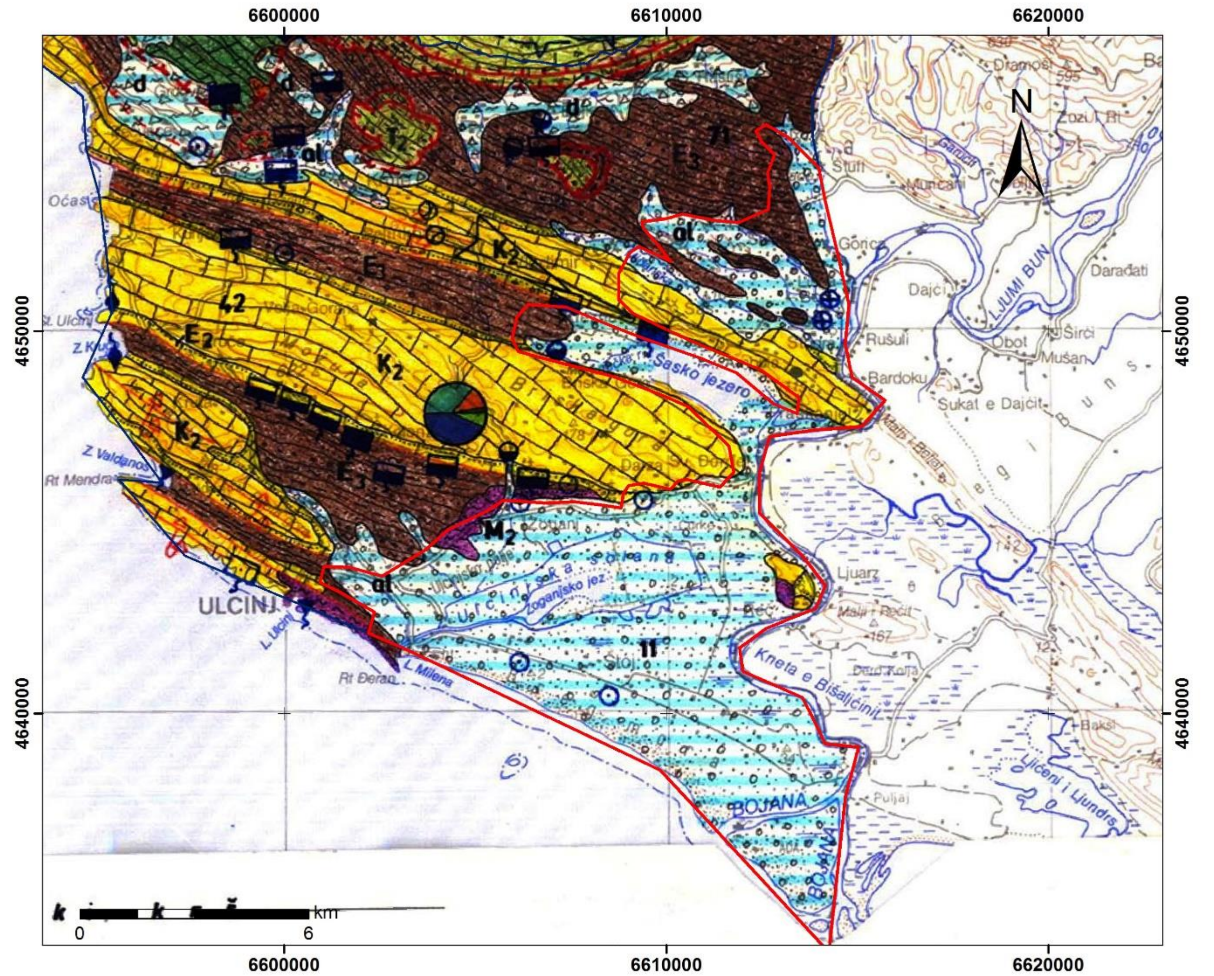

Fig. 2 Boundaries of the groundwater body "Ulcinj" (red line) on the hydrogeological map (Source of background map: Radulović M. and Radulović V., 2004)

*Appendix III Description of the group of groundwater bodies "**Možura-Paštrovići**"*

River basin	**Sub-basin**	**Name of GGWB**	**Code**	**Type of GWBs**
Adriatic Sea	Adriatic Sea	Možura-Paštrovići	ME_A_GGW_K_3	C
Area (km^2)	**Autogenous (km^2)**	**263**	**Allogenic (km^2)**	**136**

Topography and geographical description		Group of groundwater bodies is elongated along the SE-NW direction. It is distributed from Ulcinj (SE) to Sveti Stefan (NW). Elevation ranges from 0 to 1,594 m asl.
Geology of GW bodies	**Geology**	Limestone, dolomite, and chert (T,J,K); Flysch: conglomerate, sandstone and marl (T_2^1; E_3); Volcanic-sedimentary rocks (T_2^2); Andesite (α); Alluvium (al); Deluvium (d)
	Hydrogeological units (K, I, F, C)	K, F, I
	Depth to GW level (assessed)	Over 50 m (confidence level: RA)
	Hydrogeological parameters	K = 1 x 10^{-4} – 1 x 10^{-2} m/s (confidence level: RA)
	Tracer tests	Hydraulic connections between swallow holes and springs: swallow hole Vidran (Paštrovske Mountains) – Reževića Spring, Smokovijenac Spring and Vilina Cave (v=2.07-2.60 cm/s); swallow hole Dobrun (Paštrovske Mountains) – Reževića Spring, Smokovijenac Spring (v=0.93-0.98 cm/s); swallow hole Jama (Bjeliš, Bijelo Polje) – Lončar Spring (Buljarica) (v=3.27 cm/s); Velja Gorana – Gač Spring; Krute – Skili Fata Spring (Donja Klezna) (v=1.5 cm/s)
	GW flow directions	General groundwater flow direction is NE-SW
Overlaying strata	**Lithology**	Soil in autogenous area; Flysch and Volcanic-sedimentary rocks in allogenic area
	Thickness	Soil: 0-5 m; Flysch: 180-600 m; Volcanic-sedimentary rocks: 70 m
	Outcrop of GW body (%)	66%
Recharge	**Sources of recharge**	P (1,669 mm/a)
	Infiltration of atmospheric water (assessed)	60%P or 263 x 10^6 m^3/year out of 439 x 10^6 m^3/year (confidence level: RA)
Outflow	**Main springs Q_{min}/Q/Q_{max}**	Gač Spring (Q_{min}= 0, Q_{max}≈1 m^3/s); Salč Spring (Q_{min}= 0.01 m^3/s); Skili Fata Spring; Mide Spring (Q_{min}= 0.01 m^3/s); Kaliman Spring; Kajnak Spring (Q_{min}= 0.1 m^3/s); Brca Spring (Q_{min}= 0.035 m^3/s, Q_{max}≈ 0.8 m^3/s); Škurta Spring (Q_{min}= 0.013 m^3/s, Q_{max}= 0.05 m^3/s), Dobra Voda Spring (Q_{min}= 0.01 m^3/s, Q_{max}≈ 0.1 m^3/s); Zaljevo Spring (Q_{min}= 0.02m^3/s); **Reževića Spring** (Q_{min}= 0.5 m^3/s; Q_{max}≈10 m^3/s); Smokovijenac Spring (Q_{min}= 0.005 m^3/s)
	Average abstraction	Q=20 l/s (Gač); Q=23 l/s (Klezna); Q=5 l/s (Mide); Q=2 l/s (Kaliman); Q=2 l/s (Salč); Q=60 l/s (Brca); Q=70 l/s (Kajnak); Q=20 l/s (Zaljevo); Q=1 l/s (Turčini); Q=2 l/s (Sustaš); Q=8 l/s (Čanj); Q=80 l/s (Reževića Spring); Q=25 l/s (Buljarica); Q=4 l/s (Lončar); Q=2 l/s (Kaliman); Q=2 l/s (Salč) **Q_{tot}=0.326m^3/s**
	GW resources (Q, Total recharge)	Q ≈ 8 m^3/s; $\sum I_{ef}$ = 8.35 m^3/s
Surface water–Groundwater interaction		Poor interaction

Water quality	**Chemical composition**	$HCO_3 - Ca$	
	Protection zones	Delineated for the water-sources: Gač, Klezna, Mide, Kaliman, Salč, Brca, Kajnak, Zaljevo, Turčini, Sustaš, Čanj, Reževića Spring, Buljarica, Lončar, Kaliman and Salč	
Vulnerability and risk	**Vulnerability**	Very High“ vulnerability occupies around 4%	
	Assessment of pressure	**Point**	Port Bar, PE Load c. 2 000 PE
		Diffuse	Wastewater of settlements which are not connected to sewage system; Local landfills; Agriculture; Local road network; Main road Ulcinj-Budva
	Risk assessment	Not at Risk, actually	
GW status	**Quality**	Not at Risk, TBV	
	Quantity	Good status, Not at Risk	
Monitoring	**Quality**	Existing: Continual for the water sources: Gač, Klezna, Mide, Kaliman, Salč, Brca, Kajnak, Zaljevo, Turčini, Sustaš, Čanj, Reževića Spring, Buljarica, Lončar, Kaliman and Salč/ Proposed: Operational monitoring	
	Quantity	Existing: Continual for the water sources: Gač, Klezna, Mide, Kaliman, Salč, Brca, Kajnak, Zaljevo, Turčini, Sustaš, Čanj, Reževića Spring, Buljarica, Lončar, Kaliman and Salč/ Proposed: Surveillance monitoring	
Dependent ecosystems		Adriatic Sea, small streams	

General assessment of data (confidence level): Rough assessment(RA)

Sources of data: Existing hydrogeological maps, reports, books, etc.

Legend:K–karst aquifer ; I–intergranular aquifer; F–fissured aquifer; C–complex aquifer; UC–unconfined conditions; CF–confined conditions; RA–rough assessment; TBV – To be verified (based on monitoring)

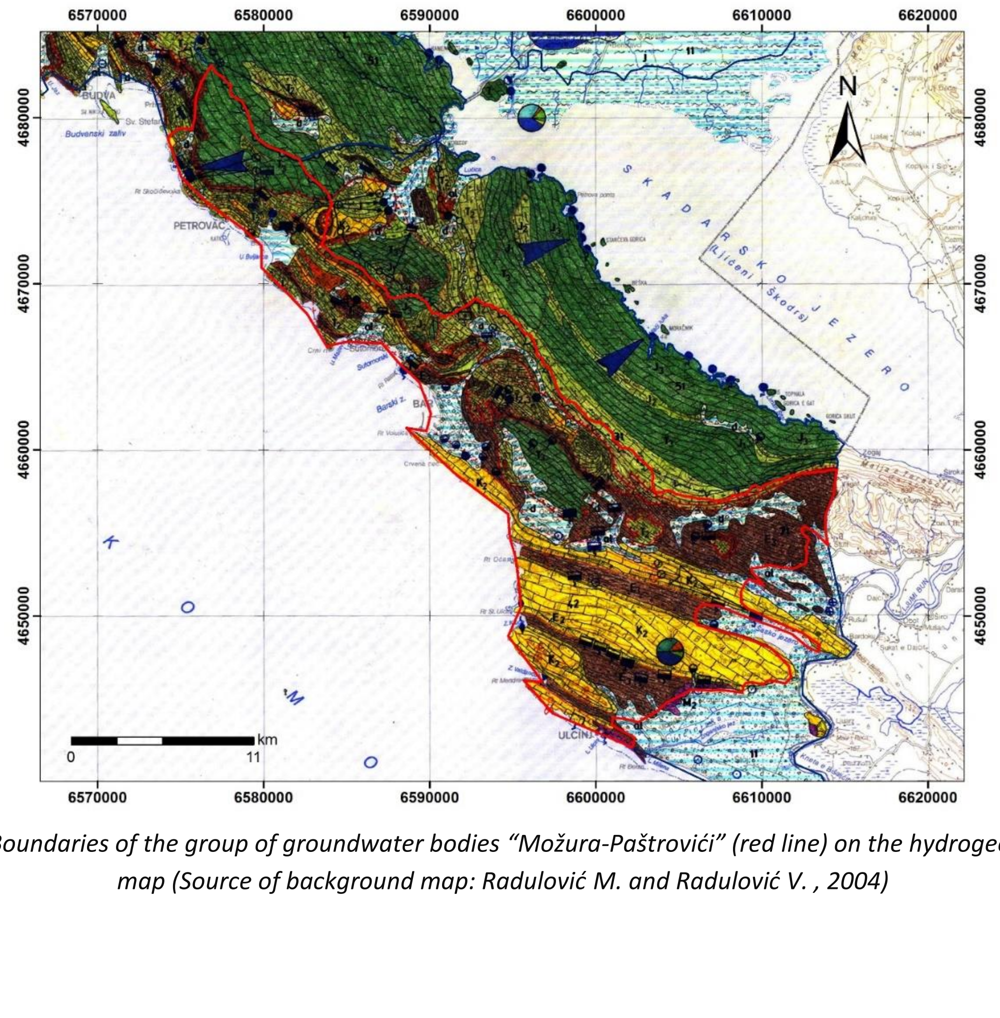

Fig. 3 Boundaries of the group of groundwater bodies “Možura-Paštrovići” (red line) on the hydrogeological map (Source of background map: Radulović M. and Radulović V. , 2004)

*Appendix IV Description of the group of groundwater bodies “**Grbalj-Luštica**“*

River basin	Sub-basin	Name of GGWB	Code	Type of GWBs
Adriatic Sea	Adriatic Sea	Grbalj-Luštica	ME_A_GGW_K_4	C
Area (km^2)	**Autogenous (km^2)**	**225.9**	**Allogenic (km^2)**	**32**

Topography and geographical description		Group of groundwater bodies is elongated along the SE-NW direction. It is distributed from Sveti Stefan (SE) to Luštica (NW). Elevation ranges from 0 to 1,474 m asl.
Geology of GW bodies	**Geology**	Limestone, dolomite, and chert (T,J,K,E); Flysch: conglomerate, sandstone and marl (T_2^1;K,Pg;E_2; E_3); Volcanic-sedimentary rocks (T_2^2); Porphyritic rocksand Diabase (α,$\beta\beta$); Alluvium (al); Deluvium (d)
Geology of GW bodies	**Hydrogeological units (K, I, F, C)**	K, F, I
Geology of GW bodies	**Depth to GW level (assessed)**	Over 50 m (confidence level: RA)
Geology of GW bodies	**Hydrogeological parameters**	K = 1 x 10^{-4} – 1 x 10^{-2} m/s (confidence level: RA)
Geology of GW bodies	**Tracer tests**	Hydraulic connections between swallow hole in Brajići and Spring under the Pyramid (v=0.53 cm/s)
Geology of GW bodies	**GW flow directions**	General groundwater flow direction is NE-SW
Overlaying strata	**Lithology**	Soil in autogenous area; Flysch and Volcanic-sedimentary rocks in allogenic area
Overlaying strata	**Thickness**	Soil: 0-5 m; Flysch: 200-500 m; Volcanic-sedimentary rocks: 100 m
Overlaying strata	**Outcrop of GW body (%)**	90%
Recharge	**Sources of recharge**	P (1,866 mm/a)
Recharge	**Infiltration of atmospheric water (assessed)**	60% P on autogenic karst or 217 x 10^6 m^3/year of 362 x 10^6 m^3/year (confidence level: RA)
Outflow	**Main springs Q_{min}/Q/Q_{max}**	Grbalj Spring, Pakočio, Rakita, Mezalinskavoda, Nova Voda, Smokvica, Kaludrak (Qmin=1 l/s), Tolinjak (Qmin=1 l/s), Piratac (Q_{min}=2 l/s; Q_{max}=25 l/s), Boretskavoda, Brca, Loznica (Q_{min}=2 l/s; Q_{max}=25 l/s), Tršljikovica, Podbabac, Babac, Kuljače, Spring under the Pyramid(Q_{min}=5 l/s), Topliš Spring (Q_{min}=1 l/s); Lončar(Q_{min}=4 l/s); Zagradac(Q_{min}=2 l/s)
Outflow	**Average abstraction**	Q=20 l/s (Topliš); Q=30 l/s (Grbaljskopolje); Q=5 l/s (Spring under the Pyramid); Q=4 l/s (Lončar); Q=2 l/s (Zagradac); Q=3 l/s (Zagora);Q=1 l/s (Topliš Spring) **Q_{tot}= 0.065m^3/s**
Outflow	**GW resources (Q, Total recharge)**	$\sum I_{ef}$= 6.9 m^3/s
Surface water–Groundwater interaction		Poor interaction
Water quality	**Chemical composition**	HCO_3 – Ca
Water quality	**Protection zones**	Delineated for the water-sources: Topliš (Tivat), Grbaljskopolje, Spring under the Pyramid, Lončar, Zagradac, Topliš Spring (Budva)

Vulnerability and risk	**Vulnerability**	67% of Moderate and <1% of High Vulnerability	
	Assessment of pressure	**Point**	15 874 PE Load
		Diffuse	Wastewater of settlements which are not connected to sewage system; Local landfills; Agriculture; Local road network; Main road Petrovac-Tivat
	Risk assessment	Potentially at Risk, PE vs Vulnerability is 12.55; need further verification through monitoring, TBV	
GW status	**Quality**	Potentially at Risk	
	Quantity	Good status / Not at Risk	
Monitoring	**Quality**	Existing: Continual for the water sources: Topliš (Tivat), Grbaljsko polje, Spring under the Pyramid, Lončar, Zagradac, Topliš Spring (Budva)/ Proposed: Operational monitoring	
	Quantity	Existing: Continual for the water sources: Topliš (Tivat), Grbaljsko polje, Spring under the Pyramid, Lončar, Zagradac, Topliš Spring (Budva)/ Proposed: Surveillance monitoring	
Dependent ecosystems		Adriatic Sea	

General assessment of data (confidence level): Rough assessment (RA)

Sources of data: Existing hydrogeological maps, reports, books, etc.

Legend: K–karst aquifer ; I–intergranular aquifer; F–fissured aquifer; C–complex aquifer; UC–unconfined conditions; CF–confined conditions; RA–rough assessment; TBV – To be verified

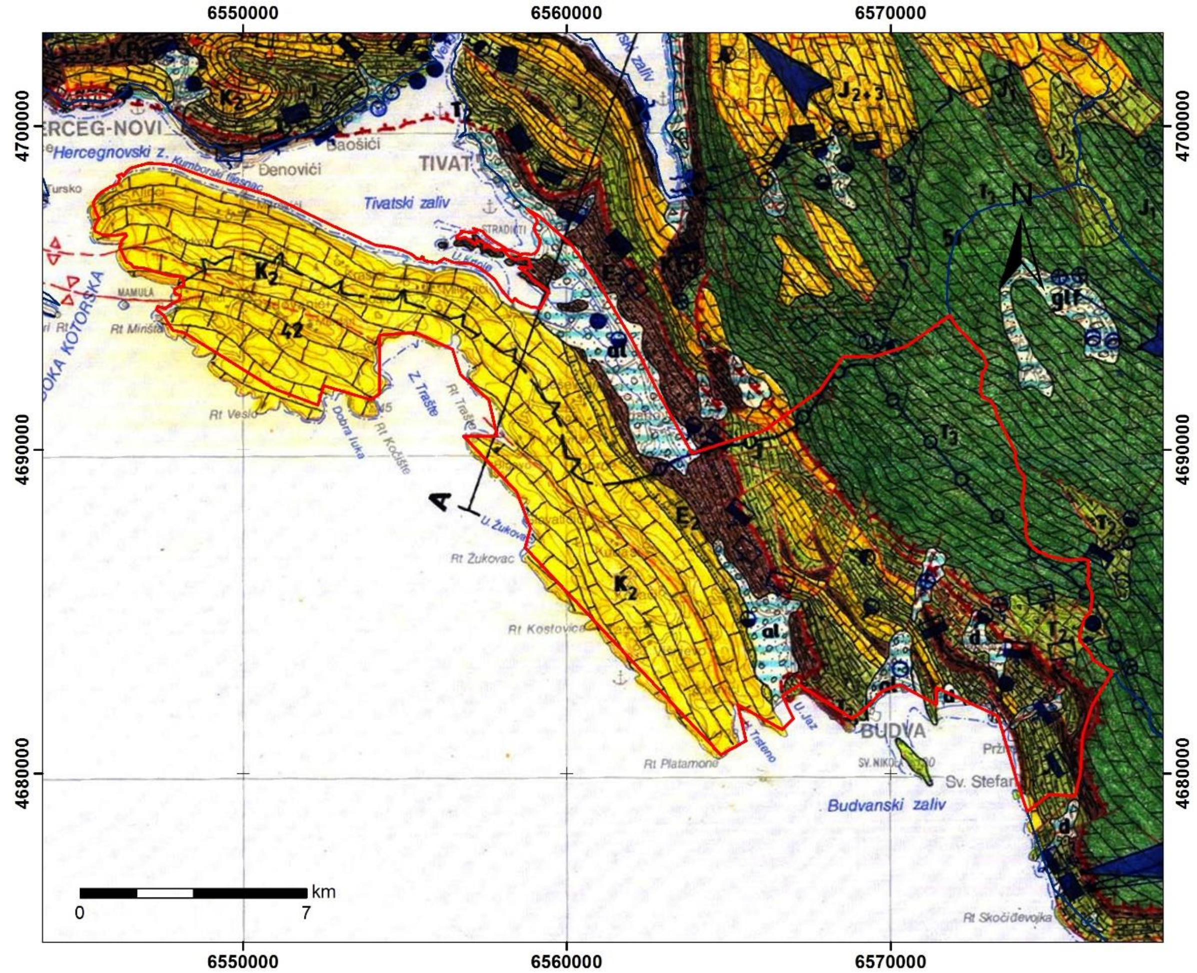

Fig. 4 Boundaries of the the group of groundwater bodies “Grbalj-Luštica” (red line) on the hydrogeological map (Source of background map: Radulović M. and Radulović V., 2004)

