Towards sustainable management of transboundary Hungarian – Serbian aquifer

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SUDEHSTRA project
Sustainable development of Hungarian - Serbian transboundary aquifer

University of Belgrade, Faculty of Mining and Geology (FMG), Belgrade, SERBIA

in partnership with

ATIKOVIZIG - Also-Tisza Videki Kornyezetvedelmi es vizugyi igazgatosag

Szeged, HUNGARY

Cross-border Cooperation Programme
MAGYARORSZÁG - ROMÂNIA
MAGYARORSZÁG - SRBIJA I CRNA GORA

ERDF / INTERREG IIIA
Community Initiative 2000 - 2006

Funded by European Agency for Reconstruction

Name of partners in Action on Serbian side :

- 1. JKP Vodovod i kanalizacija, Subotica,
- 2. Provincial Secretariat of Vojvodina for Energy and Mineral Resources (with financial support) and
- 3. JVP “Vode Vojvodine”, Novi Sad (without financial support and requests)

Target beneficiaries on Serbian side:

- The population of 11 municipalities with over 500.000 inhabitants within project area: 6 large waterworks of main cities and industries of Subotica, Sombor, Backa Topola, Bajmok, Kanjiza, as well as 16 smaller cities and villages, in addition to industry and agriculture).

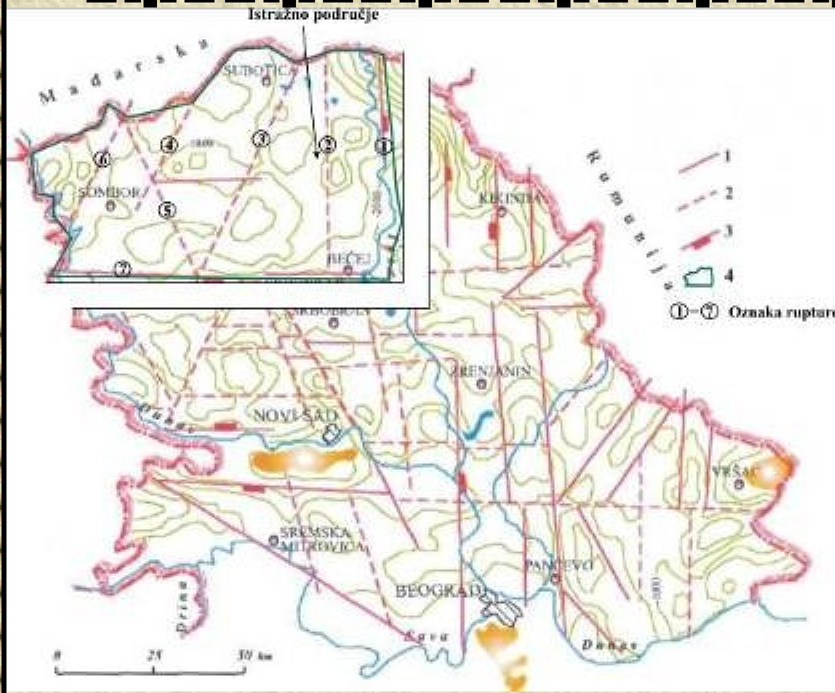
MAP OF PROJECT AREA

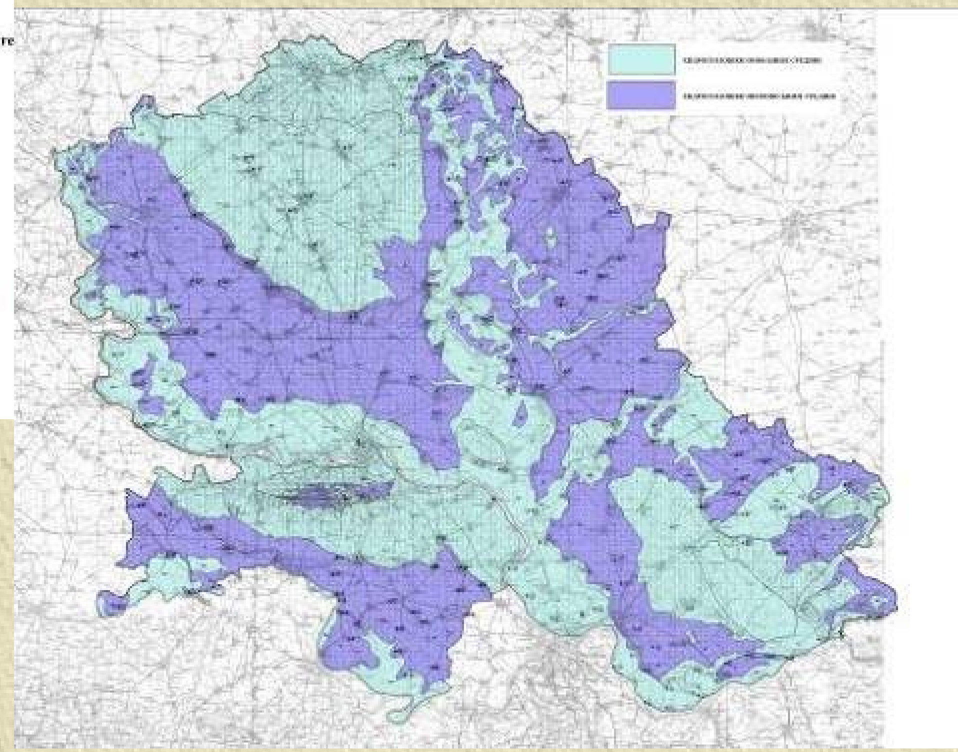
Activities

No	Task	Activities
1.	**Preparatory activities**	Collect and evaluate previous investigation data, Assess status of water consumption and demands, Select representative water points, Provide necessary equipment for field survey.
2.	**Data collection**	Complete water point inventory, Evaluate results of in-field measurements and tests, Evaluate results of laboratory analyses, Assess GW resources and their quality.
3.	**Monitoring network**	Select representative water points for GW network, Provide and install monitoring equipment, Define monitoring methodology and parameters, Evaluate preliminary data.
4.	**Hydrodynamical model**	Define conceptual hydrogeological model, Create hydrodynamical model, Calibrate and test model, Propose measures for GW sustainable use, Transfer knowledge.

Aquifer distribution

Vojvodina (Panonnian basin) by 100% is satisfying its demands in drinking water from the ground. There are more than 300 sources and centralized waterworks, and over 1,000 operational deep wells. In 1995, total GW consumption was about 6,7 m^3/s, out of which 4,9 m^3/s was tapped from deeper BGC, and 1,8 m^3/s from the alluvium.





Alluvial phreatic aquifer

- The current groundwater extraction from alluvial aquifer is most intense at Novi Sad and Pancevo areas. The large groundwater reserves of this aquifer represent the most promising groundwater potential of whole Vojvodina. The alluvium of Tisza river in spite of its large thickness and good permeability is currently exploited in a very small range.
- Lithologically, the top alluvial sediments are usually built of silt, silty clays and silty sands. The main water-bearing layer consists of gravel, sands, conglomerate, rarely clayed sand. Underlying layers are often Pleistocene and Paludinae clays and sandy shales

"Basic groundwater complex" (BGC)

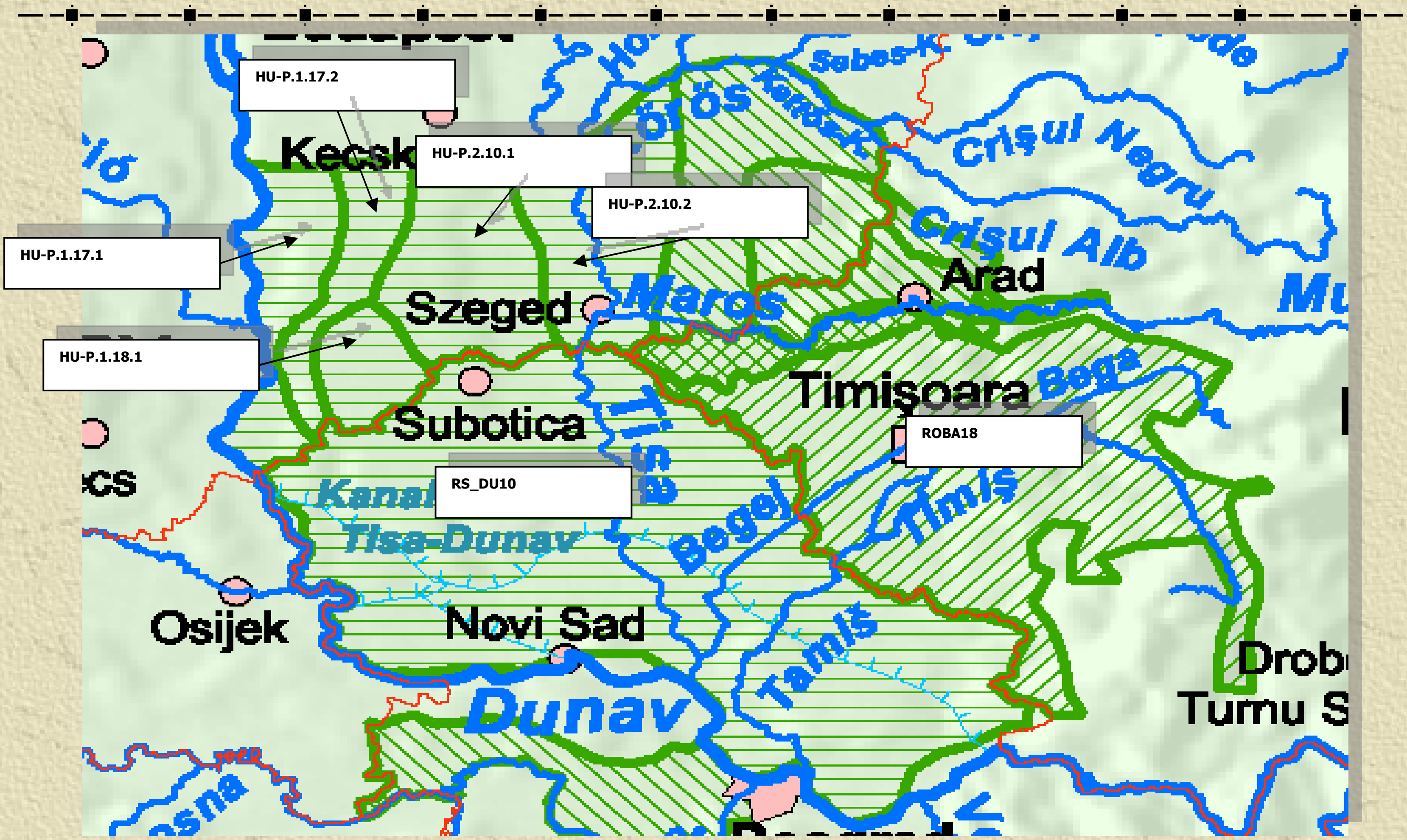
- Since Mid of XIX century till now in Vojvodina more than 3,000 wells were drilled in this aquifer.
- The main characteristic of BGC is permanent changes in lateral and vertical section and interfingering of clay and sandy layers. In vertical section usually two, and rarely up to four sandy layers are present till the depth of 200m.
- Most of wells drilled between 60-160m, but some up to 200m or even more.
- The typical construction is as follows: 800mm diameter of drilled hole and installed Ø 323mm pipes/screen.
- An average well capacity 10 - 15 l/s, depends of screen types.