*Appendix V Description of the groundwater body "**Opačica-Morinj**"*

River basin	Sub-basin	Name of GGWB		Code	Type of GWBs
Adriatic Sea	Boka Kotorska Bay	Opačica-Morinj		ME_A_GW_K_5	C
Area (km²)	**Autogenous (km²)**	**102**		**Allogenic (km²)**	**34**
Topography and geographical description	Groundwater body is distributed from Prevlaka (S) to Krivošije (N), and from Verige (E) to Debeli Brijeg (W). Elevation ranges from 0 to 1,571 m asl.				
Geology of GW bodies	**Geology**	Mesozoic limestone, dolomite, and chert (T,J,K); Flysch: conglomerate, sandstone and marl (T_2^1; K,Pg; E_3); Glacial sediments (gl); Deluvium (d); Alluvium (al)			
	Hydrogeological units (K, I, F, C)	K, I			
	Depth to GW level (assessed)	Over 200 m in average away from the coast (confidence level: RA)			
	Hydrogeological parameters	K = 1 x 10^{-4} – 1 x 10^{-2} m/s (for karst aquifer) (confidence level: RA) K= 1.4 x 10^{-3} – 1.3 x 10^{-2} m/s; T= 7.0 x 10^{-3} – 6.5 x 10^{-2} m²/s (for intergranular aquifer of Sutorinsko polje)			
	Tracer tests	Hydraulic connection of the swallow hole in Ponikve (Mokrine) with Morinj and Verige Springs (v≈2.5 cm/s)			
	GW flow directions	General groundwater flow direction is W-E			
Overlaying strata	**Lithology**	Soil in autogenous area; Flysch, glacial sediments, deluvium and alluvium in allogenic area			
	Thickness	Soil: 0-5 m; Flysch: 150-300 m			
	Outcrop of GW body (%)	75%			
Recharge	**Sources of recharge**	P (2,800 mm/a)			
	Infiltration of atmospheric water (assessed)	70%P or 258 x 10^6 m³/year of 381 x 10^6 m³/year (confidence level: RA)			
Outflow	**Main springs Q_{min}/Q/Q_{max}**	Morinj Springs (Q_{min}=1 m³/s), Opačica (Q_{min}=0.035 m³/s), Verige Springs; Česma Spring, Dizdarica Spring, Lovac Spring			
	Average abstraction	Q=50 l/s (Opačica); Q=30 l/s (Sutorinsko polje); Q_{tot}=0.08 m³/s; just 1.5% Q used			
	GW resources (Q, Total recharge)	Q ≈ 8 m³/s; ∑ I_{ef}=8.2 m³/s			
Surface water–Groundwater interaction	Poor interaction				
Water quality	**Chemical composition**	HCO_3 – Ca			
	Protection zones	Delineated for the water-sources: Opačica, Sutorinsko polje			

Vulnerability and risk	**Vulnerability**	Relatively high; To the class Moderate to High Vulnerability belong 72.7%, and to class Very High 6.8%	
	Assessment of pressure	**Point**	Port "Zelenika", PE Load 500
		Diffuse	Wastewater of settlements which are not connected to sewage system; Local landfills; Agriculture; Local road network;
	Risk assessment	Not at Risk, need verification through monitoring	
GW status	**Quality**	Actually Not at risk; PE Load / Vulnerability 0.37	
	Quantity	Good status / Not at Risk	
Monitoring	**Quality**	Existing: Continual for the water sources: Opačica, Sutorinsko polje / Proposed: Operational monitoring	
	Quantity	Existing: Opačica, Morinj springs, Sutorinsko polje / Proposed: Surveillance monitoring	
Dependent ecosystems		Adriatic Sea (Herceg Novi Bay); Sutorina River	

General assessment of data (confidence level): Rough assessment (RA)
Sources of data: Existing hydrogeological maps, reports, books, etc.
Legend: K–karst aquifer ; I–intergranular aquifer; F–fissured aquifer; C–complex aquifer; UC–unconfined conditions; CF–confined conditions; RA–rough assessment

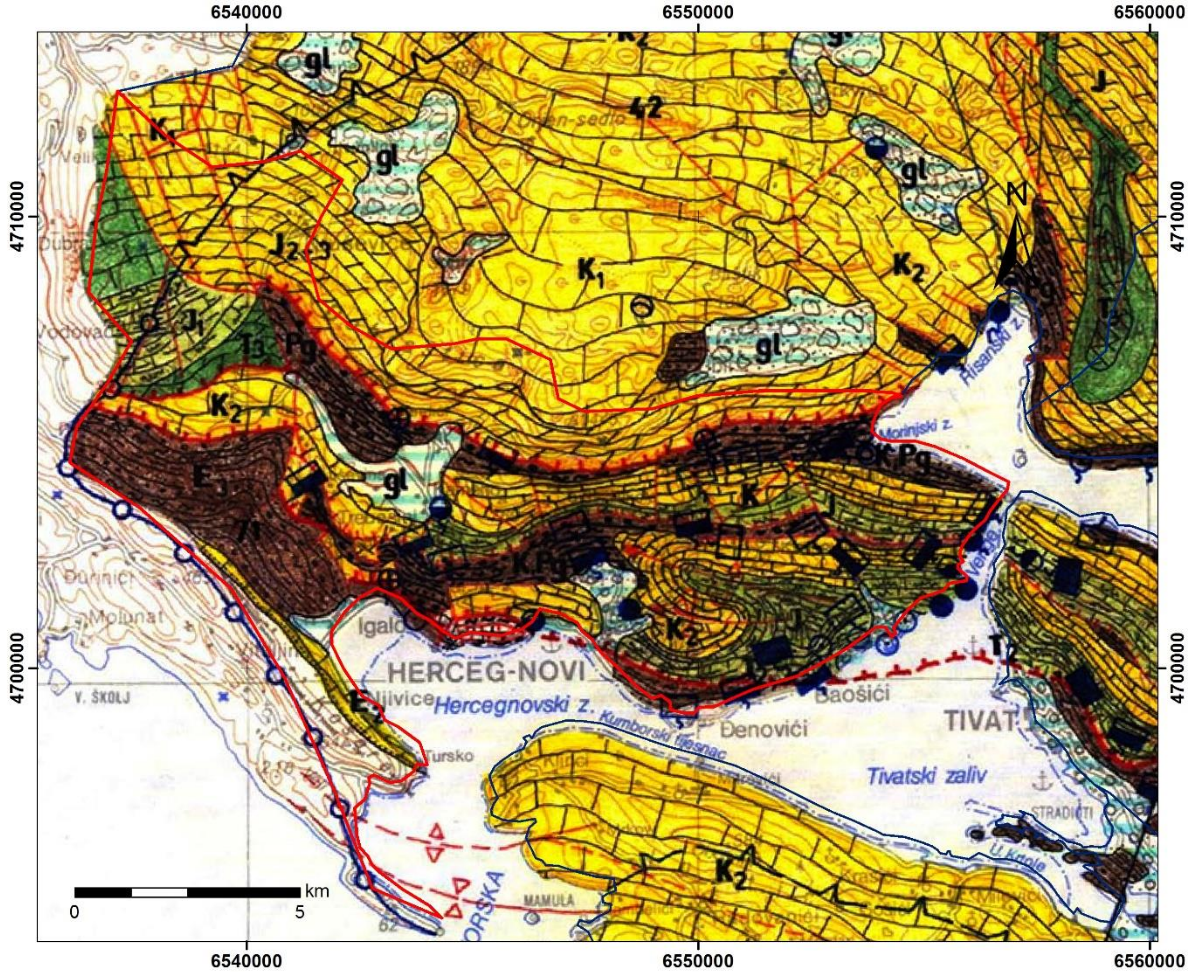

Fig. 5 Boundaries of the group of groundwater bodies "Opačica-Morinj" (red line) on the hydrogeological map (Source of background map: Radulović M. and Radulović V., 2004)

*Appendix VI Description of the groundwater body "**Orjen**"*

River basin	Sub-basin	Name of GGWB	Code	Type of GWBs
Adriatic Sea	Boka Bay	Orjen	ME_A_GW_K_6	K
Area (km^2)	**Autogenous (km^2)**	**407.3**	**Allogenic (km^2)**	**2.3**
Topography and geographical description	Groundwater body is distributed from Jabuke (N) to Lipci (S), and from Jastrebica (W) to Perast (E). Elevation ranges from 0 to 1,894 m asl.			
Geology of GW bodies	**Geology**	Mesozoic limestone, dolomite, and chert (T,J,K); Flysch: conglomerate, sandstone and claystone (E_2); Glacial sediments (gl); Deluvium (d)		
	Hydrogeological units (K, I, F, C)	K		
	Depth to GW level (assessed)	Over 300 m in most of the catchment (confidence level: RA)		
	Hydrogeological parameters	K = 1 x 10^{-4} – 1 x 10^{-1} m/s (confidence level: RA)		
	Tracer tests	Hydraulic connection between the swallow hole in Grahovo polje and Risanska Spilja Spring (*v*=12.42 cm/s)		
	GW flow directions	General groundwater flow direction is NW-SE		
Overlaying strata	**Lithology**	Soil in autogenous area		
	Thickness	Soil: 0-5 m		
	Outcrop of GW body (%)	99.3%		
Recharge	**Sources of recharge**	P (3,510 mm/a)		
	Infiltration of atmospheric water (assessed)	80%P or 1144 x 10^6 m^3/year of 1430 x 10^6 m^3/year (confidence level: RA)		
Outflow	**Main springs Q_{min}/Q/Q_{max}**	Risanska Spilja Spring (Q_{min}=0; Q_{max}=30 m^3/s); Sopot submarine spring; Smokovac Spring (Q_{min}=0.005 m^3/s); Matkova Voda, Sata, Subotića Vode, Džurina; Bljeljaj; Obodja Springs		
	Average abstraction	Q=20 l/s (Risanska Spilja); Q=5 l/s (Smokovac) Q_{tot}=0.025 m^3/s, less than 1% of total Q		
	GW resources (Q, Total recharge)	Q ≈ 35 m^3/s; ∑ I_{ef}=36.2 m^3/s		
Surface water–Groundwater interaction	Poor interaction			
Water quality	**Chemical composition**	HCO_3 – Ca		
	Protection zones	Delineated for the water-sources: Risanska Spilja and Smokovac		

Vulnerability and risk	**Vulnerability**	Moderate to High Class 74.3%, High Class 7%, but away from the Coast not densely populate area	
	Assessment of pressure	**Point**	PE Load: No
		Diffuse	Wastewater of settlements which are not connected to sewage system; Local landfills; Agriculture; Local road network; the main road Risan-Vilusi
	Risk assessment	Low due to rare population and activities	
GW status	**Quality**	Not at risk from pollution / High salinity during the summer on water source Risanska Spilja	
	Quantity	Good status	
Monitoring	**Quality**	Existing: Continual for the water sources Risanska Spilja and Smokovac Spring / Proposed: Surveillance monitoring	
	Quantity	Existing: Risanska Spilja, Smokovac Spring/ Proposed: Surveillance monitoring	
Dependent ecosystems		Adriatic Sea; Grahovo Lake (reservoir)	

General assessment of data (confidence level): Rough assessment (RA)

Sources of data: Existing hydrogeological maps, reports, books, etc.

Legend: K–karst aquifer ; I–intergranular aquifer; F–fissured aquifer; C–complex aquifer; UC–unconfined conditions; CF–confined conditions; RA–rough assessment

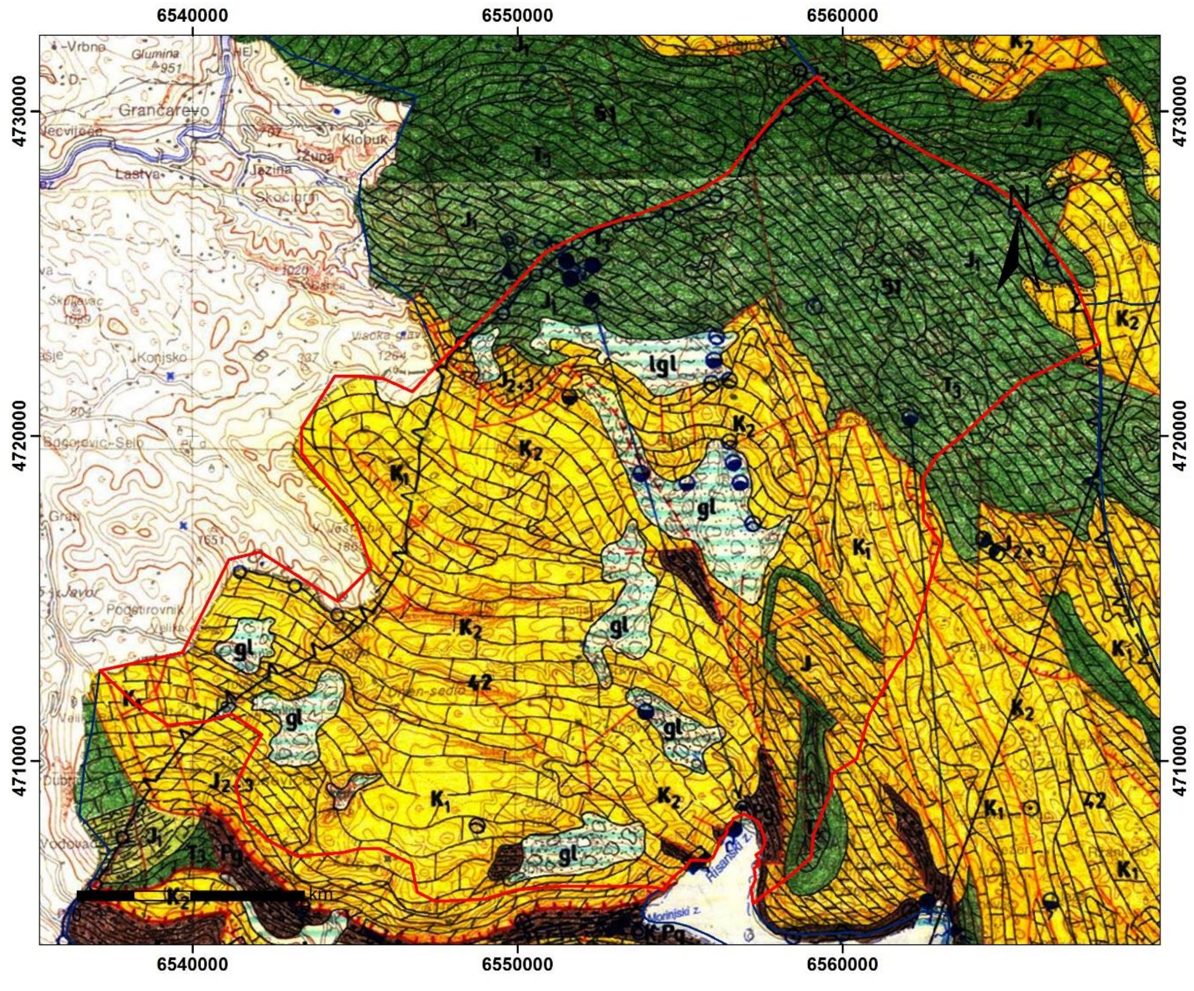

Fig. 6 Boundaries of the groundwater body "Orjen" (red line) on the hydrogeological map (Source of background map: Radulović M. and Radulović V., 2004)

*Appendix VII Description of the groundwater body "**Lovćen (Njeguši)**"*

River basin	Sub-basin	Name of GGWB	Code	Type of GWBs
Adriatic Sea	Boka Bay	Lovćen (Njeguši)	ME_A_GW_K_7	K
Area (km²)	**Autogenous (km²)**	**308.2**	**Allogenic (km²)**	**22**

Topography and geographical description		Groundwater body is distributed from Radanovići (S) to Čumojevica (N), and from Verige (W) to Resna (E). Elevation ranges from 0 to 1,749 m asl.
Geology of GW bodies	**Geology**	Mesozoic limestone, dolomite, and chert (T,J,K); Flysch: conglomerate, sandstone and marl (T_2^1; K,Pg; E_3); Glacial sediments (gl); Deluvium (d)
	Hydrogeological units (K, I, F, C)	K
	Depth to GW level (assessed)	Over 300 m away from the Sea (confidence level: RA)
	Hydrogeological parameters	K = 1 x 10^{-4} – 1 x 10^{-1} m/s (confidence level: RA)
	Tracer tests	Hydraulic connections between swallow holes and springs: swallow hole in Ivanova Korita–Gurdić Spring (Kotor) (*v*=4.70 cm/s); swallow hole Erakovića (Njeguši)–Škurda and Gurdić Spring (Kotor) (*v*=3.80-4.04 cm/s); Duboki Do Cave (Njeguši)– Škurda Spring (Kotor) (*v*=0.09 cm/s); swallow hole Erakovića (Njeguši)–Ljuta Spring (Orahovac) (*v*=3.92 cm/s); swallow hole Koritnik (Njeguši)–Ljuta Spring (Orahovac)) (*v*=2.56 cm/s); swallow hole in Trešnjevo–Ljuta Spring (Orahovac) (*v*=11.04 cm/s)
	GW flow directions	General groundwater flow direction is E-W
Overlaying strata	**Lithology**	Soil in autogenous area; Flysch in allogenic area
	Thickness	Soil: 0-5 m; Flysch: 150-300 m
	Outcrop of GW body (%)	93%
Recharge	**Sources of recharge**	P (2,370 mm/a)
	Infiltration of atmospheric water (assessed)	70%P or 511 x 10^6 m³/year of 730 x 10^6 m³/year (confidence level: RA)
Outflow	**Main springs Q_{min}/Q/Q_{max}**	Plavda (Q_{min}=0.02 m³/s), Gurdić (Q_{min}=0; Q_{max}=30 m³/s), Škurda and Tabačina Springs (Q_{min}=0.1 m³/s; Q_{max}=30 m³/s), Ljuta (Q_{min}=0.1 m³/s; Q_{max}=300 m³/s), Cicanova Kuća Spring (Q_{min}=0.05 m³/s), Spring in Tunnel Vrmac (Q_{min}=0.02 m³/s)
	Average abstraction	Q=20 l/s (Plavda); Q=200 l/s (Škurda and Tabačina); Q=120 l/s (water sources Ercegovina and Cicanova Kuća in Orahovac); Q=20 l/s (Tunnel Vrmac); Q=5 l/s (Simoš Spring); Q=15 l/s (Gornji Grbalj) Q_{tot}=0.36 m³/s
	GW resources (Q, Total recharge)	Q ≈ 10 m³/s; ∑ I_{ef}=16 m³/s
Surface water–Groundwater interaction		Poor interaction
Water quality	**Chemical composition**	HCO_3 – Ca

	Protection zones	Delineated for the water-sources: Plavda, Škurda and Tabačina, water sources Ercegovina and Cicanova Kuća in Orahovac, Tunnel Vrmac, Simoš Spring, Gornji Grbalj	
Vulnerability and risk	**Vulnerability**	To the class Moderate to High Vulnerability belong 52% and to class High 15.7%	
	Assessment of pressure	**Point**	meat processing "Niksen Cavor", port Kotor, large marina Tivat – Porto Montenegro, meat processing in Njeguši, PE Load 2500
		Diffuse	Wastewater of settlements which are not connected to sewage system; Local landfills; Agriculture; Local road network; Tunnel Vrmac
	Risk assessment	Not at Risk, need verification through monitoring	
GW status	**Quality**	Actually Not at risk; PE Load / Vulnerability 1.89 / High salinity during the summer on Plavda, Škurda and Orahovac water sources	
	Quantity	Good status	
Monitoring	**Quality**	Existing: Continual for the water sources: Plavda, Škurda and Tabačina, water sources Ercegovina and Cicanova Kuća in Orahovac, Tunnel Vrmac, Simoš Spring, Gornji Grbalj / Proposed: Operational monitoring	
	Quantity	Existing: Plavda, Škurda and Tabačina, water sources Ercegovina and Cicanova Kuća in Orahovac, Tunnel Vrmac, Simoš Spring, Gornji Grbalj / Proposed: Surveillance monitoring	
Dependent ecosystems		Adriatic Sea (Kotor Bay)	

General assessment of data (confidence level): Rough assessment (RA)

Sources of data: Existing hydrogeological maps, reports, books, etc.