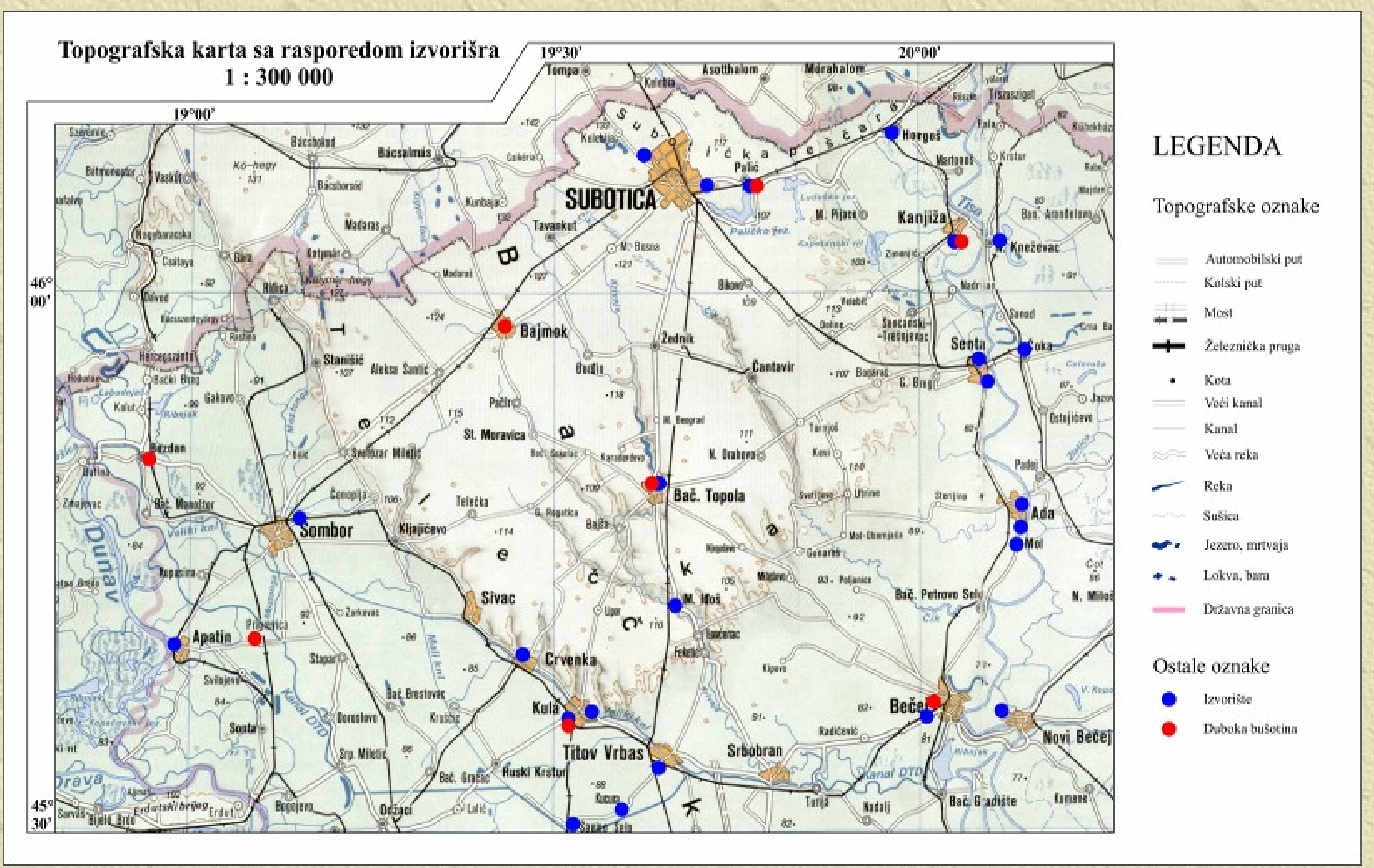
GW Quality of BGC

BGC in general:

- pH value 8,2 – 8,8
- Electroconductivity value of 660 to 800 μs/cm
- Water temperature usually 15 - 20 ^{0}C.
- "Yellowish" waters of sodium – hydrocarbonate type
- $KMnO_4$ often over 20 mg/l
- Amonia ion often over 2 mg/l
- Increased Fe, NO_3, **As, B** ions
- CH_4, CO_2 rarely increased

EU WFD / Transboundary aquifer characterization




Topografska karta sa rasporedom izvorišra
1 : 300 000
19°00'
19°30'
20°00'
46° 00'
45° 30'
SUBOTICA
Palić
Horgoš
Kanjiža
Kneževac
Bajmok
Senta
Čoka
Bač. Topola
Sombor
Ada
Mol
Apatin
Bezdan
Sivac
Crvenka
M. Iđoš
Kula
Titov Vrbas
Srbobran
Bečej
Novi Bečej
Dunav
Tisa
LEGENDA
Topografske oznake
Automobilski put
Kolski put
Most
Železnička pruga
Kota
Veći kanal
Kanal
Veća reka
Reka
Sušica
Jezero, mrtvaja
Lokva, bara
Državna granica
Ostale oznake
Izvorište
Duboka bušotina

(Q=def.)

Domestic and industrial use

Vodovod	Izvorište	Kaptirani sloj					Q naselja (l/s)	Q industr (l/s)
Ada	Ada	I					78	140
	Mol	I						
	Između Ade i Mola	I						
Apatin	Apatin	I					100	200
Bačka Topola	Bačka Topola	I					35	30
Bečej	Bečej	I					108	120
Čoka	Čoka	I					60	30
Kanjiža	Horgoš	I	II				66	40
	Kanjiža	I	II				100	60
Crvenka	Crvenka		II				31	40
Kula	Kula (Štolc) K1	I					57	50
	Kula (Krsturski put)	I					35	
Mali Iđoš	Mali Iđoš	I					15	20
Novi Bečej	Novi Bečej	I					90	80
Novi Kneževac	Novi Kneževac		II				50	80
Senta	Senta Sever	I					58	60
	Senta Jug	I						
Sombor	Sombor Jaroš	I					210	50
	Sombor Bunari u gradu		II				80	120
Subotica	Subotica (Vodozahvat 1)	I	II				250	100
	Subotica (Vodozahvat 2)	I	II				73	
Vrbas	Vrbas (Ravno selo)		II				16.7	160
	Vrbas (Savino selo)		II				44	
	Vrbas (kucura)		II				25	
Kanjiža	Duboka bušotina				IV		9.2	
Bačka Topola	Duboka bušotina				IV		10.8	
Palić	Duboka bušotina				IV		17.7	
Bečej	Duboka bušotina				IV		25	
Bajmok	Duboka bušotina				IV		1	
Kula	Duboka bušotina					V	14.2	
Prigrevica	Duboka bušotina					V	20.5	
Bezdan	Duboka bušotina			III			15	

Current groundwater exploitation

In Serbia it is assumed that the current exploitation of the transboundary aquifer is about **2.8 m³/s**, half of which is for centralized waterworks and half for industrial purposes. Groundwater is often used for irrigation purposes, but to a greater extent for municipal and industrial water supply. In the Hungarian part of the model domain, the estimated exploitation is **2 m³/s**, 60 % of which is used for municipal and the rest for industrial water supply and irrigation. Tapping of shallow aquifer is prevalent in Serbia, whereas the deeper aquifer layers are more exploited in Hungary.