Legend: K–karst aquifer ; I–intergranular aquifer; F–fissured aquifer; C–complex aquifer; UC–unconfined conditions; CF–confined conditions; RA–rough assessment (based on Vulnerability-Hazard-Risk maps)

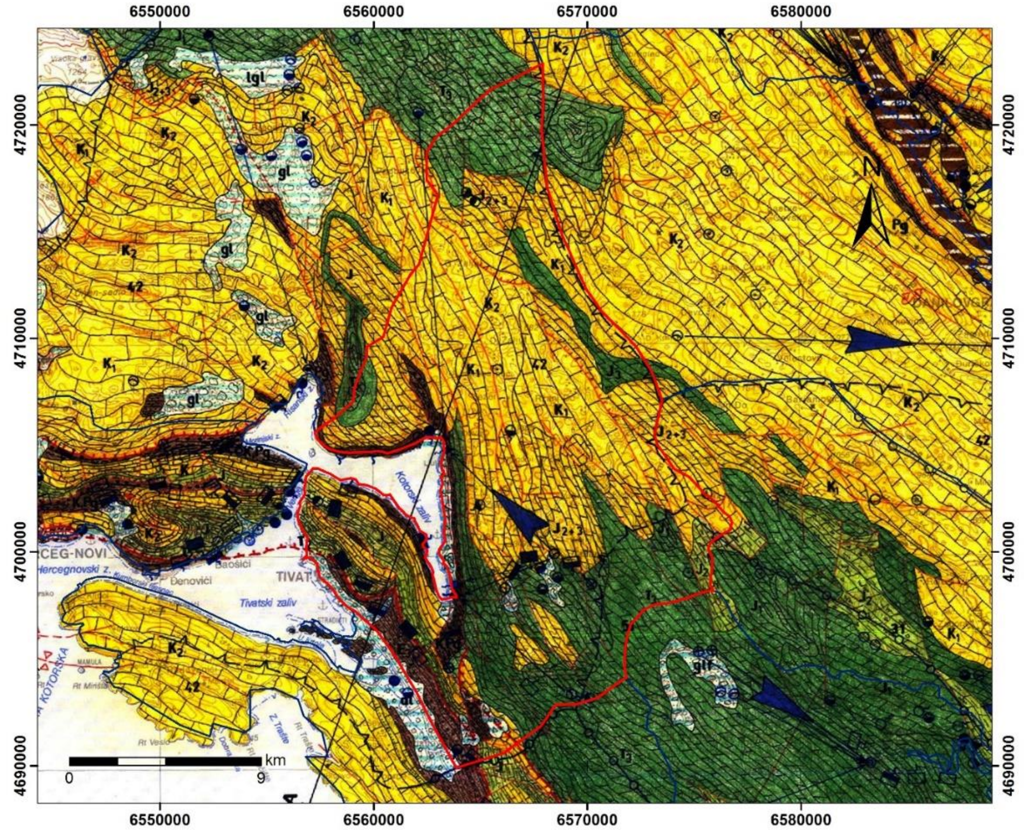

Fig. 7 Boundaries of the group of groundwater bodies "Lovćen (Njeguši)" (red line) on the hydrogeological map (Source of background map: Radulović M. and Radulović V. 2004)

*Appendix VIII Description of the group of groundwater body "**Orahovštica-Rijeka Crnojevića**"*

River basin	Sub-basin	Name of GGWB	Code	Type of GWBs
Bojana River	Skadar Lake	Orahovštica-Rijeka Crnojevića	ME_A_GGW_C_8	C
Area (km^2)	**Autogenous (km^2)**	**237.5**	**Allogenic (km^2)**	**3.8**

Topography and geographical description	Group of groundwater bodies is distributed from Lovćen Mountain (W) to Skadar Lake (E), and from Jankovići (N) to Paštrovska Mountain (S). Elevation ranges from 5 to 1,749 m asl.	
Geology of GW bodies	**Geology**	Sandstone, marl and limestone (T_1); Flysch: conglomerate, sandstone and marl (T_2^1); Bedded limestone with interbeds and nodules of chert and reef limestone (T_2^2); Volcanic-sedimentary rocks (T_2^2); Bedded limestone and dolomite with megalodons (T_3); Bedded limestone and dolomite with lithiotes and red limestone with ammonites (J_1); Bedded and thick bedded limestone with interbeds of chert (K_2); Alluvium (al); Moraine (gl; Deluvium (d); Glaciofluvial sediments (glf)
	Hydrogeological units (K, I, F, C)	Limestone and dolomite (K), Alluvium (I); Hydrodynamic conditions – UC and CF (just for alluvial aquifer of Orahovsko Polje)
	Depth to GW level (assessed)	Up to 400 m (confidence level: RA)
	Hydrogeological parameters	α=0.015-0.065 (Crnojevića Spring); T=1.52 x 10^{-2} – 8.0 x 10^{-2} m^2/s, K_f = 1.90 x 10^{-3} – 1.0 x 10^{-2} m/s (water-source "Sjenokos"); T=5.0 x 10^{-3} – 5.0 x 10^{-2} m^2/s, K_f = 3.0 x 10^{-4} – 3.0 x 10^{-3} m/s (water-source "Orahovsko polje")
	Tracer tests	Hydraulic connections between swallow holes and springs: Obzovica-Podgor Spring (v=13.82 cm/s); Seoca-Podgor Spring (v=5.21 cm/s); Ugnji-Crnojevića Spring (v=2.75 cm/s); Cetinje-Crnojevića Spring (v=0.25-5.5 cm/s)
	GW flow directions	General groundwater flow direction is NW-SE ("Dinaric path")
Overlaying strata	**Lithology**	Soil in autogenous area; Flysch sediments and volcanic-sedimentary rocks in allogenic area
	Thickness	Soil: 0-5 m; Flysch sediments and volcanic-sedimentary rocks: 230 m
	Outcrop of GW body (%)	98.5%
Recharge	**Sources of recharge**	P (2,853 mm/a), sinking streams (Orahovštica River)
	Infiltration of atmospheric water (assessed)	75%P or 516 x 10^6 m^3/year of 688 x 10^6 m^3/year (confidence level: RA)
Outflow	**Main springs Q_{min}/Q/Q_{max}(l/s)**	Podgor (Q_{min}=0.237 m^3/s; Q=1.64 m^3/s; Q_{max}=11.9 m^3/s), Crnojevića spring (Q_{min}=1,12m^3/s; Q=6.15m^3/s; Q_{max}=12.26 m^3/s); Uganjska springs (Q=10-20 l/s); Obzovica Spring (Q=1 l/s)
	Average abstraction (m^3/s)	Q=0.2m^3/s (Podgor), Q=0.01 m^3/s (Uganjska springs), Q=0.001 m^3/s (Obzovica Spring); Q = 0.15 m^3/s(water-source "OrahovskoPolje"); Q = 0.1m^3/s(water-source "Sjenokos") **Q_{tot}=0.461 m^3/s**
	GW resources (Q, Total recharge)	Q = 8.4 m^3/s; $\sum I_{ef}$= 16.4 m^3/s
Surface water–Groundwater interaction	Poor interaction within catchment areas of springs, and good interaction along Orahovštica River.	
Water quality	**Chemical composition**	HCO_3 – Ca – Mg

	Protection zones	Delineated for Podgor, Uganjska springs, Obzovica spring, water-source “Orahovsko Polje” and water-source “Sjenokos”	
Vulnerability and risk	**Vulnerability**	To the class Low and Moderate Vulnerability belong 96%	
	Assessment of pressure	**Point**	Wastewater from Cetinje polje is discharging into the swallow hole and further to karst aquifer; factory of paper "Kartonaža", meat processing "Interproduct", fish processing "Ribarstvo Rijeka"
		Diffuse	Wastewater of settlements which are not connected to sewage system; Local landfills; Agriculture; Main road Podgorica-Budva
	Risk assessment	Potentially at risk, Due to high PE Load of 17650	
GW status	**Quality**	Under the pressure; Potentially at risk, Ratio PE Load vs. Vulnerability 14.78	
	Quantity	Good status	
Monitoring	**Quality**	Existing: Continual for Podgor, Uganjska springs, Obzovica springs, water-source “Orahovsko Polje” and water-source “Sjenokos”/ Proposed: Operational monitoring	
	Quantity	Existing: Continual for Crnojevića spring and temporary for Podgor, Uganjska springs and Obzovica spring / Proposed: Surveillance monitoring	
Dependent ecosystems		Skadar Lake, Crnojevića River, Orahovštica River	

General assessment of data (confidence level): Rough assessment (RA)
Sources of data: Existing hydrogeological maps, reports, books, etc.
Legend: K–karst aquifer ; I–intergranular aquifer; F–fissured aquifer; C–complex aquifer; UC–unconfined conditions; CF–confined conditions; RA–rough assessment

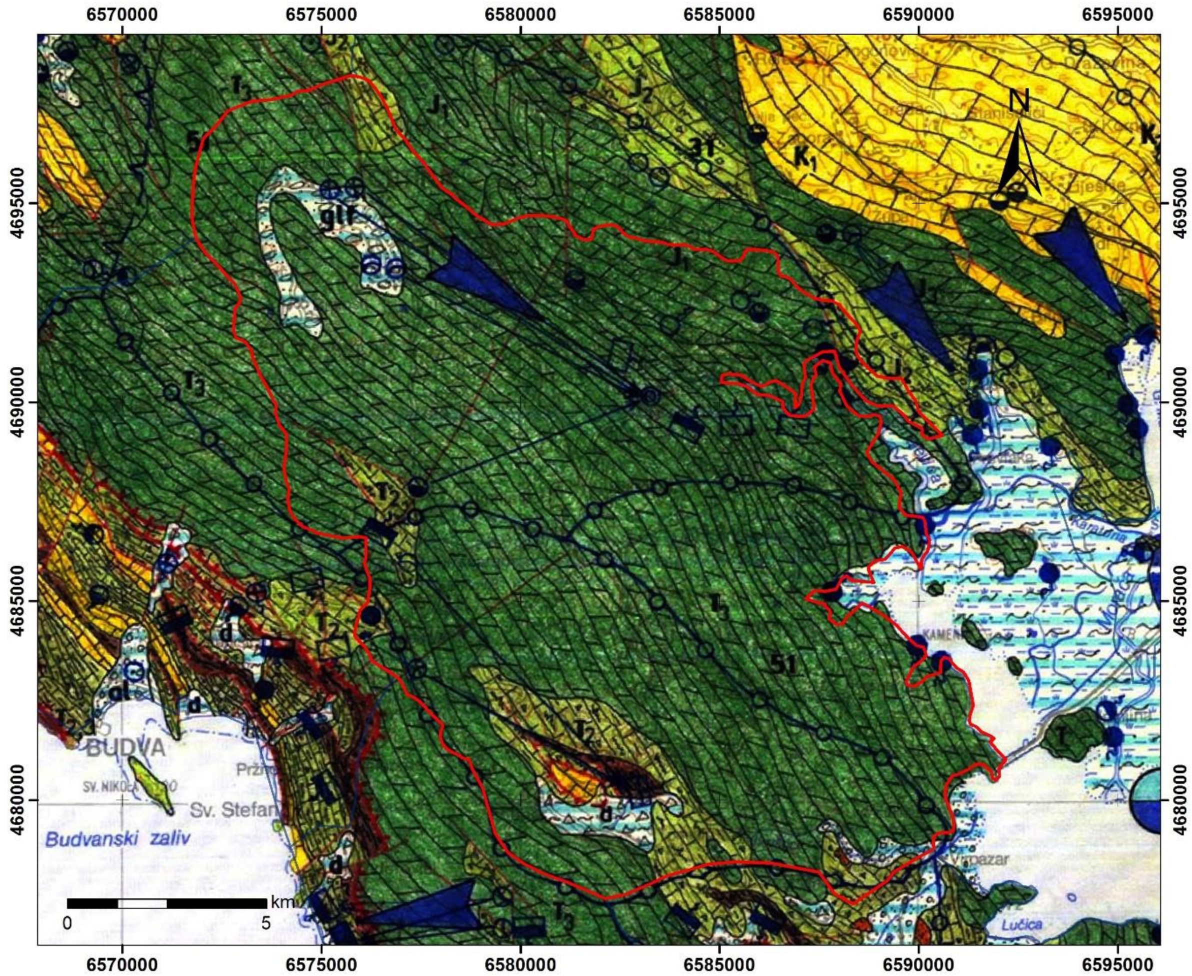

Fig. 8 Boundaries of the group of groundwater bodies “Orahovštica-Rijeka Crojevića” (red line) on the hydrogeological map (Source of background map: Radulović M. and Radulović V. 2004)

*Appendix IX Description of the group of groundwater body “**Karuč-Sinjac**“*

River basin	**Sub-basin**	**Name of GGWB**	**Code**	**Type of GWBs**
Bojana River	Skadar Lake	Karuč-Sinjac	ME_A_GGW_K_9	K
Area (km^2)	**Autogenous (km^2)**	**277.2**	**Allogenic (km^2)**	**0**

Topography and geographical description		Group of groundwater bodies is elongated along the NW-SE direction. It is distributed from Bjelice (NW) to Malo Blato (SE). Elevation ranges from 5 to 1,203 m asl.
Geology of GW bodies	**Geology**	Mesozoic limestone and dolomite (T_3, J_1, J_2, J_3, K_1, K_2); Lacustrine sediments (*j*)
	Hydrogeological units (K, I, F, C)	K
	Depth to GW level (assessed)	Up to 200 m (confidence level: RA)
	Hydrogeological parameters	K=7.9 x 10^{-2} m/s
	Tracer tests	Hydraulic connections between swallow holes and springs: Štitari-Volač Spring (v=5.4 cm/s); Lainje-Djurov Spring, Karuč Spring, Volač Spring (v=0.65-0.67 cm/s); Brežine-Kaluđerov Spring (v=2.3 cm/s); Borehole IBG2 (Grbavci)-Čkanjak Spring (v=2.5 cm/s); Borehole B8 (30 m from the spring) – Bolje Sestre Sprng (v=12.5 cm/s)
	GW flow directions	General groundwater flow direction is NW-SE (“Dinaric path”)
Overlaying strata	**Lithology**	Soil
	Thickness	0-5 m
	Outcrop of GW body (%)	100%
Recharge	**Sources of recharge**	P (2,700 mm/a)
	Infiltration of atmospheric water (assessed)	70%P or 524 x 10^6 m^3/year of 748 x 10^6 m^3/year (confidence level: RA)
Outflow	**Main springs Q_{min}/Q/Q_{max}(l/s)**	**Springs of Karuč Bay**: Karuč, Volač, Đurovo Oko, Studenac, Radiševo Oko, Žabino Oko, Grivo Oko and Bazagurska Spring (total discharge: Q_{min}=2.5 m^3/s, Q=7 m^3/s, Q_{max}=25 m^3/s; Zogović 1992); **Springs of Malo Blato**: Kaludjerovo Oko, Velja Šuica, Mala Šuica, Oko Krakala, Oko Bivo, Crno oko, Bolje Sestre, Oko Brodić, Biotsko oko, Oko Pod Bobovine and Krstato Oko (total discharge: Q_{min}=5 m^3/s, Q=12 m^3/s; Radulović et al. 1979)
	Average abstraction (m^3/s)	Q=1.5 m^3/s (water-source “Bolje Sestre”); Q=5 l/s (Rvaši); Q=5 l/s (Drušići); Q=5 l/s (Župa Dobrska); water-source Goljemadi (Kaludjerovo Oko) is under construction **Q_{tot}=1.515 m^3/s**
	GW resources (Q, Total recharge)	Q = 19 m^3/s; $\sum I_{ef}$= 16.6 m^3/s
Surface water–Groundwater interaction		Poor (indirect) interaction via alluvium of Morača and Cijevna
Water quality	**Chemical composition**	HCO_3 – Ca – Mg

	Protection zones	Delineated for water-source “Bolje Sestre” and “Župa Dobrska”	
Vulnerability and risk	**Vulnerability**	Very high 31%, moderate 49.7%	
	Assessment of pressure	**Point**	In adjacent GWB Zetska ravnica - Gravel extraction at Cijevna River mouth and along Morača River, potential threats of planned waste water treatment plant and highway crossing this GW body
		Diffuse	Wastewater of settlements which are not connected to sewage system; Local landfills; Agriculture; Main road Podgorica-Budva
	Risk assessment	Potentially at risk	
GW status	**Quality**	Under the pressure, potentially at risk, despite PE vs. Vulner. Is 0	
	Quantity	Good status	
Monitoring	**Quality**	Existing: Continual for Bolje Sestre Spring / Proposed: Operational monitoring	
	Quantity	Existing: Continual for Bolje Sestre Spring / Proposed: Operational monitoring	
Dependent ecosystems		Skadar Lake, Malo Blato	

General assessment of data (confidence level): Rough assessment (RA)
Sources of data: Existing hydrogeological maps, reports, books, etc.
Legend: K–karst aquifer ; I–intergranular aquifer; F–fissured aquifer; C–complex aquifer; UC–unconfined conditions; CF–confined conditions; RA–rough assessment

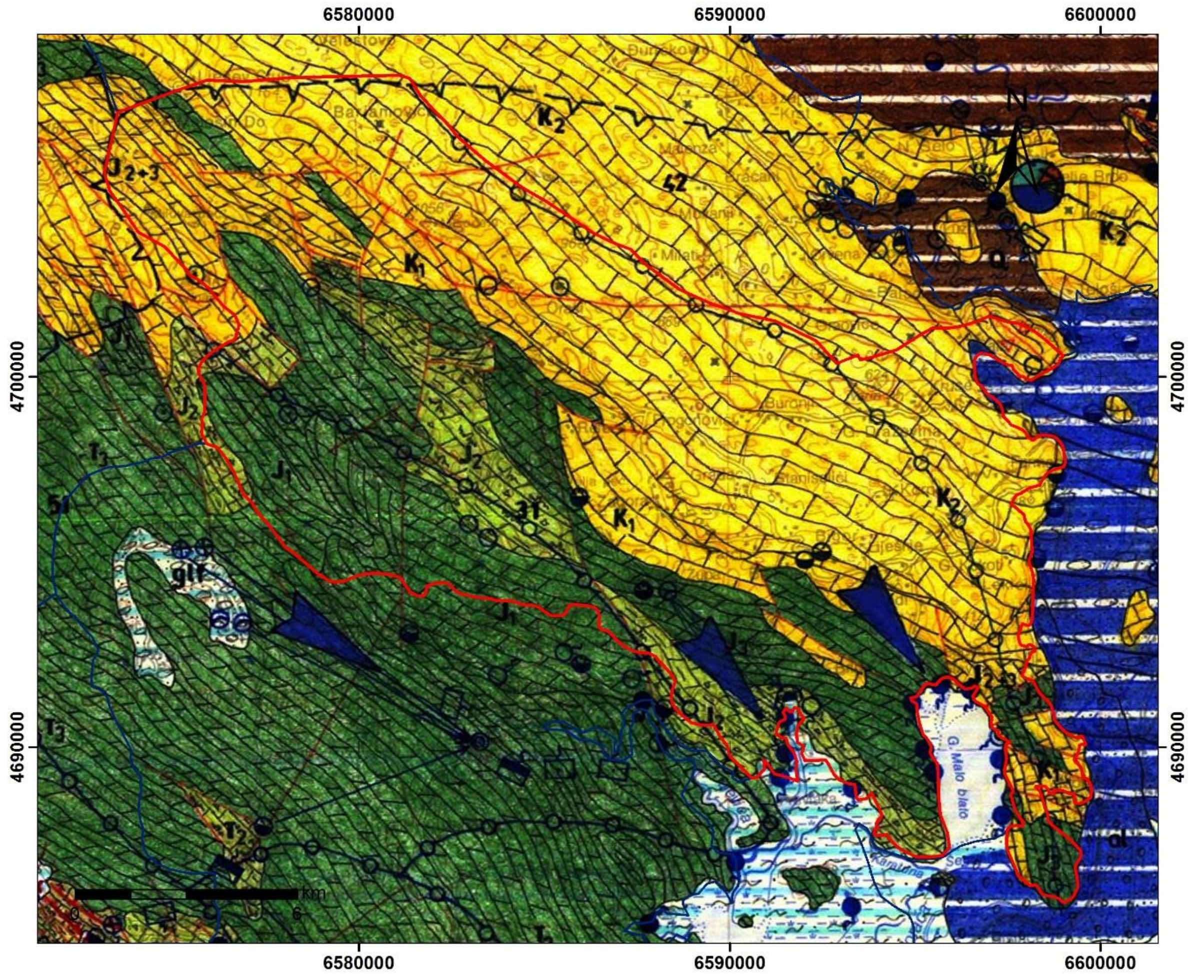

Fig. 9 Boundaries of the group of groundwater bodies “Karuč Sinjac” (red line) on the hydrogeological map (Source of background map: Radulović M. and Radulović V. 2004)

*Appendix X Description of the group of groundwater body “**Zeta Valley**“*

River basin	Sub-basin		Name of GGWB	Code	Type of GWBs
Bojana River	Skadar Lake		Zeta Valley	ME_A_GGW_I_10	C
Area (km^2)	**Autogenous (km^2)**		**248.5**	**Allogenic (km^2)**	**0**
Topography and geographical description	Group of groundwater bodies is distributed from Zlatica (N) to Skadar Lake (S), and from Donji Kokoti (W) to Tuzi (E). Elevation ranges from 5 to 80 m asl.				
Geology of GW bodies	**Geology**	Glaciofluvial (glf), alluvial (al) and lacustrine sediments (j) are distributed in the surface zone (thickness up to 100 m), and limestone and dolomite (J, K) below them. Besides the carbonates rocks, the bottom of the quaternary sediment is built of marl and claystone (Pl), but just in the southern part of the valley.			
	Hydrogeological units (K, I, F, C)	Alluvial (al) and glaciofluvial (glf) sediments (I), Limestone and dolomite (K); Hydrodynamic conditions – UC			
	Depth to GW level (assessed)	15 m in average (confidence level: RA)			
	Hydrogeological parameters	T=1.79 x 10^{-2} m^2/s, K_f = 5.0 x 10^{-3} /s (glaciofluvial sediments)			
	Tracer tests	N/A			
	GW flow directions	General groundwater flow direction is N-S			
Overlaying strata	**Lithology**	Soil			
	Thickness	Up to 5 m			
	Outcrop of GW body (%)	100%			
Recharge	**Sources of recharge**	P (1,636 mm/a); Losing rivers: Morača, Zeta, Ribnica, Cijevna, Sitnica; Subterranean inflow from the surrounding karst aquifer			
	Infiltration of atmospheric water (assessed)	50%P or 195 x 10^6 m^3/year of 390 x 10^6 m^3/year (confidence level: RA)			
Outflow	**Main springs Q_{min}/Q/Q_{max}(l/s)**	Springs of following streams: Plavnica, Zetica, Gostiljska River, Svinješ, Pjavnik, Velika Mrka, Mala Mrka, and many other nameless streams (total discharge is around 12 m^3/s in average)			
	Average abstraction (m^3/s)	Q=410 l/s (Ćemovsko polje), Q=545 l/s (Zagorič), Q=12 l/s (Tuzi); Q = 70 l/s (Dinoši); Q = 130 l/s (Vuksan Lekić); Q=2,000 l/s (“Plantaže”); Q=1,000 l/s (Aluminium Plant); Private wells (Q=?) **Q_{tot}=4.2 m^3/s**			
	GW resources (Q, Total recharge)	Q = 12 m^3/s; $\sum I_{ef}$= 6.2 m^3/s			
Surface water–Groundwater interaction	Good interaction along Morača, Zeta, Ribnica, Cijevna and Sitnica River.				
Water quality	**Chemical composition**	HCO_3 – Ca			
	Protection zones	Delineated for the following water-sources: Ćemovsko polje, Zagorič, Tuzi, Dinoši, Vuksan Lekić			

Vulnerability and risk	**Vulnerability**	Even 89% belong to class Very high vulnerability	
	Assessment of pressure	**Point**	Factory of wine and vineyards "Plantaže", Processing of fruits and vegetables "Plodovi Crne Gore", chemical industry "Hemko", Aluminium Plant, gravel extraction at Cijevna mouth
		Diffuse	Wastewater of settlements which are not connected to sewage system; red mud flotation lake of Aluminium Plant; local landfills; agriculture; road network
	Risk assessment	At risk	
GW status	**Quality**	Under the pressure, PE is 120750, while PE vs. Vulnerab. Is 204.95	
	Quantity	Under pressure, 50% of renewable GW is exploited	
Monitoring	**Quality**	Existing: Continual for water-sources Ćemovsko polje, Zagorič, Tuzi, Dinoši, Vuksan Lekić / Proposed: Operational monitoring	
	Quantity	Existing: Continual for water-sources Ćemovsko polje, Zagorič, Tuzi, Dinoši, Vuksan Lekić / Proposed: Operational monitoring	
Dependent ecosystems		Skadar Lake, Morača Cijevna and rivers	

General assessment of data (confidence level): Rough assessment (RA)

Sources of data: Existing hydrogeological maps, reports, books, etc.

Legend: K–karst aquifer ; I–intergranular aquifer; F–fissured aquifer; C–complex aquifer; UC–unconfined conditions; CF–confined conditions; RA–rough assessment

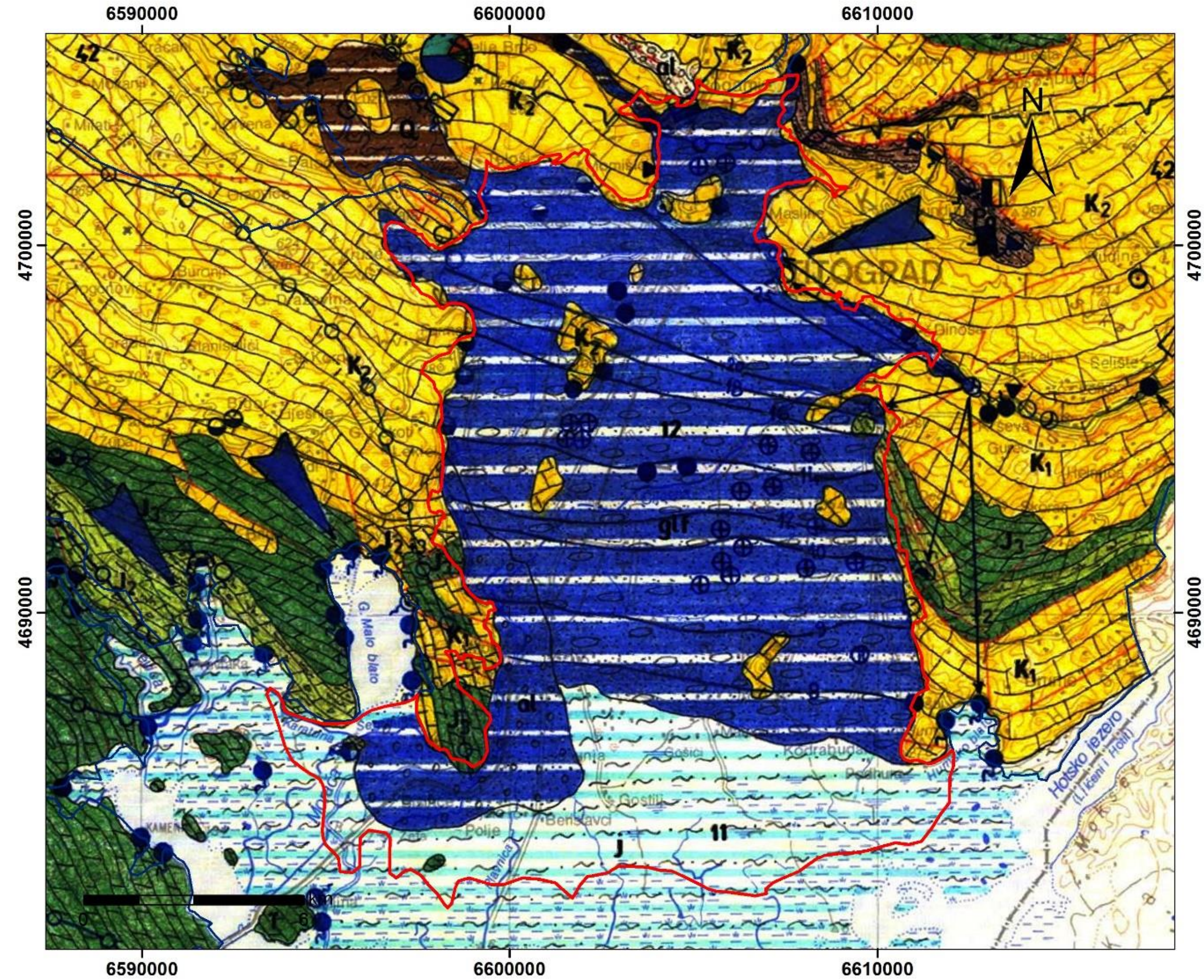

Fig. 10 Boundaries of the group of groundwater bodies "Zeta Valley" (red line) on the hydrogeological map (Source of background map: Radulović M. and Radulović V. 2004)

*Appendix XI Description of the group of groundwater body "**Prekornica - Bjelopavlići** "*

<table>
<tr><th>River basin</th><th>Sub-basin</th><th>Name of GGWB</th><th>Code</th><th>Type of GWBs</th></tr>
<tr><td>Bojana River</td><td>Zeta</td><td>Prekornica - Bjelopavlići</td><td>ME_A_GGW_C_11</td><td>C</td></tr>
<tr><td>Area (km²)</td><td>Autogenous (km²)</td><td>319</td><td>Allogenic (km²)</td><td>99</td></tr>
<tr><td>Topography and geographical description</td><td colspan="4">Group of groundwater bodies is distributed from Zeta Valley (SE) to Mijokusovići (NW), and from Frutak (SW) to Brajovićka Ponikvica (NE). Elevation ranges from 31 to 1,559 m asl (the top of Maglić Mountain).</td></tr>
<tr><td rowspan="6">Geology of GW bodies</td><td>Geology</td><td colspan="3">Mesozoic limestone and dolomite (T_3, J_1, $J_{2,3}$, K_1, $K_{2,3}$); Flysch: conglomerate, sandstone, aleurolite, limestone and marl (E_2); Quaternary clay and sand (Q_1); glacial sediments (gl)..</td></tr>
<tr><td>Hydrogeological units (K, I, F, C)</td><td colspan="3">K, I</td></tr>
<tr><td>Depth to GW level (assessed)</td><td colspan="3">Over 300 m (confidence level: RA)</td></tr>
<tr><td>Hydrogeological parameters</td><td colspan="3">K = 1 x 10^{-4} – 1 x 10^{-1} m/s (confidence level: RA)</td></tr>
<tr><td>Tracer tests</td><td colspan="3">Hydraulic connections between swallow holes and springs: Swalllow hole Tubin (Grbe)-Kraljičino Oko Spring (v=2.78 cm/s); Swalllow hole in Zorski Lug-Kraljičino Oko Spring (v=3.4 cm/s); Borehole B3 (Agrokombinat "13. JUL")-Kraljičino Oko Spring (v=0.51 cm/s); Borehole B2 (Velje Hill)-Kraljičino Oko Spring (v=1.32 cm/s)</td></tr>
<tr><td>GW flow directions</td><td colspan="3">General groundwater flow direction is NE-SW</td></tr>
<tr><td rowspan="3">Overlaying strata</td><td>Lithology</td><td colspan="3">Soil in autogenous area; Quaternary clay/sand and flysch sediments in allogenic area</td></tr>
<tr><td>Thickness</td><td colspan="3">Soil: 0-5 m; Quaternary clay and sand: 50 m; Flysch: 150 m</td></tr>
<tr><td>Outcrop of GW body (%)</td><td colspan="3">69%</td></tr>
<tr><td rowspan="2">Recharge</td><td>Sources of recharge</td><td colspan="3">P (2,200 mm/a)</td></tr>
<tr><td>Infiltration of atmospheric water (assessed)</td><td colspan="3">70%P or 491 x 10^6 m³/year of 702 x 10^6 m³/year (confidence level: RA)</td></tr>
<tr><td rowspan="3">Outflow</td><td>Main springs Q_{min}/Q/Q_{max}(l/s)</td><td colspan="3">Mareza (Qmin=1.6 m³/s, Qav≈6 m3/s; Qmax≈12 m³/s), Kraljičino Oko Sprig (Qmin≈0.020 m³/s; Qmax≈1 m³/s), Crno Oko Spring, Vriješki Spring, Straganica springs, Iverak Spring (Qav≈0.012 m³/s), Studeno Spring (Q≈0.001 m³/s), Žarića Jama Spring (Qmin=0; Qmax≈1 m³/s), Braovića Jama Spring, Slatina Springs (Qmin=0.015 m³/s, Qav≈0.076 m³/s; Qmax≈0.2 m³/s), Smrdan Spring, Viški Springs</td></tr>
<tr><td>Average abstraction (m³/s)</td><td colspan="3">Q=2110 l/s (Mareza Springs); Q=35 l/s (Žarića Jama); Q=32 l/s (Brajovoća Jama); Q=15 l/s (Slatina Springs); Q=10 l/s (Viški Well); Q≈1 l/s
Q_{tot}=2.203 m³/s</td></tr>
<tr><td>GW resources (Q, Total recharge)</td><td colspan="3">Q ≈ 15 m³/s; ∑ I_{ef}=15.6 m³/s</td></tr>
<tr><td>Surface water–Groundwater interaction</td><td colspan="4">Poor interaction</td></tr>
<tr><td>Water quality</td><td>Chemical composition</td><td colspan="3">HCO_3 – Ca</td></tr>
</table>

	Protection zones	Delineated for water-sources “Mareza”, “Slatina”, “Iverak”.	
Vulnerability and risk	**Vulnerability**	The class high vulnerability 15%, and moderate to high 63%	
	Assessment of pressure	**Point**	Stone processing "Mermer", juice factory "Pirella", facory of coffee "Crnagoracoop", factory of animal feed in Spuž, milk factory "Lazine"
		Diffuse	Wastewater of settlements which are not connected to sewage system; Local landfills; Agriculture; Secondary road Podgorica-Glava Zete
	Risk assessment	PE 4000, while ratio PE vs. Vulner. Is 4.03	
GW status	**Quality**	Actually not at risk	
	Quantity	Good status	
Monitoring	**Quality**	Existing: Continual for Mareza Springs, Slatina Spring, Žarića Jama, Brajovića Jama, Iverak, Viški Well / Proposed: Operational monitoring	
	Quantity	Existing: Continual for Mareza Spring / Proposed: Operational monitoring	
Dependent ecosystems		Zeta River	

General assessment of data (confidence level): Rough assessment (RA)

Sources of data: Existing hydrogeological maps, reports, books, etc.

Legend: K–karst aquifer ; I–intergranular aquifer; F–fissured aquifer; C–complex aquifer; UC–unconfined conditions; CF–confined conditions; RA–rough assessment;

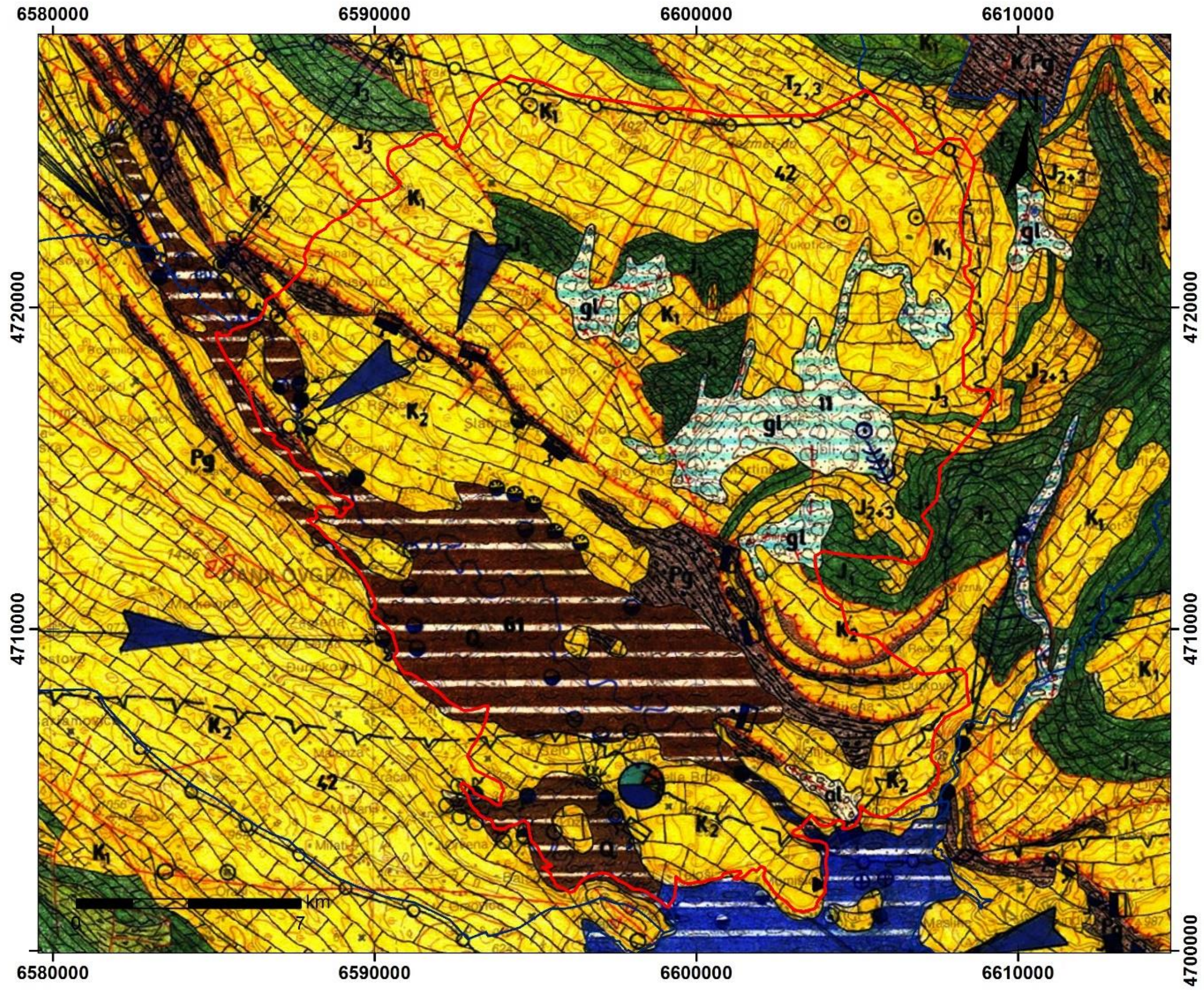

Fig. 11 Boundaries of the group of groundwater bodies “Prekornica-Bjelopavlići” (red line) on the hydrogeological map (Source of background map: Radulović M. and Radulović V. 2004)

*Appendix XII Description of the group of groundwater body “**Garač**“*

River basin	Sub-basin	Name of GGWB	Code	Type of GWBs
Bojana River	Zeta	Garač	ME_A_GGW_K_12	K
Area (km^2)	**Autogenous (km^2)**	**335.2**	**Allogenic (km^2)**	**3.2**

Topography and geographical description		Group of groundwater bodies is elongated along the NW-SE direction. It is distributed from Ilijina Strana (NW) to Zelenika (SE), and from Lipa (W) to Bjelopavlićka Valley (E). Elevation ranges from 32 to 1,436 m asl.
Geology of GW bodies	**Geology**	Mesozoic limestone and dolomite (J_1, $J_{2,3}$, K_1, K_2); Flysch: conglomerate, sandstone, aleurolite, limestone and marl (E_2)
	Hydrogeological units (K, I, F, C)	K
	Depth to GW level (assessed)	Up to 400 m (confidence level: RA)
	Hydrogeological parameters	K = 1 x 10^{-4} – 1 x 10^{-1} m/s (confidence level: RA)
	Tracer tests	Hydraulic connections between swallow holes and springs: Swalllow hole Orluina (Čevo)-Oraška Jama Spring (v=5.34 cm/s)
	GW flow directions	General groundwater flow direction is NW-SE (“Dinaric path”)
Overlaying strata	**Lithology**	Soil in autogenous area; Flysch sediments in allogenic area
	Thickness	Soil: 0-5 m; Flysch: 150 m
	Outcrop of GW body (%)	99%
Recharge	**Sources of recharge**	P (2,246 mm/a)
	Infiltration of atmospheric water (assessed)	70%P or 532 x 10^6 m^3/year of 760 x 10^6 m^3/year (confidence level: RA)
Outflow	**Main springs Q_{min}/Q/Q_{max}(l/s)**	**Springs of Tunjevo:** Milojevića Spring (Q_{min}=0.05 m^3/s, Q_{max}≈20 m^3/s), Dobrik Spring (Q_{min}=0.005 m^3/s, Q_{max}≈0.1 m^3/s), Tunjevo Sring; **Periodical springs along the Sušica River:** Oraška Jama, Šabovo Oko, Grgurovo Oko, Žablje Oko, Modro Oko (total discharge: Q_{min}= 0 m^3/s, Q_{max}≈10 m^3/s); **Periodical springs of Bandići**: Vučiji Studenac, Modro Oko, Oko Kručice, Blizanci (total discharge: Q_{min}= 0 m^3/s, Q_{max}≈10 m^3/s); **Orluina (Čevo) Spring** (Q_{min}=0.0005 m^3/s).
	Average abstraction (m^3/s)	Q=120 l/s (water-source “Oraška Jama”); Q=60 l/s (Milojevića Spring); Q=20 l/s (Vučiji Studenac). **Q_{tot}=0.2 m^3/s**
	GW resources (Q, Total recharge)	Q ≈ 17 m^3/s; ∑ I_{ef}=16.9 m^3/s
Surface water–Groundwater interaction		Poor interaction
Water quality	**Chemical composition**	HCO_3 – Ca
	Protection zones	Delineated for water-sources “Oraška Jama” and “Milojevića Spring”

Vulnerability and risk	**Vulnerability**	Very high (7.4%) and Moderate to high (81%)	
	Assessment of pressure	**Point**	N/A
		Diffuse	Wastewater of settlements which are not connected to sewage system; Local landfills; Agriculture; Main road Podgorica-Nikšić
	Risk assessment	No PE, means not at risk	
GW status	**Quality**	Not under pressure, good status	
	Quantity	Good status	
Monitoring	**Quality**	Existing: Continual for “Oraška Jama” and “Milojevića Spring” / Proposed: Surveillance monitoring	
	Quantity	Existing: Continual for “Oraška Jama” and “Milojevića Spring” / Proposed: Surveillance monitoring	
Dependent ecosystems		Zeta River, Sitnica (Matica) River	

General assessment of data (confidence level): Rough assessment (RA)

Sources of data: Existing hydrogeological maps, reports, books, etc.