The larger consumption of groundwater in Serbia can be the result of:

- 1. Lower water taxes in Serbia (currently two to three times less than in Hungary, including the waste water treatment tariff);
- 2.The larger number of inhabitants (about 60% of the total);
- 3. A slightly larger transboundary area included in the analyses;
- 4. Possible errors in calculating pumping rates due to insufficient data of local water enterprises;
- 5. Unregistered wells and their yields on both sides (expertise, however, estimated some value which has been incorporated into the model).

Towards Database as a management tool:

Field visits and Questionnaire

The field reports consist of overview of geology, hydrogeology, aquifer systems (main water bearing horizons), permeability parameters, water wells conditions (number, capacities, discharges, dynamic water table etc.), total source capacity, groundwater quality and current treatment. The representative cross section for each source is also drawn.

PODACI O IZVORIŠTU PODZEMNIH VODA

Izvorište za grad/naselje: Senta

Naziv izvorišta: Vodozahvat " Jug" i vodozahvat "Sever"

Lokalnost:

Najbliže veće poznato naselje: Subotica

Koordinate izvorišta (videti objašnjenje 1* na kraju ankete)

X		Y		Z	
1. Sever 5	[m]	1.Sever 7 4	[m]		[m.n.m]
2.Sever 5 (	[m]	2.Sever 7 4	[m]		[m.n.m]
3.Sever 5 (	[m]	3.Sever 7 4	[m]		[m.n.m]
4.Sever 5 (	[m]	4.Sever 7 4	[m]		[m.n.m]

Naziv organizacije koja gazduje izvorištem: Javno komunalno-stambeno preduzeće Senta

Opština: Senta

Adresa: Ilije Birčanina 2

Vlasnički odnos nad područjem izvorišta (pravi vlasnik, suvlasnik, zakupac, dr.): Korisnik

Hronologija rada izvorišta:		tip/vrsta objekta	godina		kapacitet	Sadašnji
1	otvoreno	Bunar	Sever 1979	[god]	100	[l/s]
2	prošireno	Bunar	Sever 1982	[god]	2,65	[l/s]
3	prošireno	Bunar	Jug 1987	[god]	15	[l/s]
4	prošireno	Bunar	Jug 1989	[god]	12,3	[l/s]
5	prošireno	Bunar	Jug1989	[god]	12,1	[l/s]
7	prošireno	Bunar	Jug1990	[god]	13,3	[l/s]
8	prošireno	Bunar	Jug 1991	[god]	12,6	[l/s]
9	prošireno	Bunar	Jug2003	[god]	16,9	[l/s]
10	poslednja godina izvođenja hidrogeoloških i drugih istraživanja				2006	[god]

IZVORIŠTE SENTA

Geološka građa

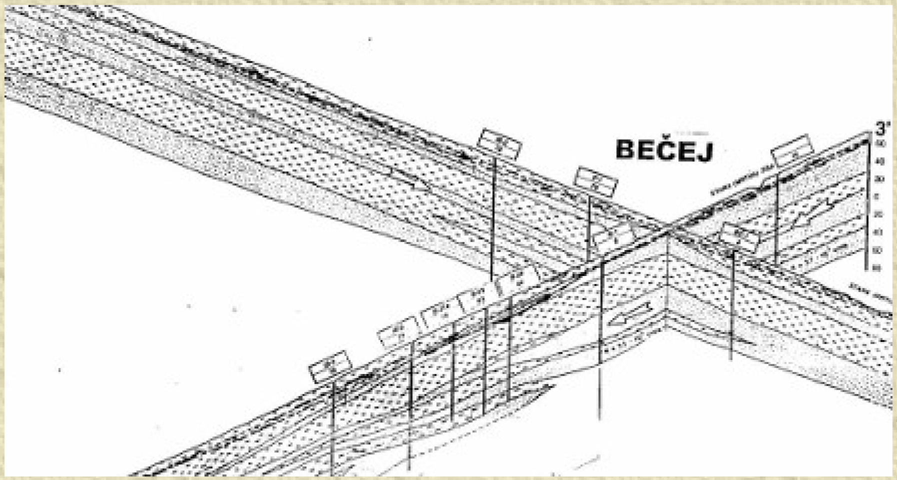
Osnovne hidrogeološke karakteristike

Na teritoriji izvorišta Senta dominantnu ulogu imaju dva tipa izdani:

- zbijeni tip izdani sa slobodnim nivoom i
- zbijeni tip izdani sa nivoom pod pritiskom.