Legend: K–karst aquifer ; I–intergranular aquifer; F–fissured aquifer; C–complex aquifer; UC–unconfined conditions; CF–confined conditions; RA–rough assessment

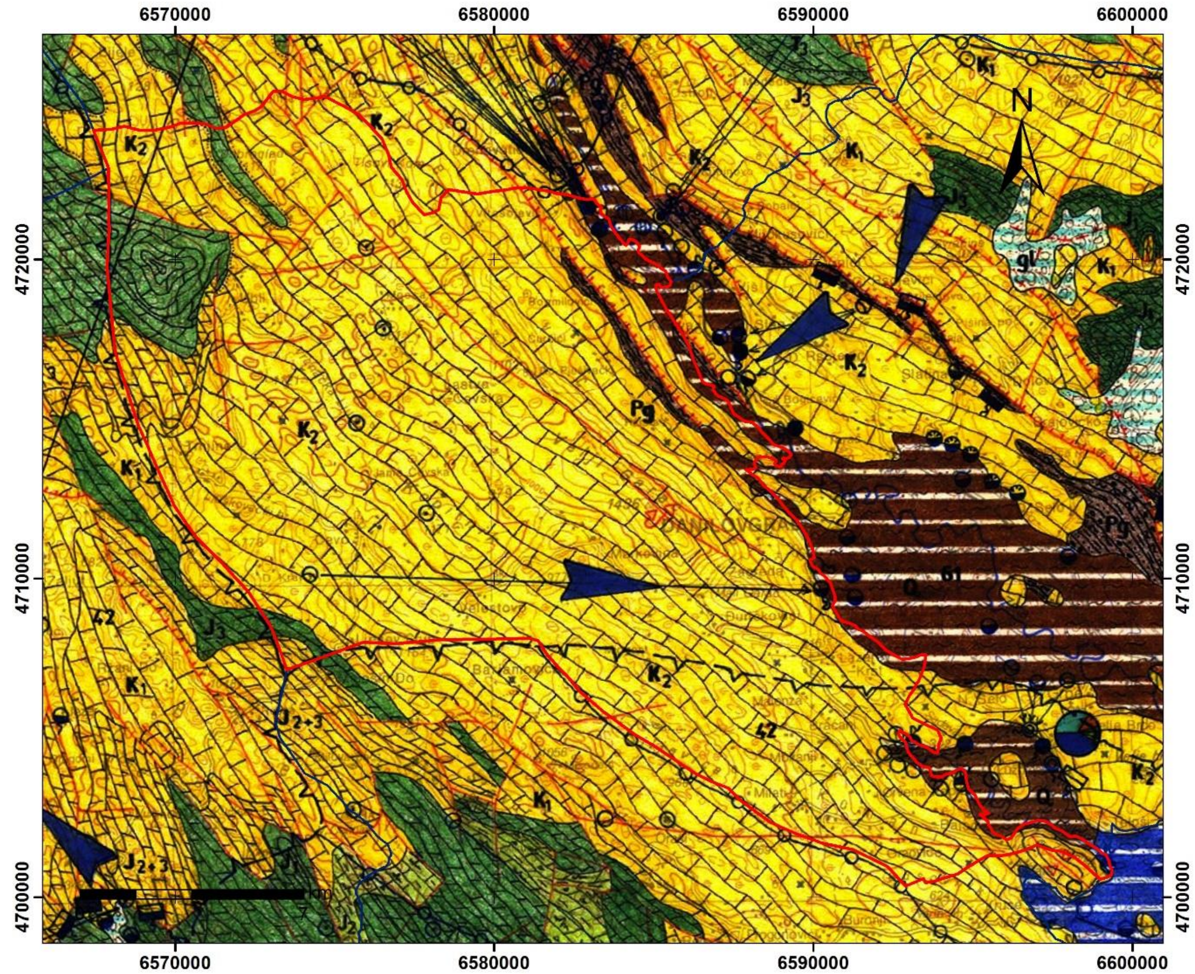

Fig. XII Boundaries of the group of groundwater bodies “Garač” (red line) on the hydrogeological map (Source of background map: Radulović M. and Radulović V. 2004)

*Appendix XIII Description of the group of groundwater body "**Vojnik**"*

River basin	Sub-basin		Name of GGWB	Code	Type of GWBs
Bojana River	Zeta		Nikšić	ME_A_GGW_K_13	K
Area (km^2)	**Autogenous (km^2)**		**423**	**Allogenic (km^2)**	**25.5**
Topography and geographical description	Group of groundwater bodies is distributed from Vidrovan (S) to Vojnik (N), and from Goslić (W) to Gackove Grede (E). Elevation ranges from 650 to 1,998 m asl.				
Geology of GW bodies	**Geology**	Mesozoic limestone and dolomite (T,J,K); Flysch: marlstone, claystone and marly limestone (K,Pg); glacial sediments (gl)			
	Hydrogeological units (K, I, F, C)	K			
	Depth to GW level (assessed)	Over 300 m (confidence level: RA)			
	Hydrogeological parameters	K = $1 \times 10^{-4} – 1 \times 10^{-1}$ m/s (confidence level: RA)			
	Tracer tests	Hydraulic connection: swallow hole in the riverbed of Vidrovan River – Zoja Spring and Rastovac Spring (v=0.37 cm/s);			
	GW flow directions	General groundwater flow direction is N-S			
Overlaying strata	**Lithology**	Soil in autogenous area; flysch and glacial sediment in allogenic area			
	Thickness	Soil: 0-5 m; glacial sediments: 20 m; Flysch: 150 m			
	Outcrop of GW body (%)	94.3%			
Recharge	**Sources of recharge**	P (2,054 mm/a)			
	Infiltration of atmospheric water (assessed)	70%P or 645×10^6 m^3/year of 921×10^6 m^3/year (confidence level: RA)			
Outflow	**Main springs Q_{min}/Q/Q_{max}(l/s)**	Upper Vidrovan Spring (Q_{min}= 0.2 m^3/s; Qmax≈10 m^3/s), Lower Vidrovan Spring (Q_{min}= 0.15 m^3/s; Qmax≈5 m^3/s), Vukov Spring (Q_{min}= 0.33 m^3/s), Zoja Spring, Rastovac Spring (Q_{min}= 0.2 m^3/s), Gornjepoljski Spring			
	Average abstraction (m^3/s)	Q=200 l/s (water source "Vidrovan") **Q_{tot}=0.2 m^3/s**			
	GW resources (Q, Total recharge)	Q ≈ 18.4 m^3/s; ∑ I_{ef}=20.5 m^3/s			
Surface water–Groundwater interaction	Good interaction				
Water quality	**Chemical composition**	HCO_3 – Ca			
	Protection zones	Delineated for water-source "Vidrovan"			

Vulnerability and risk	**Vulnerability**	Very high (19%) and Moderate to high (58%)	
	Assessment of pressure	**Point**	No
		Diffuse	Wastewater of settlements which are not connected to sewage system; Local landfills; Agriculture; The main roads Nikšić-Plužine and Nikšić-Žabljak
	Risk assessment	PE is O, not at risk	
GW status	**Quality**	Good status, Not at risk	
	Quantity	Good status	
Monitoring	**Quality**	Existing: Continual for water source “Vidrovan”/Proposed: Surveillance monitoring	
	Quantity	Existing: Continual for water source “Vidrovan” / Proposed: Surveillance monitoring	
Dependent ecosystems		Sušica River and Rastovac River, i.e. Zeta River	

General assessment of data (confidence level): Rough assessment (RA)

Sources of data: Existing hydrogeological maps, reports, books, etc.

Legend: K–karst aquifer ; I–intergranular aquifer; F–fissured aquifer; C–complex aquifer; UC–unconfined conditions; CF–confined conditions; RA–rough assessment;

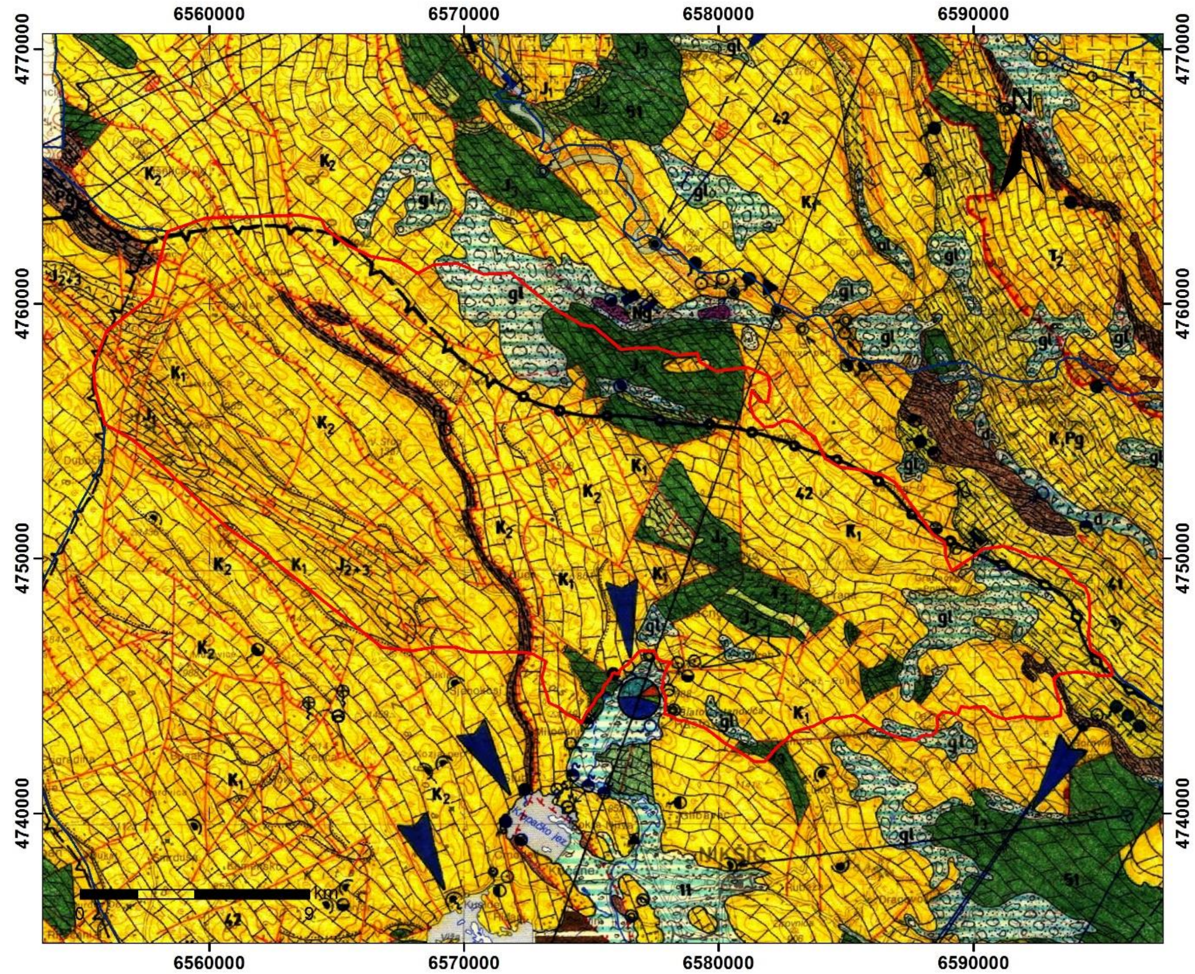

Fig. 13 Boundaries of the group of groundwater bodies “Vojnik” (red line) on the hydrogeological map (Source of background map: Radulović M. and Radulović V. 2004)

*Appendix XIV Description of the group of groundwater body "**Nikšićko polje**"*

River basin	Sub-basin		Name of GGWB	Code	Type of GWBs
Bojana River	Zeta		Nikšić	ME_A_GGW_C_14	C
Area (km^2)	**Autogenous (km^2)**		**938.2**	**Allogenic (km^2)**	**52**
Topography and geographical description	Group of groundwater bodies is distributed from Mijokusovići (S) to Vidrovan (N), and from Miljanići (Banjani) (W) to Maganik (E). Elevation ranges from 50 to 2,124 m.				
Geology of GW bodies	**Geology**	Mesozoic limestone and dolomite (T,J,K); Flysch: marlstone, claystone and marly limestone (K,Pg); limno-glacial (lgl) and glacial sediments (gl)			
	Hydrogeological units (K, I, F, C)	K, I			
	Depth to GW level (assessed)	Over 300 m in the catchment area of Nikšić Polje, and around 20 m in the area of Nikšić Polje (confidence level: RA)			
	Hydrogeological parameters	K = 1 x 10^{-4} – 1 x 10^{-1} m/s (confidence level: RA)			
	Tracer tests	The main hydraulic connections between swallow holes and springs: Slano Lake-Obošnica Spring; Vrtac-Obošnica Spring; Vrtac-Glava Zete Spring; Slivlje-Glava Zete Spring; Liverovići-Glava Zete Spring; Bojovića Bare-Dobropoljski Springs, Cigovica Bara-Glava Zete Spring, Lučica-Bistrica Spring; Zavrh-Poklonci Springs; Zavrh-Blaca Springs; Krupačka Jama-Klačinska Spring; Trepča-Svinjički Springs; Average tracer velocity: 3 cm/s			
	GW flow directions	General groundwater flow direction is NW-SE			
Overlaying strata	**Lithology**	Soil in autogenous area; limno-glacial, glacial and flysch sediments in allogenic area			
	Thickness	Soil: 0-5 m; limno-glacial and glacial sediments: 20 m; Flysch: 150 m			
	Outcrop of GW body (%)	94%			
Recharge	**Sources of recharge**	P (1,941 mm/a)			
	Infiltration of atmospheric water (assessed)	70%P or 1345 x 10^6 m^3/year of 1922 x 10^6 m^3/year (confidence level: RA)			
Outflow	**Main springs Q_{min}/Q/Q_{max}(l/s)**	Poklonci and Blaca Springs (Q_{min}=0.3 m^3/s), Studenački Spring (Q_{min}=0.05 m^3/s), Mrkošnica Spring, Krupačko Oko Spring (Q_{min}=0.13 m^3/s), Zminac and Žabica Springs (Q_{min}=0.1 m^3/s), Kusidska Springs, Slansko Oko Spring, Manito Oko Spring, Stružica and Krbanja Springs (Q_{av}=6.5 m^3/s), Bistrica Spring, Glibavačka Springs, Obošničko Oko Spring (Q_{min}=0.1 m^3/s), Glava Zete Spring (Q_{min}=3 m^3/s; Qmax=30 m^3/s), Svinjički Springs, Dobropoljski Springs (Q_{min}= 1 m^3/s; Qmax≈5 m^3/s)			
	Average abstraction (m^3/s)	Q=200 l/s (water source "Poklonci") **Q_{tot}=0.2 m^3/s**			
	GW resources (Q, Total recharge)	Q ≈ 40 m^3/s; ∑ I_{ef}=43 m^3/s			
Surface water–Groundwater interaction	Good interaction				

Water quality	**Chemical composition**	HCO_3 – Ca	
	Protection zones	Delineated for water-source “Poklonci”	
Vulnerability and risk	**Vulnerability**	Moderate to high (69%)	
	Assessment of pressure	**Point**	Iron Factory, Brewery “Nikšić”, Hospital “Brezovik”, Bauxite Mine in Župa, Fishpond in Rastovac, Mill "Nikšić", Meat factory "Goranović" (TBD)
		Diffuse	Wastewater of settlements which are not connected to sewage system; Local landfills; Agriculture; The main road Podgorica-Nikšić
	Risk assessment	At risk, PE is 73000, while ration PE vs. Vulner. Is 65.72	
GW status	**Quality**	Poor status, At Risk	
	Quantity	Good status	
Monitoring	**Quality**	Existing: Continual for water source “Poklonci”/Proposed: Operational monitoring	
	Quantity	Existing: Continual for water source “Poklonci” / Proposed: Surveillance monitoring	
Dependent ecosystems		Zeta River, Gračanica River, Slano Lake, Krupac Lake, Liverovići Lake	

General assessment of data (confidence level): Rough assessment (RA)
Sources of data: Existing hydrogeological maps, reports, books, etc.
Legend: K–karst aquifer ; I–intergranular aquifer; F–fissured aquifer; C–complex aquifer; UC–unconfined conditions; CF–confined conditions; RA–rough assessment; TBV – To be verified

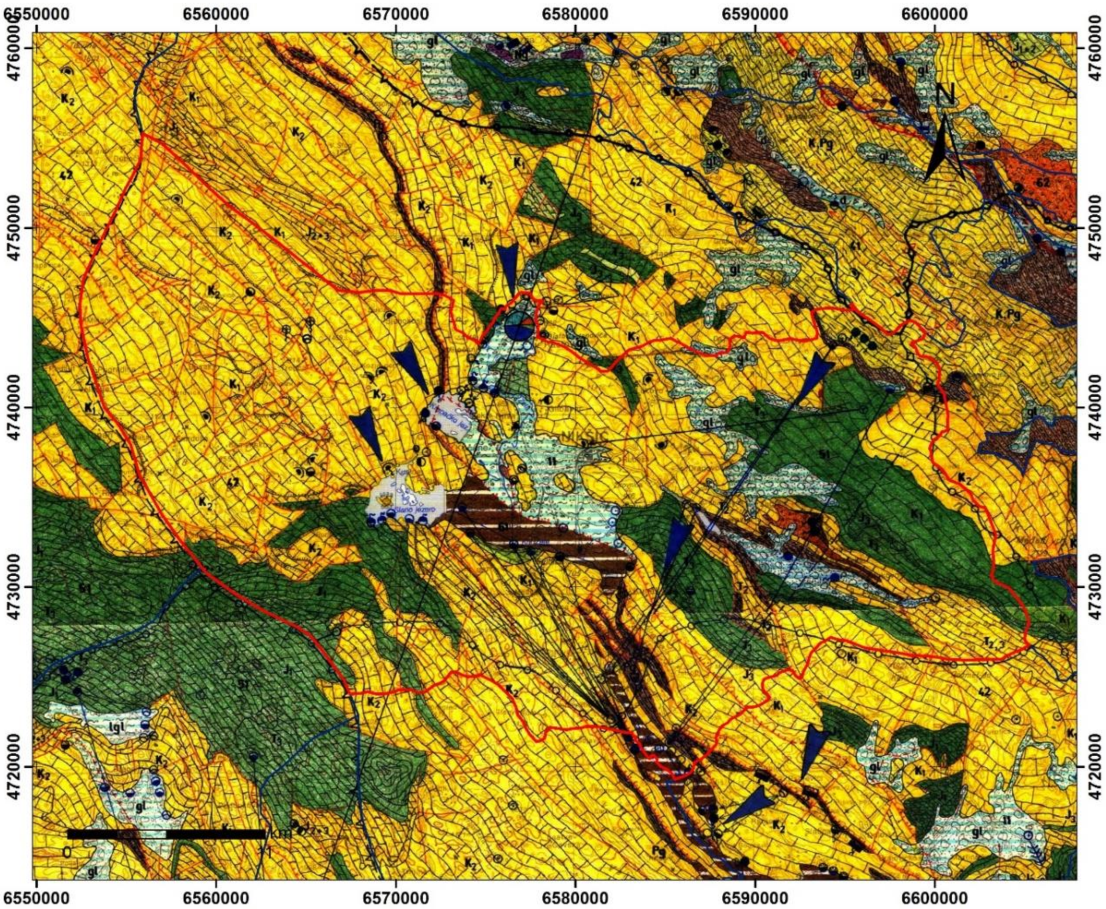

Fig. 14 Boundaries of the group of groundwater bodies “Nikšićko polje” (red line) on the hydrogeological map (Source of background map: Radulović and Radulović 2004)

*Appendix XV Description of the group of groundwater body “**Trebišnjica (Bilećko Lake)**“*

River basin	Sub-basin	Name of GGWB	Code	Type of GWBs
Trebišnjica River	Bilećko Lake	Trebišnjica (Bilećko Lake)	ME_A_GGW_K_15	K
Area (km^2)	**Autogenous (km^2)**	**567.5**	**Allogenic (km^2)**	**8**

Topography and geographical description		Group of groundwater bodies is distributed from Jabuke (S) to Čarađe (N), and from Miljanići (Banjane) (E) to Bilećko Lake (W). Elevation ranges from 347 to 1,596 m.
Geology of GW bodies	**Geology**	Mesozoic limestone and dolomite (T,J,K); Flysch: marlstone, claystone and marly limestone (K,Pg);
	Hydrogeological units (K, I, F, C)	K
	Depth to GW level (assessed)	Over 300 m (confidence level: RA)
	Hydrogeological parameters	K = 1 x 10^{-4} – 1 x 10^{-1} m/s (confidence level: RA)
	Tracer tests	The hydraulic connection of swallow hole Dobra Voda (Čarađe) with Springs in Fatničko polje and Sinjac Spring (Piva) (v=0.63-0.68 cm/s)
	GW flow directions	General groundwater flow direction is E-W
Overlaying strata	**Lithology**	Soil in autogenous area; flysch sediments in allogenic area
	Thickness	Soil: 0-5 m; Flysch: 150 m
	Outcrop of GW body (%)	98.6%
Recharge	**Sources of recharge**	P (1,578 mm/a)
	Infiltration of atmospheric water (assessed)	70%P or 636 x 10^6 m^3/year of 908 x 10^6 m^3/year (confidence level: RA)
Outflow	**Main springs Q_{min}/Q/Q_{max}**	Zaslapnica Spring (Q_{min} =54 l/s; Q_{av}=168 l/s; Q_{max}=1,381 l/s); Crni Virovi; Zvjernica Spring; Bara Spring; Račevina Spring (Q_{min} =20 l/s), Močila Spring, Korita Spring; Česmine, Nozdre Spring, Sige Spring, Mora Spring; Čarađe Spring (Q_{min}≈1 l/s); Mali Sopot; Veliki Sopot; Ogradenac Spring (territory of Montenegro); Tebišnjica Springs (Nikšić Springs and Dejanova Cave) (Q_{min}= 2m^3/s; Q_{max}> 800 m^3/s) (territory of Bosnia and Hercegovina)
	Average abstraction	Zaslapnica Spring (Q=50 l/s); Čarađe Spring (Q=1 l/s); **Q_{tot}=0.051 m^3/s**
	GW resources (Q, Total recharge)	Q ≈ 20 m^3/s; ∑ I_{ef}=20.2 m^3/s
Surface water–Groundwater interaction		Poor interaction
Water quality	**Chemical composition**	HCO_3 – Ca
	Protection zones	-

Vulnerability and risk	**Vulnerability**	Moderate to high (83%)	
	Assessment of pressure	**Point**	No
		Diffuse	Wastewater of settlements which are not connected to sewage system; Local landfills; Agriculture; The main roads Nikšić-Trebinje, Vilusi-Bileća and Nikšić-Gacko
	Risk assessment	Not at risk, ES is O	
GW status	**Quality**	Good status, Not at Risk	
	Quantity	Good status	
Monitoring	**Quality**	Existing: There are no monitoring points /Proposed: Surveillance monitoring	
	Quantity	Existing: There are no monitoring points / Proposed: Surveillance monitoring	
Dependent ecosystems		Bilećko Lake (Trebišnjica River), Zaslapnica River	

General assessment of data (confidence level): Rough assessment (RA)

Sources of data: Existing hydrogeological maps, reports, books, etc.

Legend: K–karst aquifer ; I–intergranular aquifer; F–fissured aquifer; C–complex aquifer; UC–unconfined conditions; CF–confined conditions; RA–rough assessment;

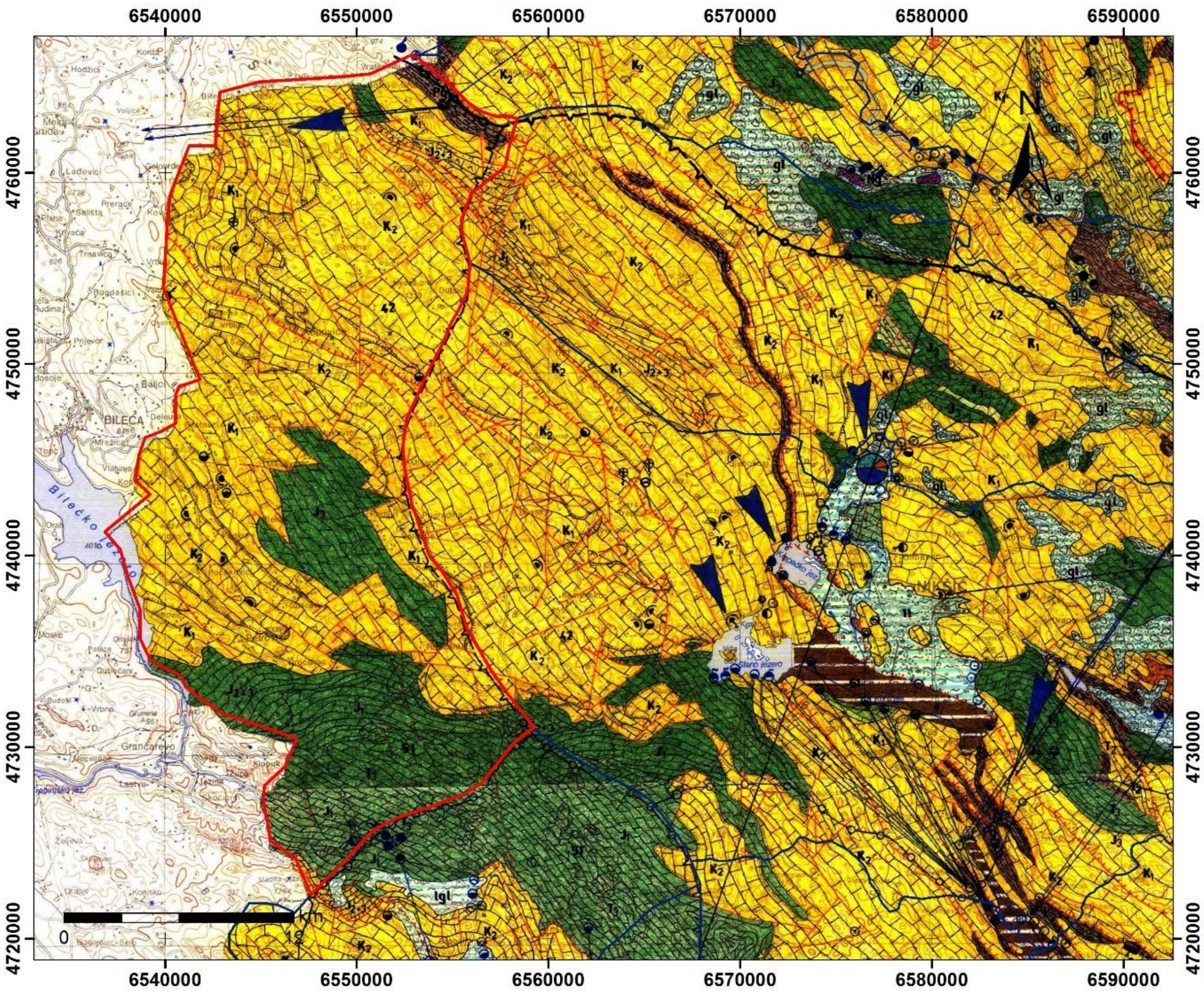

Fig. 15 Boundaries of the group of groundwater bodies “Trebišnjica” (red line) on the hydrogeological map (Source of background map: Radulović M. and Radulović V. 2004)

*Appendix XVI Description of the group of groundwater body "**Kuči**"*

River basin	Sub-basin	Name of GGWB	Code	Type of GWBs
Bojana River	Skadar Lake	Kuči	ME_A_GGW_C_16	C
Area (km^2)	**Autogenous (km^2)**	**424.2**	**Allogenic (km^2)**	**6.6**

Topography and geographical description	Group of groundwater bodies is distributed from Zeta Valley (W) to Korita Kučka (E), and from Brskut (N) to Skadar Lake (S). Elevation ranges from 5 to 2,184 m asl.	
Geology of GW bodies	**Geology**	Mesozoic limestone and dolomite (T,J,K); Flysch: conglomerate, sandstone, aleurolite, limestone and marl (E_2); glacial and glacio-fluvial sediments (gl)
	Hydrogeological units (K, I, F, C)	K, I
	Depth to GW level (assessed)	Over 300 m (confidence level: RA)
	Hydrogeological parameters	K = 1 x 10^{-4} – 1 x 10^{-1} m/s (confidence level: RA)
	Tracer tests	Hydraulic connections between swallow holes and springs: swallow holes in the canyon of Cijevna River (close to Dinoša)–Mileš Spring, Krvenica Spring, Vitoja Spring (*v*=2.05-3.07 cm/s); swallow holes in the canyon of Cijevna River (close to Dinoša)–Ribnica Springs (*v*=0.87 cm/s); Dugačko Lake – Springs in canyon of Mala River (*v*=3.2 cm/s); Swallow hole on Žijovo Mountain-Bare Spring (Mala River) (*v*=3.1 cm/s)
	GW flow directions	General groundwater flow direction is E-W
Overlaying strata	**Lithology**	Soil and glacial sediments in autogenous area; Flysch sediments in allogenic area
	Thickness	Soil: 0-5 m; glacial sediments: 20 m; Flysch: 150 m
	Outcrop of GW body (%)	100%
Recharge	**Sources of recharge**	P (2,344 mm/a)
	Infiltration of atmospheric water (assessed)	70%P or 707 x 10^6 m^3/year of 1010 x 10^6 m^3/year (confidence level: RA)
Outflow	**Main springs Q_{min}/Q/Q_{max}(l/s)**	Ribnica Springs (Q_{min}≈0.001 m^3/s; Q_{max}≈100 m^3/s); Milješ Sring (Q_{min}= 0; Q_{max}≈2 m^3/s), Krvenica Spring (Q_{min}= 0; Q_{max}≈10 m^3/s; Vitoja Spring (Q_{min}≈0.01); Traboin Springs (Q_{min}≈0.002; Q_{max}≈0.1 m^3/s); Fundina Springs (Q_{min}≈0.002 m^3/s); Springs in canyon of Cijevna River; Springs in canyon of Mala River
	Average abstraction (m^3/s)	Q=80 l/s (water source "Milješ"); Q=100 l/s (water source "Bioče") **Q_{tot}=0.18 m^3/s**
	GW resources (Q, Total recharge)	Q ≈ 20 m^3/s; ∑ I_{ef}=22.4 m^3/s
Surface water–Groundwater interaction	Good interaction	
Water quality	**Chemical composition**	HCO_3 – Ca

	Protection zones	Delineated for water-sources “Milješ” and “Bioče”	
Vulnerability and risk	**Vulnerability**	Moderate to high (74%)	
	Assessment of pressure	**Point**	No
		Diffuse	Wastewater of settlements which are not connected to sewage system; Local landfills; Agriculture; The secondary road Dinoša-Šumica; Local road network
	Risk assessment	PE 1600, while ratio PE vs. Vulner. Is 1.65	
GW status	**Quality**	Actually not at risk	
	Quantity	Good status	
Monitoring	**Quality**	Existing: Continual for water sources “Milješ” and “Bioče”/Proposed: Operational monitoring	
	Quantity	Existing: Continual for water sources “Milješ” and “Bioče” / Proposed: Surveillance monitoring	
Dependent ecosystems		Skadar Lake, Cijevna River, Ribnica, Morača and Mala River	

General assessment of data (confidence level): Rough assessment (RA)
Sources of data: Existing hydrogeological maps, reports, books, etc.
Legend: K–karst aquifer ; I–intergranular aquifer; F–fissured aquifer; C–complex aquifer; UC–unconfined conditions; CF–confined conditions; RA–rough assessment

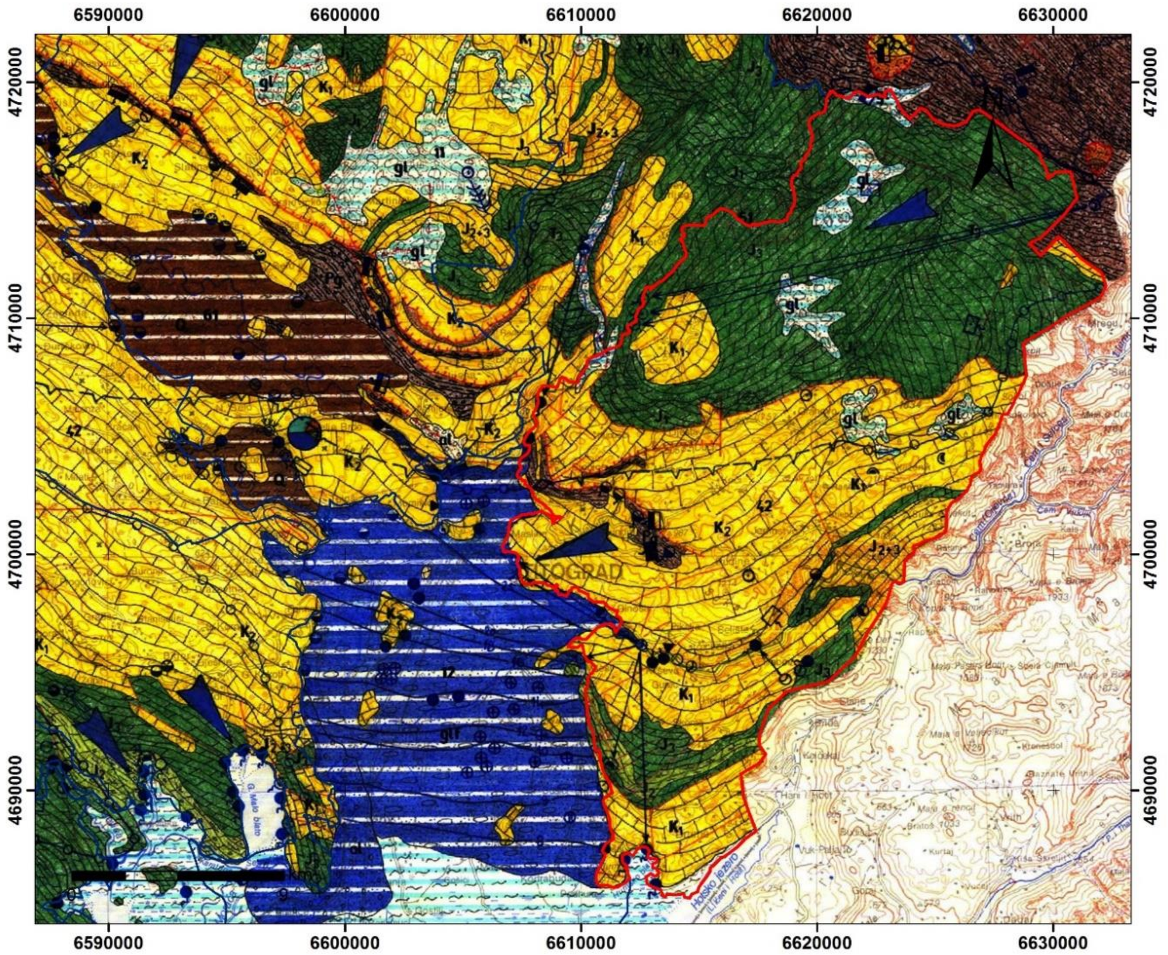

Fig. 16 Boundaries of the group of groundwater bodies “Kuči” (red line) on the hydrogeological map (Source of background map: Radulović M. and Radulović V. 2004)

*Appendix XVII Description of the group of groundwater body "**Morača**"*

River basin	Sub-basin	Name of GGWB	Code	Type of GWBs
Bojana River	Morača	Morača	ME_A_GGW_K_17	K
Area (km^2)	**Autogenous (km^2)**	**355.2**	**Allogenic (km^2)**	**0**
Topography and geographical description	Group of groundwater bodies is distributed from Smokovac (S) to Gornja Morača (N), and from Maganik (W) to Vjeternik (E). Elevation ranges from 60 to 2,135 m asl.			
Geology of GW bodies	**Geology**	Mesozoic limestone and dolomite (T,J,K); Breccia, sandy limestone and marly limestone (K,Pg); glacial sediments and glacio-fluvial sediments (glf)		
	Hydrogeological units (K, I, F, C)	K		
	Depth to GW level (assessed)	Over 300 m (confidence level: RA)		
	Hydrogeological parameters	K = 1 x 10^{-4} – 1 x 10^{-1} m/s (confidence level: RA)		
	Tracer tests	Hydraulic connections between swallow holes and springs: Estavelle near Monastery mill-Spring at Piletića household (between Zlatica and Bioče) (*v*=1.55-1.64 cm/s); Lazbe Kolovratske Estavelle - Spring at Piletića household (between Zlatica and Bioče) (*v*=0.35-0.89 cm/s); Swallow hole on Semolj Mountain-Simov Spring (Gornja Morača) (*v*=1.25 cm/s)		
	GW flow directions	General groundwater flow direction is W-E and E-W		
Overlaying strata	**Lithology**	Soil, glacial and glacio-fluvial sediments		
	Thickness	Soil: 0-5 m; glacial sediments: 20; glacio-fluvial: 50 m		
	Outcrop of GW body (%)	100%		
Recharge	**Sources of recharge**	P (1,925 mm/a)		
	Infiltration of atmospheric water (assessed)	70%P or 479 x 10^6 m^3/year of 684 x 10^6 m^3/year (confidence level: RA)		
Outflow	**Main springs Q_{min}/Q/Q_{max}(l/s)**	Bijeli Nerini Srings (Q_{min}= 0.5 m^3/s), Svetigora Spring (Monastery Morača), Springs under Vjetrina, Lanjevik Spring, Spring at Piletića household, Bešića Spring, Smokovac Spring, Kaludjer Spring, Bare Spring, Simov Spring		
	Average abstraction (m^3/s)	There are no official abstraction (Q_{tot}=0 m^3/s)		
	GW resources (Q, Total recharge)	Q ≈ 15 m^3/s; ∑ I_{ef}=15.2 m^3/s		
Surface water–Groundwater interaction	Good interaction			
Water quality	**Chemical composition**	HCO_3 – Ca		

	Protection zones	Protection zones are not delineated (there are no water-sources).	
Vulnerability and risk	**Vulnerability**	73% represent classes from Moderate to Very High	
	Assessment of pressure	**Point**	No
		Diffuse	Wastewater of settlements which are not connected to sewage system; Local landfills; Agriculture; The main road Podgorica-Kolašin, secondary road Bioče-Mateševo and Highway section Smokovac-Mateševo (under construction)
	Risk assessment	Not at risk, ES is O	
GW status	**Quality**	Good status, Not at Risk	
	Quantity	Good status	
Monitoring	**Quality**	Existing: No / Proposed: Surveillance monitoring	
	Quantity	Existing: No / Proposed: Surveillance monitoring	
Dependent ecosystems		Morača River, Mala River and Mrtvica River	

General assessment of data (confidence level): Rough assessment (RA)

Sources of data: Existing hydrogeological maps, reports, books, etc.

Legend: K–karst aquifer ; I–intergranular aquifer; F–fissured aquifer; C–complex aquifer; UC–unconfined conditions; CF–confined conditions; RA–rough assessment; TBD – To be decided (based on Vulnerability-Hazard-Risk maps)

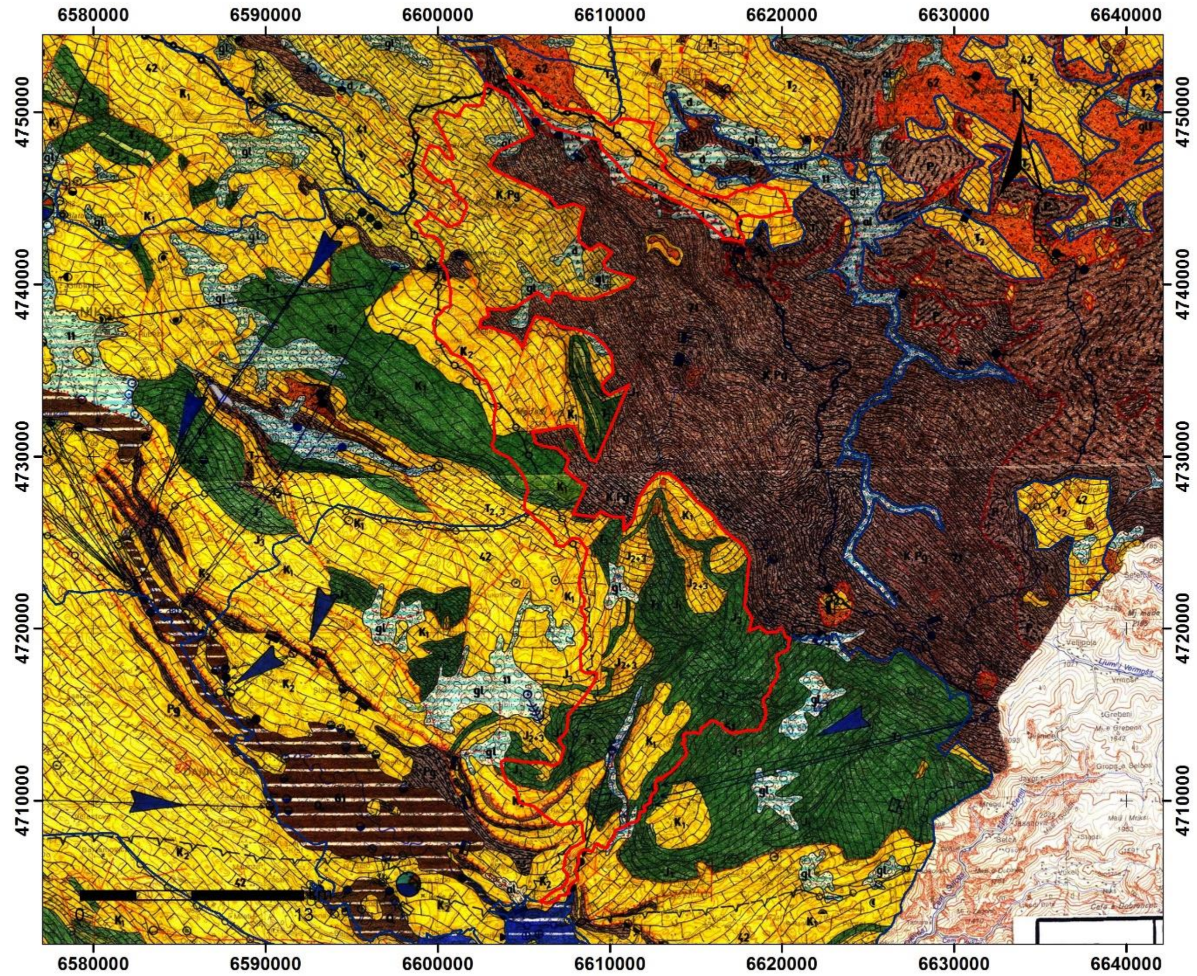

Fig. 17 Boundaries of the group of groundwater bodies "Morača" (red line) on the hydrogeological map (Source of background map: Radulović M. and Radulović V. 2004)

A basic data for groundwater bodies characterisation
- General hydrogeology of Montenegro

The whole territory of Montenegro belongs to just one large geostructural unit – Dinarides. The Dinaric system (Dinarides) represents a geologically heterogeneous, south European orogenic belt of the Alpine mountain chain (Alpides). The main orientation of the system is NW-SE, parallel to the Adriatic Sea. It is a long, mostly mountainous structure with numerous intermountain depressions, large karst poljes or valleys created by numerous perennial or sinking streams (Radulović M. 2000; Stevanović, 2011, 2016).

Earlier geological and hydrogeological research

The Dinaric region is a karst holotype. Not only was the term karst born in the area, but based on the doctoral dissertation of Jovan Cvijić “Das Karstphänomen” (1893) who performed most of his work in the Dinaric karst, a new scientific discipline - karstology had been founded here. Thanks to Cvijić the local terms for dissolutional landforms in Dinaric Kras (germanised as “karst”) are now applied worldwide. Cvijić stated that "there is no deeper and more thorough karst development than Herzegovina-Montenegro's karst located between the lower Neretva River, Skadar Lake and the Adriatic Sea" (1926).

Following Cvijić’s research, large number of authors from former Yugoslavia contributed to the improvement of the knowledge about the Dinarides in terms of hydrology, geomorphology, geology, hydrogeology.

Martel (1883), Gesman (1905), Wolf (1910), have explored potholes and pits in the holokarst of Montenegro, in the area between the Boka Kotorska Bay, Cetinje and Nikšić.

Tietze (1884) and Hassert (1895) collected and studied data of circulation of groundwater in karst terrains.

Lahner (1916) has carried out the genuine speleologic venture for those times. He descended into the 340m deep pothole, in which he discovered underground stream connected to the Kotor´s submerged karst springs Gurdić and Škurda.