Zbijeni tip izdani sa slobodnim nivoom zaleže do dubine od oko 90 m. U zavisnosti od povlate ova izdan može biti mestimično pod pritiskom. Nivo izdani se u neporemećenim uslovima nalazi na dubini od oko 0,5 m tj. na koti od oko 76,5 mnm. Pripovršinski deo do dubine od oko 45 m izgrađuju polupropusne, slabopropusne i nepropusne tvorevine, a donji deo od oko 45-90 m izgrađuju nevezani, sitnozrni do srednjezrni peskovi. Koeficijent filtracije ove izdani je 1-5 x 10^{-4} m/s, a koeficijent transmisibilnosti je 4,5-22,5 x 10^{-3} m^2/s. Prihranjivanje izdani se vrši infiltracijom površinskih voda, i na kontaktu izdani sa rekom Tisom i kanalskom mrežom. Manji deo dotiče i sa bokova gde je ova izdan u vezi sa dubljiom izdani koja je pod pritiskom. Dreniranje izdani se odvija preko vodozahvatnih objekata, oticajima prema vodotocima i evapotranspiracijom.

Zbijeni tip izdani sa nivoom pod pritiskom je formiran u okviru alevritskih peskova, peskovitih alevrita i peskovito-šljunkovitih alevrita čija se debljina kreće od 30-75 m, a zaleže na dubini od oko 60 do oko 90 m. Na samom izvorištu JUG bunarima se zahavata voda iz intervala od 70-90 m. Pritisak u ovim akviferima se nalazi na oko 10 m ispod površine terena ili na koti oko 72 mnm. Koeficijent filtracije ove izdani je 2,5-3,2 x 10^{-4} m/s, a koeficijent transmisibilnosti je 3,5-5,5 x 10^{-3} m^2/s. Prihranjivanje izdani se odvija doticajem iz podine i povlate. Dreniranje izdani se odvija veštačkim putem preko vodozahvatnih objekata.



Broj bunara u okviru izvorišta

Vodosnabdevanje Sente organizovano je zahvatanjem podzemne vode na izvorištima SEVER i JUG vodovoda koja se nalaze na severnom i južnom rubu grada. Na izvorištu SEVER se eksploatišu 2 bunara, a na izvorištu JUG se eksploatiše 6 bunara. Što znači da se za vodosnabdevanje Sente eksploatiše ukupno 8 bunara.

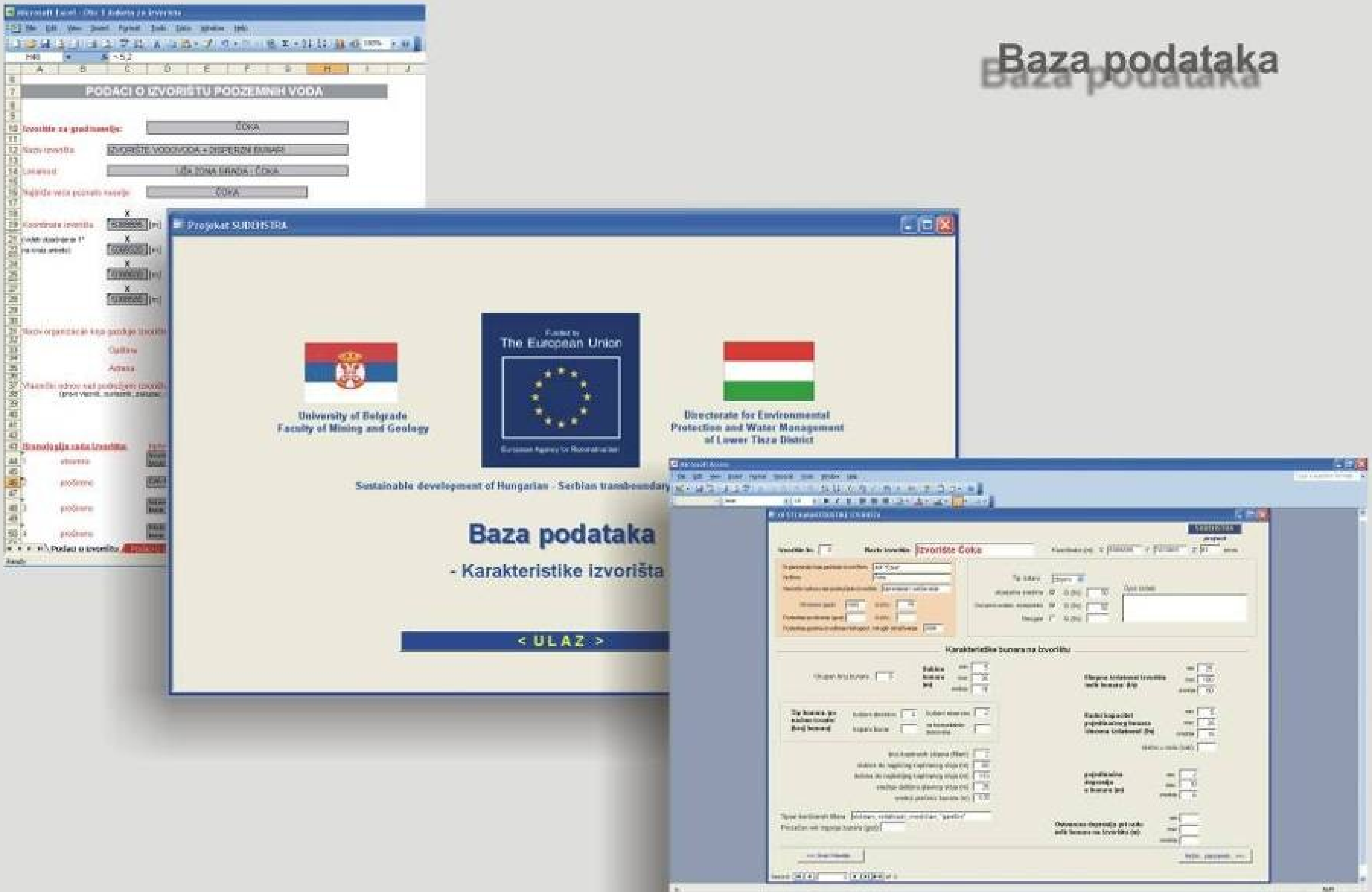
Kapacitet izvorišta

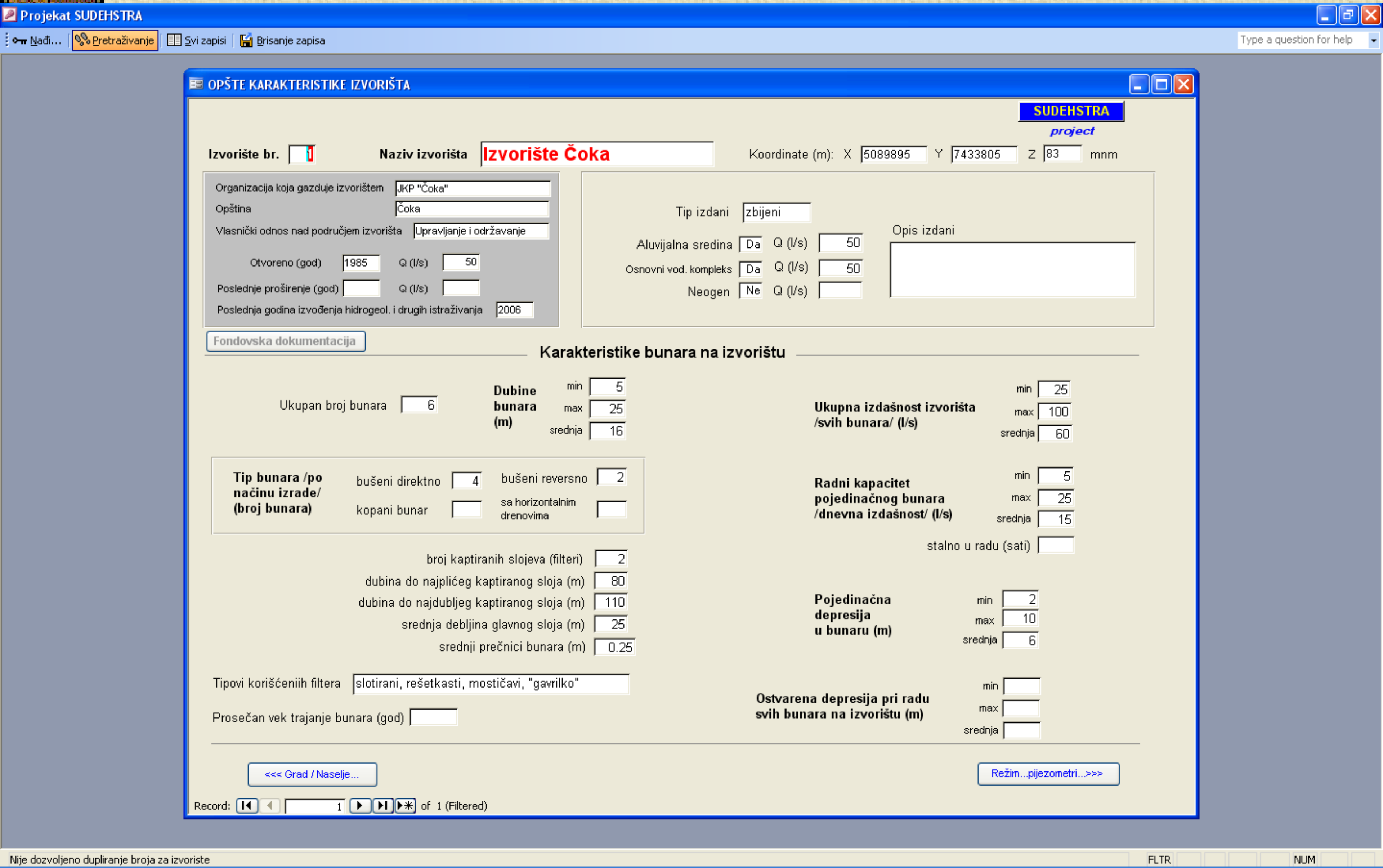
Na izvorištu SEVER se eksploatišu 2 bunara ukupnim kapacitetom od oko 7,5 l/s. Na izvorištu JUG se eksploatiše 6 bunara ukupnim kapacitetom od oko 60 l/s. Ukupni kapacitet oba izvorišta, gde se eksploatiše ukupno 8 bunara je oko 67,5 l/s.