After WW II the geological setting and tectonics were explored by Bešić (1951, 1959, 1960), Petković (1958, 1960 i 1961), Miladinović (1955, 1957, 1962, 1964), Milovanović (1953, 1955, 1957) and Roksandić (1966).

After WW II work the Basic Geological Map of Yugoslavia, on the scale 1:100.000 (with working sheets 1:25.000), enabled upgrading of the geological information about Dinaric karst including Montenegro. This map was also a base for creation of Geological Map of Montenegro in scale 1:200.000 (Mirković *et al.* 1985) which is extensivelly used in this project.

Concerning tectonic classifications of Dinaric karst in the territory of the Former Yugoslavia the works of Bešić, Stepanović, Herak, Komatina should be emphasized.

Systematic hydrogeological research of karst terrain of Montenegro began also after WW II, in order to solve various practical and economic problems. These attempts resulted in a numerous data, monographs and publications on the hydrogeological characteristics of the karst terrain of Montenegro. The surveys were conducted for utilization of hydropower potentials of Zeta, Morača, Piva, Tara, Ćehotina and Lim rivers; water management plans and

Skadar Lake and Bojana River; water supply of settlements and industry; irrigation of Zeta Valley and other lowland areas; water supply of coastal area. Some projects evaluated problems of groundwater reserves of groundwater sources, delineation of sanitary protection zones, bottling of potable groundwater.

The results of the hydrogeological study of Nikšićko polje and Upper Zeta basin aiming at utilizes great hydro potential have been synthesized in works of Vlahović (1952-1962). Vlahović also published the monograh (1975), discussing problems of water losses from highly karstified rocks of Nikšićko polje and remedial measures applied.

By publishing several books on geology of Montenegro Bešić (1969) also contributed to the knowledge of karst and karst waters distribution.

Regional hydrogeological explorations of Skadar basin (Radulović V. 1973, 1989) and South Adriatic (Ivanović 1973) provided an important and valuable dataset on characteristics of groundwater of these areas which comprises almost half of national territory.

In "Hydrogeology of the Skadar Lake basin" (1989) V. Radulović provides valuable data on the hydrogeological and hydrological characteristics, directions and velocity of the groundwater flow, water balance, physical and chemical characteristics of groundwater of this region.

M. Radulović (1999) classified groundwater occurrences and aquifer systems of Montenegro. He distinguished 120 occurrences in karstic and intergranular aquifers plus 5 mineral water springs. He also published “Karst hydrogeology of Montenegro” in 2000. This book is important overview with many summarized data on hydrogeologic conditions, aquifer boundaries and budget, discharge of karstic springs, groundwater circulation.

For the Master Plan of Montenegro Hydrogeological Map of Montenegro in scale 1:100.000 has been completed (Radulović M., Radulović V., Popović, 1982).

In 1982 Burić completed the Map of Groundwater Protection of Montenegro. Problems of groundwater protection have also been discussed in works of Žunjić (1971, 1975), Filipović (1975), Radulović V. (1977), Filipović, Radulović M, Mišurović (1991).

Some data on hydrogeology of Boka Kotorska and wider coastal area, Nikšić polje and Trebišnjica catchment can be found in works of B. Mijatović (1984) and P. Milanović (2005).

In period 2006-2010 Stevanović and M. Radulović published several papers on hydrogeology of Bolje sestre source tapped out for regional water supply of Montenegro coastal area.

M.M. Radulović in 2012 completed doctoral dissertation, which discusses problems of subterranean flow along southern margin of Skadar Lake. Within the frame of UNDP project M.M. Radulović et al. (2014) delineated groundwater bodies in the Skadar Lake Basin.

Concerning groundwater monitoring some data are available at IHMS who organized measurements of discharges at some karstic springs and groundwater table of selected boreholes in Zeta Plain near Podgorica. Unfortunately, these activities were only sporadically conducted, and currently no systematic monitoring of groundwater is taking place.

CLEAG project (2009) undertaken under CEI, includes a proposal for creation of water monitoring network (both, surface and ground waters) and general specification of required equipment.

Basic hydrogeological maps 1: 100,000 with explanatory notes have been made for several sheets: "Titograd” (1982), "Bar "and" Ulcinj "(1989)," Nikšić "(1999), etc. The Hydrogeological

Map of Montenegro in scale 1:200.000 with Guide is result of work of Radulović M. and Radulović V. (2004).

Geostructural units and stratigraphy

Throughout its early geologic history, the Dinaric region was part of the Mediterranean geosyncline (Tethys). It was not until the Late Paleozoic that carbonate sediments were deposited in quantities favourable for karstification. The first sedimentation cycle represents the interval between Upper Devonian and Middle Jurassic. In most of the internal Dinarides, marine sedimentation started in Upper Permian and lasted until the end of Lower Jurassic (Ćirić, in: Mijatović, 1984). In the External Dinarides this cycle extended until Upper Cretaceous. Ćirić (1984) also stated that some flysch formations in Middle Triassic (Anisian) and Jurassic-Cretaceous (Thitonian – Valanginian) indicate some movements (deepening of the basin) but no unconformity can be observed.

"The upper part of the Lower Triassic is characterized by a gradual diminishing of the clastic deposits and by an overwhelming abundance of carbonate sediments. The Middle Triassic is represented by various facies, with shallow water limestones… The clastic facies are only locally distributed and are represented by lenses in the carbonate complexes. In the Anisian they consist predominantly of shales and subordinately of conglomerates with carbonate clastic components. They are locally associated with some igneous rocks. In the Ladinian the clastic elements are represented by siliceous, calcareous, argillaceous and pyroclastic elements, also sporadically associated with igneous rocks.

Basal sediments of the Carnian Stage of the Upper Triassic in the Dinaric Mountains usually consist of clastics (calcareous conglomerates and alternating series of sandstones and pelites with sporadic admixtures of tuffaceous sediments and tuffs), and only exceptionally of bauxitic lenses and dolomites. The upper part of this stage, as well as the Norian and Rhaetian, consists of more or less uniform dolomites often grading vertically and laterally into reef limestones..."[1].

The second sedimentation cycle (substage) in the Internal Dinarides began in the Middle Jurassic and lasted until Uppermost Jurassic. In that time oceanisation was developed to the maximum in the geosynclinal troughs resulting in the formation of ophiolitic complex. The third substage in the Internal Dinarides corresponds to the second one in the External Dinarides (Ćirić, 1984). During this period flysch type sedimentation developed in many regions throughout the Dinarides.

Herak (1972) stated that Jurassic carbonate sediments in the Dinaric Mountains are very well developed, mostly as a continuous sequence of limestones and dolomites, bedded or massive. There are some bauxites also present and in the Upper Jurassic, as well as local chert intercalations in the well-bedded limestones. Montenegro like other Dinaric countries is characterized by a variability of facies, consisting of carbonate and clastic deposits with some igneous components (Fig. 18).

[1] Herak M.: Karst of Yugoslavia, p.27

Fig. 18 Karstified rocks of Sinjajevina Mt., northern Montenegro (photo Z.Stevanović.)

At the end of Upper Cretaceous and during Paleocene intensive uplifting and folding took place, and most of the carbonate and flysch rocks were tectonized. After the Laramian tectonic phase, the next intensive movements took place in the Helvetian phase (Eocene/Oligocene). All main nappes along the Adriatic / Ionian Sea coastline can be related to this stage.

The Cretaceous of the Dinaric Mountains is almost entirely carbonate (limestones and dolomites) with the exception of Durmitor Mountain, where Upper Cretaceous flysch is also developed.

The Lower Paleogene of the Dinaric Mountains consists mainly of limestones. The Lower Molassic substage begins in Upper Eocene, while the Upper Molassic substage in Mio-Pliocene resulted in the deepening and forming of large depressions such as Skadar basin as well as in the deposition of terrigenous lacustrine sediments. This substage continued through Holocene and resulted in the creation of the Adriatic / Ionian Sea bottom.

The majority of supporters of the "Plate tectonics" theory suggest that Tethys was created by the moving of depositional depression from large continental plates Euro-Asian in the north and African in the south, while closing of the basin and collision triggered the uplifting of the Alpine chains.

Three major tectonic units are usually distinguished in the Dinarides (Fig. 19). They are: External, Central and Inner Dinarides.

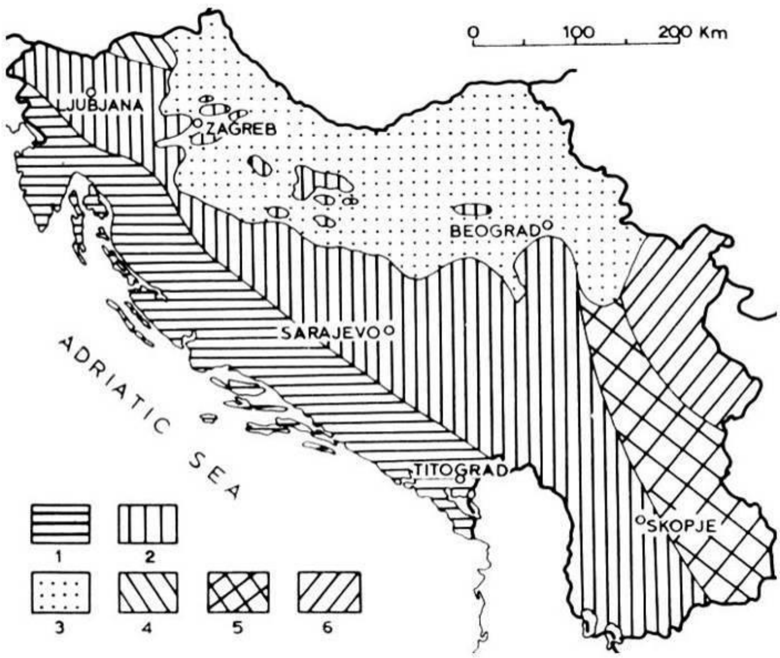

Fig.19 Major tectonic areas at the territory of former Yugoslavia (Herak, 1972). 1 = External Dinaric units (Adriatic and high karst); 2 = Inner Dinaric and south Alpine units; 3 = Pannonian Basin; 4 = eastern Alps; 5 = Serbo-Macedonian Belt; 6 = Carpathian-Balkan Belt.

The External Dinarides are often consider as a Zone of deep karst, while the Central Dinarides can be distinguished into two sub-zones: 1. The Central ophiolitic zone, and 2. The zone of Palaeozoic shale and Mesozoic limestone. The Inner Dinarides cover northernmost part of the Montenegro territory.

After Bešić (1969) and Radulović V. & Radulović M. (1997) the following geotectonic subunits are present in the External Dinarides of Montenegro (from S to N, Fig. 20): A) Adriatic folds system, B) Budva - Cukali zone, C) High karst zone D) Durmitor nappe zone.

A) In the *Adriatic folds* (part of the Adriatic-Ionian fold system) the carbonate and flysch facies prevail. The carbonate facies consist of limestone, dolomite-limestone and sporadically of dolomite of the Upper Cretaceous and Eocene, while flysch facies consist of clay, marl, sandstone, breccia and conglomerates of the Eocene age.

B) Terrains of the *Budva - Cukali zone* (or Pindus - Cukali zone) are composed of several stratigraphic-lithologic members, starting with Permian-Triassic up to the end of the Eocene: flysch-clastic facies of the Lower and Middle Triassic; sedimentary-volcanic facies of the Middle Triassic; carbonate facies of the Triassic, Jura, Cretaceous and Paleogene, and flysch facies of the Paleogene.

C) The major part of the territory of Montenegro belongs to the *High karst zone*. Its geology is very complex: Mesozoic limestone and dolomite prevail, but there are also spread-out non-karstic rocks such as Lower Paleozoic schist-argillaceous marl layers; Lower and Middle Triassic marl, sandstone and conglomerates as well as Middle Triassic porphyrite, quartz-porphyrite, dacite and andesite. In addition to the above, in two narrow zones across the entire territory of Montenegro from the southwest towards the southeast, there appear Upper Cretaceous – Paleogene sediments of flysch, represented by marl, argillite, limestone, sandstone, breccias and conglomerates.

D) Inner Dinarides in Montenegro are represented by large *Durmitor nappe* which extend over ca. 5000 km^2. Thick limestones and dolomites complex are mostly Triassic and Jurassic ages, and is intersected by volcanic rocks or ophiolite impervious rocks. This is an area with highest mountains in Montenegro.

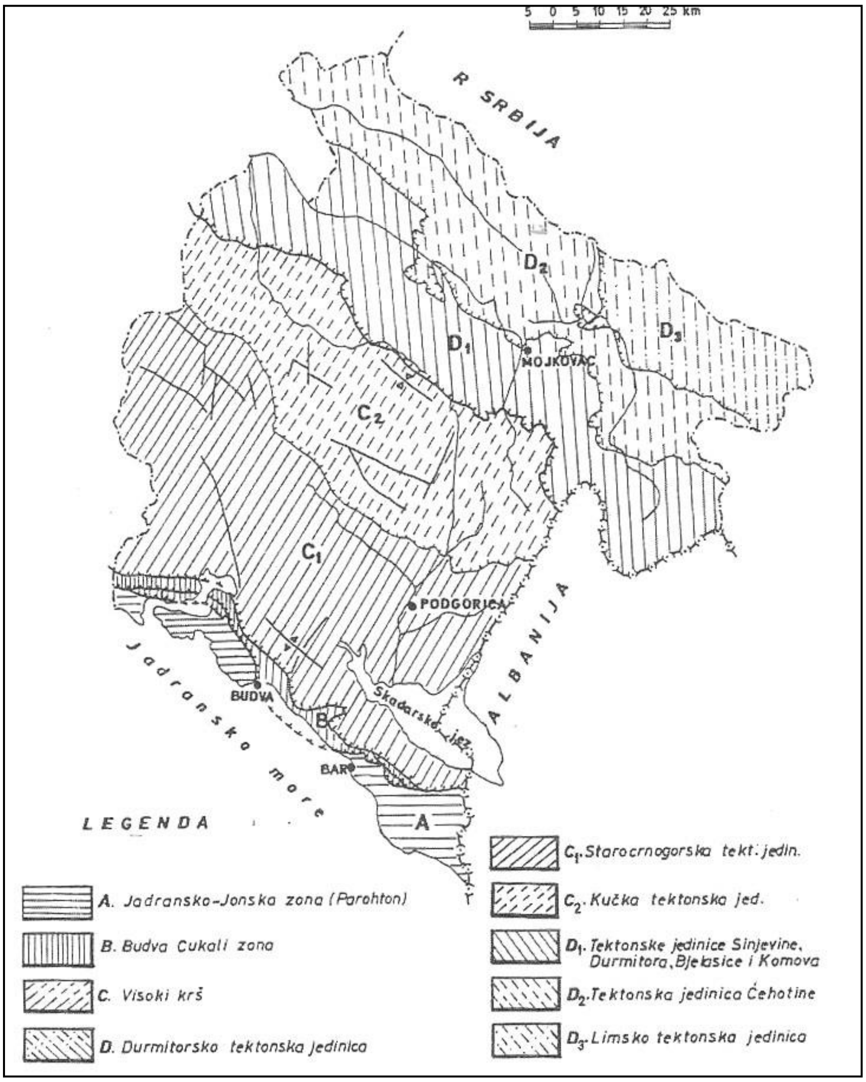

Fig. 20 Geotectonic units of Montenegro (from south to the north: horizontal lines – Adriatic folds Paraauchtochton (southern part), Vertical lines – Budva - Cukali zone, other type lines – different subunits of High karst zone, and Durmitor nappe as a northernmost unit) (after V. Radulović and Geological map of Montenegro 1:200.000)

Although Basic Geological Maps of SFRY 1:100.000 (including territory of Montenegro) comprise more diverse litho-stratigraphical units for the purpose of this Project some generalization has been made and is accordingly applied. Therefore, the following main units are distinguished (Fig. 21):

- Paleozoic metamorphic rocks D,C,P,
- Permian sandstones P,
- Porphyrites, andesites and clastic Lower Triassic rocks T_1,

- Sedimentary-volcanic formations of Middle Triassic T_2,
- Carbonate rocks of Middle and Upper Triassic T_2, T_3,
- Lower and Middle Jurassic carbonate rocks (limestones, dolomites) J_1, J_2,
- Ophiolite formation (diabase-chert) of Middle and Upper Jurassic $J_{2,3}$
- Upper Jurassic carbonate rocks J_3,
- Lower Cretaceous carbonate rocks K_1,
- Upper Cretaceous carbonates $K_{2,}$
- Carbonate flysch ("Durmitor facies") K_2,Pc
- Paleocene and Eocene flysch Pc, $E_{1.2}$,
- Numulitic Eocene limestones E_2,
- Upper Eocene flysch E_3,
- Neogene sediments Ng,
- Quaternary (Pleistocene) fluvio-glacial deposits $Q_{gl,f}$,
- Quaternary (Pleistocene) terrace Q_t,
- Quaternary (Holocene) alluvial deposits Q_{al}.

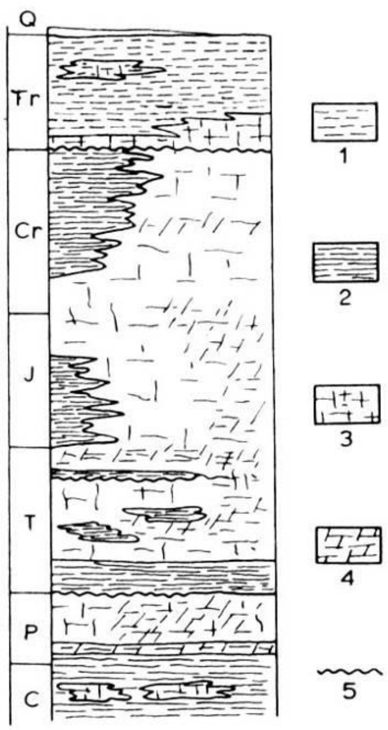

Fig. 21 Schematic lithostratigraphic column of Dinaric region (Herak, 1972). Legend: 1 = Tertiary clastic deposits; 2 = Palaeozoic and Mesozoic clastics; 3 = limestones; 4 = dolomites; 5 = main unconformities; C = Carboniferous; P = Permian; T = Triassic; J = Jurassic; Cr = Cretaceous; Tr = Tertiary; Q = Quaternary.

As part of the Dinaric system, Montenegro is a classical karst country. Dinaric carbonate rock complex is the result of the Alpine orogenic phase with the most intensive tectonic movements during the Tertiary. Tectonic events resulted in a complex system of faults and fractures as privileged subterranean water paths. Moreover, climatic conditions, particularly the successions of wet and warm periods, significantly contributed to karstification.

List of References for Groundwater Characterization and Status Assessment :

Agency for Sava River Basin (ASRB), 2016: Sava River Basin Management Plan in Federation of B&H, draft version, Sarajevo (Available at: www.voda.ba)

Aller, L., Bennet, T., Lehr, J. H., Petty, R. J., Hackett, G., 1987: DRASTIC: a standardized system for evaluating groundwater pollution potential using hydrogeological setting. US EPA, 622 p.

Bešić Z., 1969: Geology of Montenegro. Vol. II, Karst of Montenegro (in Serbian). Geological Survey of Montenegro, Titograd, 415 p.

Bonacci O., 1987: Karst Hydrology; with special reference to the Dinaric Karst. Springer-Verlag,Berlin;184p.

Boni CF, Bono P, Kovalevsky VS, 1984: Evaluation of water resources. In: Burger A and Dubertret L (eds) Hydrogeology of karstic terrains. Case histoires. International Contributions to Hydrogeology, IAH, vol 1. Verlag Heinz Heise, Hannover, 9-17

Bošković M., Živaljević R., Bajković I., 2006: Quantitative characteristics of surface runoff of waters in Montenegro. In: Saveljić M, Sekulić G. (eds) Water, water supply systems, sanitary technologies (in Serbian). Adriatic Fair, Budva, 1–8.

Brown M, Wigley T, Ford D, 1969: Water budget studies in karst aquifers. J Hydrol, 9: 113-116

Castany G, 1967: Traite Pratique des Eaux Souterraines. Dunod, Paris.

CEI (Central European Initiative), 2009: CLEAG (CLimate and Environment protection progrAm in MonteneGro dedicated to the hydrosphere monitoring, pollution control and raising awareness), Feasibility study. Czech Republic, Development Cooperation, Fund of HMZCG.

Custodio, E. 1992.Hydrogeological and hydrochemical aspects of aquifer over-exploitation. Selected Papers of IAH, Hydrogeology, Verlag Heinz Heise, Hannover, Vol.3: 3-27.

Cvijić J., 1893: Das Karstphänomen. Versuch einer morphologischen Monographie. Geographischen Abhandlung, Wien, V(3); 218-329.

Cvijić J., 1926: Geomorfologija 2, Izd. Drž. Štamparija, 506 p.

Cvijić, J. 1960. La Géographie des terrains calcaires. Academie Serbe des Sciénces et des Arts, Beograd, Monographies, T. CCCXLI; 212 p.

Ćorović A., Radulović M., Filipović S., Živaljević R., 1999: Springs for long-term water supply of settlements in Montenegro and possibilities of their protection. Proceedings of 28th Conference of Yugoslav Society for Water Pollution Control.

Čenčur Curk, B. (Ed), 2014: CC – WARE Mitigating Vulnerability of Water Resources under Climate Change, WP3 – Vulnerability of Water Resources in SEE, annual report

Dörflinger, N., Zwahlen, F., 1997: EPIK: a new method for outlining of protection areas in karstic environment; In: Gunay, G., & Johnson, A.L., (Eds), International Symsposium and Field Seminar on Karst Water and Environmental Impacts, Balkema, Rotterdam, pp. 117-123

Dragović D., 1976: Water master Plan (Vodoprivredna osnova Crne Gore, Sliv Jadranskog mora), vol. 3., General data, 1, Titograd.

Đorđević B., Sekulić G., Radulović M., Šaranović M., 2010: Water potentials of Montenegro (in Montenegrin). MASA, Special Publications, vol. 74, Podgorica.

Đurić D., Josipović J., Zogović D., Komatina M., Stevanović Z., Đokić I., Lukić V., 2004: ICPDR Roof Report for 2004. Institute „J. Černi“, Ministry of Agriculture, Forestry and Water Management of Serbia, Belgrade.

Eptisa, 2015: Nacrt plana upravljanja vodama za vodno područje rijeke Save u Federaciji Bosne i Hercegovine, Nacrt pratećeg dokumenta #4 - Podzemne vode, Sarajevo

European Commission, 2000: Directive 2000/60/EC of the European Parliament and of the Council – Establishing a framework for Community action in the field of water policy. Brussels, Belgium, 23 October 2000.

Foster, S., Loucks, DP. 2006: Non-renewable groundwater resources: a guidebook on socially-sustainable management for water-policy makers. UNESCO IHP-VI Series on Groundwater 10, UNESCO, Paris

Foster S., McDonald, A., 2014: The ‘water security’ dialogue: why it needs to be better informed about groundwater. Hydrogeology Journal, November 2014, 22/7: 1489-1492

German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety and the German Federal Environment Agency, 2007: Implementation of the EU Water Framework Directive in Bulgaria. Structure of a River Basin Management Plan for the Danube-River-Basin, Sub-River Basins Osam and Vit, Sofia

Goldscheider N., 2005: Karst groundwater vulnerability mapping: application of a new method in the Swabian Alb, Germany, Hydrogeology Journal, 13, 4: 555-565

Government of Brčko Distrikt, 2016: Sava River Basin Management Plan in Brčko Distrikt, draft version, Brčko (Available at: www.bdcentral.net)

Groundwater Working Group, 2001: Guidance Document GW1. Water Framework Directive (WFD) River Basin District Management Systems: Technical Requirements for Groundwater and Related Aspects. Interim Report of Working Group on Groundwater, Dublin, 32 pp.

Groundwater Working Group, 2005: Guidance document no. GW6. Advice on the implementation of guidance on monitoring groundwater WFD- River Basin District Management Systems, Dublin

Group of authors, 1971: Crnogorske elektrane (Montenegro Hydropower Plants), Nikšić.

Healy RW, Winter TC, LaBaugh JW, Franke OL, 2007: Water budgets: Foundations for effective water-resources and environmental management: U.S. Geological Survey Circular 1308, p. 90

HGI – Institut za Geološka Istraživanja – Zagreb, Zavod za hidrogeologiju i inženjersku geologiju, 2015: Karakterizacija vodnih cjelina na Jadranskom slivu u okviru implementacije okvirne direktive o vodama EU, Zagreb

Hrvačević S., 2004: Surface water resources of Montenegro. "EPCG" AD Niksic, 195-236.

ICPDR 2014: Danube River Basin Management Plan, Vienna Austria, www.icpdr.org

IHMS, 2003: Measurements of water level of the Gornjepoljski Vir. Institute for Hydrometeorology and Seismology of Montenegro, Podgorica

IHMS, 2007a: Hydrology analysis of profiles of small (mini, micro) hydro power plants (sHPPs) on tributaries of main watercourses in Montenegro. Institute for Hydrometeorology and Seismology of Montenegro, Podgorica

IHMS, 2008a: Hydrology analysis of profiles of small (mini, micro) hydro power plants (sHPPs) on tributaries of main watercourses in Montenegro. Institute for Hydrometeorology and Seismology of Montenegro, Podgorica

IHMS, 2010a: Hydrology analysis of profiles of small (mini, micro) hydro power plants (sHPPs) on tributaries of main watercourses in Montenegro. Institute for Hydrometeorology and Seismology of Montenegro, Podgorica

IHMS, 2011a: Hydrology analysis of profiles of small (mini, micro) hydro power plants (sHPPs) on tributaries of main watercourses in Montenegro. Institute for Hydrometeorology and Seismology of Montenegro, Podgorica

IHMS, 2007b: Quality of water in Montenegro for 2006. Institute for Hydrometeorology and Seismology of Montenegro, Department for Water Quality, Podgorica

IHMS, 2008b: Quality of water in Montenegro for 2007. Institute for Hydrometeorology and Seismology of Montenegro, Department for Water Quality, Podgorica

IHMS, 2009: Quality of water in Montenegro for 2008. Institute for Hydrometeorology and Seismology of Montenegro, Department for Water Quality, Podgorica

IHMS, 2010b: Quality of water in Montenegro for 2009. Institute for Hydrometeorology and Seismology of Montenegro, Department for Water Quality, Podgorica

IHMS, 2011b: Quality of water in Montenegro for 2010. Institute for Hydrometeorology and Seismology of Montenegro, Department for Water Quality, Podgorica

IHMS, 2012: Quality of water in Montenegro for 2011. Institute for Hydrometeorology and Seismology of Montenegro, Department for Water Quality, Podgorica

IHMS, 2013: Quality of water in Montenegro for 2012. Institute for Hydrometeorology and Seismology of Montenegro, Department for Water Quality, Podgorica

IHMS, 2014: Quality of water in Montenegro for 2013. Institute for Hydrometeorology and Seismology of Montenegro, Department for Water Quality, Podgorica

IHMS, 2015: Quality of water in Montenegro for 2014. Institute for Hydrometeorology and Seismology of Montenegro, Department for Water Quality, Podgorica

IHMS, 2016: Quality of water in Montenegro for 2015. Institute for Hydrometeorology and Seismology of Montenegro, Department for Water Quality, Podgorica

IHMS, 2017: Quality of water in Montenegro for 2016. Institute for Hydrometeorology and Seismology of Montenegro, Department for Water Quality, Podgorica

IHMS, 2017: Hydrological database. Institute for Hydrometeorology and Seismology of Montenegro, Podgorica

IMPRESS, 2002. Smjernice za analizu pritisaka i uticaja u skladu sa Okvirnom Direktivom o Vodama. Zajednička radna grupa za strategiju implementacije 2.1, Kancelarija za Zvanične publikacije Evropske zajednice. p. 156

Institute “Jaroslav Černi”, Belgrade, 2001: Water Master Plan for Montenegro. Government of Montenegro, Podgorica

IPH 2017: Results of water quality analyses of the samples from the public water sources. Institute for Public Health, Podgorica

ISRBS 2013: Sava River Basin Management Plan, Zagreb, Croatia, www.savacommisison.org

Janković M., 1983: Water budget of Skadar Lake (in Serbian), vol 2., Vodoprivredna org. “Zeta”- Titograd.

Komatina M. 1983: Hydrogeologic features of Dinaric karst. In: Hydrogeology of the Dinaric Karst. Mijatovic B (ed.). Spec. ed. Geozavod, Belgrade. 45-58.

Kresic N, 2007: Hydrogeology and groundwater modeling, Second ed. CRC Press/Taylor and Francis, Boca Raton, FL

Kresic N., 2013: Water in karst. Management, vulnerability, restoration. McGraw Hill,

Lankford B., 2013: Water security: principles, perspectives and practices. Routledge, London

Lerner D, Issar A, Simmers I, 1990: Groundwater recharge, a guide to understanding and estimating natural recharge. International Contributions to Hydrogeology, vol. 8. Verlag Heinz, Heise. Hannover

Luchshewa AA, 1976: Prakticheskaya gidrologija (Practical hydrology, in Russian). Gidrometeoizdat. Leningrad (St. Petersburg)

Margat J. Gun van der J., 2013: Groundwater around the World: A Geographic Synopsis. CRC Press, Taylor & Francis Group, Boca Raton, pp. 348

Marinović, V. & Stevanović, Z., 2019: Karst groundwater quantity assessment and sustainability: the approach appropriate for river basin management plans; Environmental Earth Sciences (2019) 78:362, doi.org/10.1007/s12665-019-8364-3

Mijatović B., 1984: Hydrogeology of the Dinaric Karst. International Association of Hydrogeologists, Heise, Hannover. Vol. 4: 254 p.

Mijatović B, 1990: Karst. Hydrogeology of karst aquifers. Spec. ed. Geozavod, Belgrade

Milanović P., 2005: Water potential in southeastern Dinarides. In: Stevanović Z. & Milanović P. (eds): Water Resources and Environmental Problems in Karst—CVIJIĆ 2005,. Spec. ed. FMG. Belgrade, 249–257.

Mirković M, Žvaljević M, Đokić V, Perović Z, Kalezić M, Pajović M. 1985: Geological map of Montenegro 1:200,000. The Republic Self Managing Community of Interest for Geological Exploration of Montenegro, Titograd

Neukum, C., Hötzl, H., 2005: Standardisation of vulnerability map, In: Proceedings of International Conference "Water Resources and Environmental Problems in Karst - CVIJIĆ", Stevanović, Z., and Milanović, P., (Eds), Beograd-Kotor, p. 11-19.

Quevauviller P. 2008: Integrated management principles for groundwater in the EU-WFD context. RSC, London, 473–493.

Padilla A, Pulido-Bosch A, Mangin A, 1994: Relative importance of baseflow and quickflow from hydrographs of karst spring. Ground Water, 32: 2, 267

PLTWSM, 2016: Review and update of "Projection of long-term water supply in Montenegro". Government of Montenegro, Ministry of Sustainable Development and Tourism & AMPLITUDO DOO, Podgorica

Public Institute “Vode Srpske” (“Water of Srpska”), 2016: Sava River Basin Management Plan in the Republic of Srpska, draft version, Bijeljina (Available at: www.voders.org)

Quevauviller P. 2008: Integrated management principles for groundwater in the EU-WFD context. RSC, London, 473–493.

Radulović V., 1989: Hydrogeology of the Skadar Lake. Published Doct. Dissert., Geological Survey of SR Montenegro, Titograd, 224 p.

Radulović V., 1995: Hydrogeology Map of Montenegro, 1:200.000, Geological Survey of Montenegro, Podgorica.

Radulović V., Radulović M., 1997: Karst of Montenegro, In: 100 Years of Hydrogeology in Yugoslavia (Ed. Z. Stevanović), Fac. Min. & Geol. University of Belgrade, Belgrade, pp. 147-185

Radulović M., Radulović V., Popović Z., 1982: The explanatory notes of the Basic hydrogeological map, sheet "Titograd" 1:100 000, Geological Survey of SR Montenegro, Titograd.

Radulović M., Popović Z., Vujisić M., Novaković D., 1998: The explanatory notes of the Basic hydrogeological map of SRY 1:100,000, sheet ‘‘Bar’’ (in Serbian). Geological Survey of Montenegro, Titograd

Radulović M., 1999: Groundwater occurrences. In: Mineral resources and mining activities in Montenegro (ed. M. Gomilanović), Ministry of industry, energy and mining of Montenegro, Podgorica, 595-760.

Radulović M., 2000: Karst hydrogeology of Montenegro. Sep. issue of Geological Bulletin, vol. XVIII, Spec. ed. Geol. Survey of Montenegro, Podgorica, 271 p.

Radulović M., 2002: Actual problems of water supply of Montenegro coastal area. Proceedings of the Yugoslav Symp. on hydrogeol. and eng. Geol., Vol. 2, Hydrogeology, Herceg Novi.

Radulović M., Radulović V. 2004: Hidrogeološka karta Crne Gore 1:200.000, Zavod za geološka istraživanja, Podgorica

Radulović M., 2010: Multi-purpose use of existing and planned reservoirs. Montenegro in the twenty-first century in the Era of Competitiveness Energy. MASA 73/7. Podgorica.

Radulović MM., Matović M. 2010: Report of groundwater modelling of the Zeta Valley (in Serbian). Geoprojekt, Podgorica

Radulović MM., 2011: Hydrogeology of karstic aquifers along southern rim of the Skadar Lake, Doct. Dissert. Faculty of Min. & Geol., University of Belgrade, Belgrade.

Radulović MM., Stevanović Z., Radulović M., 2012: A new approach in assessing recharge of highly karstified terrains–Montenegro case studies. Environ Earth Sci 65(8):2221–2230.

Radulović MM., Novaković D., Sekulić G., 2013: Geological and hydrogeological characteristics of the Montenegrin part of the Skadar Lake catchment area (in Serbian). In: Development of hydrogeological and hydraulic study of regulation of Skadar Lake and Bojana river water regime (Sekulić G, Bushati S., eds), PA Project –Volume 1. Montenegrin Academy of Sci. and Arts, Podgorica, 9–115.

Radulović M.M., Novaković D., Dević N., Blagojević M., 2014: Final report on the project "Delineation of water bodies according to the WFD". UNDP & Institute for Hydrometeorology and Seismology of Montenegro, Podgorica.

Radulović MM., Radulović M., Stevanović Z., Sekulić G., Radulović V., Burić M., Novaković D., Vako E., Blagojević M., Dević N., Radojević D., 2015: Hydrogeology of the Skadar Lake basin (Southeast Dinarides) with an assessment of considerable subterranean inflow. Environmental Earth Science, 74/1: 71-82.

Sistem-MNE, 2016: Hydrometric measurements on the Ravnjak Spring. Sistem-MNE doo, Podgorica

Stevanović Z., Radulović M., Puri S., Radulović MM., 2008: Karstic source Bolje sestre - Optimal solution for regional water supply of Montenegro coastal area. Rec. de rapp. du Com. pour le karst et spéléologie Acad. Serbe des Sciences et des Arts, Belgrade, 9: 33-64.

Stevanović Z. 2010: Intake of the Bolje Sestre karst spring for the regional water supply of the Montenegro coastal area. In: Krešić, N. & Stevanović, Z. (eds.): Groundwater Hydrology of Springs: Engineering, Theory, Management, and Sustainability, Elsevier Inc., 459-480.

Stevanović Z., 2011: DIKTAS project – Annual report of the international consultant. (http://diktas.iwlearn.org)

Stevanović Z. 2011: Menadžment podzemnih vodnih resursa (Management of Groundwater Resources), Fac. Min. & Geol. Univ. of Belgrade, Belgrade, 340 p.

Stevanović, Z. (Ed.), 2015: Karst Aquifers – Characterization and Engineering, Springer International Publishing Switzerland, pp. 692

Stevanović Z., Marinović V., Merdan S., Skopljak F., Jolović B., 2015 Conception of creating basic documents in hydrogeology for river basin management plans, Proceedings of I Geological Congress of Bosnia & Herzegovina, Tuzla, p. 150-151

Stevanović Z., Kukurić, N., Pekaš, Ž., Jolović B., Pambuku A., Radojević D., 2016: Dinaric Karst Aquifer – One of the world's largest transboundary systems and an ideal location for applying innovative and integrated water management. In: Karst Without Boundaries, Stevanović Z., Kresic N., Kukuric N. (eds.), CRC Press/Balkema, Taylor & Francis Group, London, 3-25

Stevanović Z.: Karst aquifers of Southeast Europe – Essential and rich resource of potable waters, Rec. de rapp. du Com. pour le karst et spéléologie Acad. Serbe des Sciences et des Arts, Belgrade, vol. 11 (*in press*)

SWMM, 2017: Strategy for water managment in Montenegro. Government of Montenegro, Ministry of Agriculture and Rural Development, Podgorica

Torbarov K., Radulović V., 1966: Regional hydrogeological research of Montenegro and Eastern Herzegovina (in Serbian). Geological Survey of Montenegro, Titograd.

Thornthwaite CW, 1948: An approach toward a rational classification of climate. Geograph. Rev., 38, 55

Turc L, 1954: Le bilan d'eau des sols: relations entre les precipitations, l' evaporation et l' ecoulement. Ann. Agron. 5: 491-596

United Kingdom Technical Advisory Group, 2005: Approach to Delineation of Groundwater Bodies, Paper by the Working Group on Groundwater, Guidance document no. GW2

United Kingdom Technical Advisory Group, 2005: Methodology for Risk Characterization of Ireland's Groundwater, Paper by the Working Group on Groundwater, Guidance document no. GW8

United Kingdom Technical Advisory Group, 2005: Technical Requirements for Groundwater and Related Aspects, Paper by the Working Group on Groundwater, Guidance document no. GW1

Vías, J.M., Andreo, B., Perles, M.J., Carrasco, F., Vadillo, I., Jiménez, P., 2002: Preliminary proposal for contamination vulnerability mapping in carbonate aquifers. Karst & Environment,pp.75-83.

Vlahović V., 1975: Karst of Nikšić polje and its hydrogeology (Kras nikšićkog polja i njegova hidrogeologija), Society for Science and Arts of Montenegro, Spec. ed, vol. III, Dept. of Natur. Sci., Titograd, 204 p.

Vrba, J., Zaporozec, A.,1994: Guidebook on mapping groundwater vulnerability. IAH. Verlag Heinz Heise. Vol 16. 131 p.

Zaporozec A., 2004: Groundwater contamination inventory. A methodological guide. IHP-VI, Series on groundwater no.2, UNESCO, Paris

Zogović D., 1992: Final report of hydrogeological exploration of Karuč source (in Serbian). Energoprojekt, Beograd.

Zwahlen, F., (Ed) (2004): Vulnerability and risk mapping for the protection of carbonate (karst) aquifers, Cost Action 620, Office for Official Publications of the European Communities, Luxembourg

Živaljević M., 1989: The explanatory notes of the geological map of SR Montenegro, 1:200 000, Geological Survey of SR Montenegro. Special Issue of the Geological Bulletin, Vol. VIII, Titograd.

Živaljević R., Bošković M., 1984: The results of hydrological measurements in the catchment area of Orahovštica (in Serbian). Hydrological and Meteorological Service of Montenegro, Podgorica.

Živaljević R.,1992: Hydrogeological analysis of the movement of karst water in the case of the River Crnojevica basin. Doct. Dissert., Faculty of Civil Engineering, University "Veljko Vlahović", Titograd.

Directives, legislation acts, web sites:

European Commission, 2000: Directive 2000/60/EC of the European Parliament and of the Council – Establishing a framework for Community action in the field of water policy. Brussels, Belgium, 23 October 2000.

European Commission, 2008: Groundwater protection in Europe. EC Office for Official Publications, Luxembourg.

European Commission, 2015: Guidance document on the application of water balances for supporting the implementation of the WFD, Final – Version 6.1 (Smjernice o primjeni vodnih bilansa za podršku implementacije WFD-a, Konačna – Verzija 6.1) – 18/05/2015, Technical report 2015/090

European Environmental Agency: www.eea.europe.eu

European Environment Agency, 2006: CORINE Land Use Map

FAO, Rome: www.fao.org/nr/aquastat

Groundwater Daughter Directive to WFD 2006/118/EC.

ICPDR, www.icpdr.org

ISRBS, www.savacommisison.org

Regulation on establishing and maintaining of zones and belts of sanitary protection of water sources, "Official Gazette" of Montenegro 66/09.

Regulation on the classification and categorization of surface and groundwater, Official Gazette of Montenegro, No. 2/07.

United Kingdom Technical Advisory Group 2005: Technical Requirements for Groundwater and Related Aspects, Paper by the Working Group on Groundwater, Guidance document no. GW1

United Kingdom Technical Advisory Group, 2005a: Approach to Delineation of Groundwater Bodies, Paper by the Working Group on Groundwater, Guidance document no. GW2

United Kingdom Technical Advisory Group, 2005b: Methodology for Risk Characterization of Ireland's Groundwater, Paper by the Working Group on Groundwater, Guidance document no. GW8

Water Management Plan of Montenegro, 2001: Republic of Montenegro. Inst. of Wat. Res. Manag. "Jaroslav Černi", Belgrade - Ministry of Agriculture, Forestry and Water Management, Podgorica.

Water Framework Directive WFD, 2000: Official Journal of EU, L 327/1, 2000/60, Brussels

Water Law, 2007: Official Gazette of Montenegro, No. 27/2007.

WFD CIS Guidance Document No. 1 2003: Common Implementation Strategy for the Water Framework Directive (2000/60/EC) Economics and the Environment The Implementation Challenge of the Water Framework Directive WATECO. Directorate General Environment of the European Commission, Brussels

WFD CIS Guidance Document No. 2, 2003 : Common Implementation Strategy for the Water Framework Directive (2000/60/EC) Identification of Water Bodies, Directorate General Environment of the European Commission, Brussels

WFD CIS Guidance Document No. 3, 2003: Common Implementation Strategy for the Water Framework Directive (2000/60/EC) Analysis of Pressures and Impacts, Produced by Working Group 2.1 – Impress, Directorate General Environment of the European Commission, Brussels.

WFD CIS, 2005: Common Implementation Strategy for the Water Framework Directive (2000/60/EC) Groundwater Summary Report, Directorate General Environment of the European Commission, Brussels.

WFD CIS Guidance Document No. 16, 2006: Common Implementation Strategy for the Water Framework Directive (2000/60/EC) Guidance on Groundwater in Drinking Water Protected Areas, Directorate General Environment of the European Commission, Brussels

WFD CIS Guidance Document No. 15, 2007: Common Implementation Strategy for the Water Framework Directive (2000/60/EC) Guidance on Groundwater Monitoring, Directorate General Environment of the European Commission, Brussels.

WFD CIS Guidance Document No. 18, 2009: Common Implementation Strategy for the Water Framework Directive (2000/60/EC) Guidance on Groundwater Status and Trend Assessment, Directorate General Environment of the European Commission, Brussels.

WFD Technical Report No. 6, 2011: Common Implementation Strategy for the Water Framework Directive (2000/60/EC) Technical report on groundwater dependent terrestrial ecosystems, Directorate General Environment of the European Commission, Brussels