Minimalni i maksimalni kapacitet izvorišta

Minimalni radni kapacitet pojedinačnog bunara (dnevna izdašnost) Q_{min}=5 l/s, maksimalni radni kapacitet pojedinačnog bunara (dnevna izdašnost) Q_{max}=18 l/s, a srednji radni kapacitet pojedinačnog bunara (dnevna izdašnost) Q_{sr}=11,5 l/s.

Baza podataka




Projekat SUDEHSTRA
Nađi... Pretraživanje Svi zapisi Brisanje zapisa
Type a question for help
OPŠTE KARAKTERISTIKE IZVORIŠTA
SUDEHSTRA
project
Izvorište br. 1
Naziv izvorišta Izvorište Čoka
Koordinate (m): X 5089895 Y 7433805 Z 83 mnm
Organizacija koja gazduje izvorištem JKP "Čoka"
Opština Čoka
Vlasnički odnos nad područjem izvorišta Upravljanje i održavanje
Otvoreno (god) 1985 Q (l/s) 50
Poslednje proširenje (god) Q (l/s)
Poslednja godina izvođenja hidrogeol. i drugih istraživanja 2006
Tip izdani zbijeni
Aluvijalna sredina Da Q (l/s) 50
Osnovni vod. kompleks Da Q (l/s) 50
Neogen Ne Q (l/s)
Opis izdani
Fondovska dokumentacija
Karakteristike bunara na izvorištu
Ukupan broj bunara 6
Dubine bunara (m) min 5 max 25 srednja 16
Ukupna izdašnost izvorišta /svih bunara/ (l/s) min 25 max 100 srednja 60
Tip bunara /po načinu izrade/ (broj bunara)
bušeni direktno 4
bušeni reversno 2
kopani bunar
sa horizontalnim drenovima
Radni kapacitet pojedinačnog bunara /dnevna izdašnost/ (l/s) min 5 max 25 srednja 15
stalno u radu (sati)
broj kaptiranih slojeva (filteri) 2
dubina do najplićeg kaptiranog sloja (m) 80
dubina do najdubljeg kaptiranog sloja (m) 110
srednja debljina glavnog sloja (m) 25
srednji prečnici bunara (m) 0.25
Pojedinačna depresija u bunaru (m) min 2 max 10 srednja 6
Tipovi korišćeniih filtera slotirani, rešetkasti, mostičavi, "gavrilko"
Prosečan vek trajanje bunara (god)
Ostvarena depresija pri radu svih bunara na izvorištu (m) min max srednja
<<< Grad / Naselje...
Režim...pijezometri...>>>
Record: 1 of 1 (Filtered)
Nije dozvoljeno dupliranje broja za izvoriste
FLTR NUM

Karta vodovoda sa intenzitetom potrošnje
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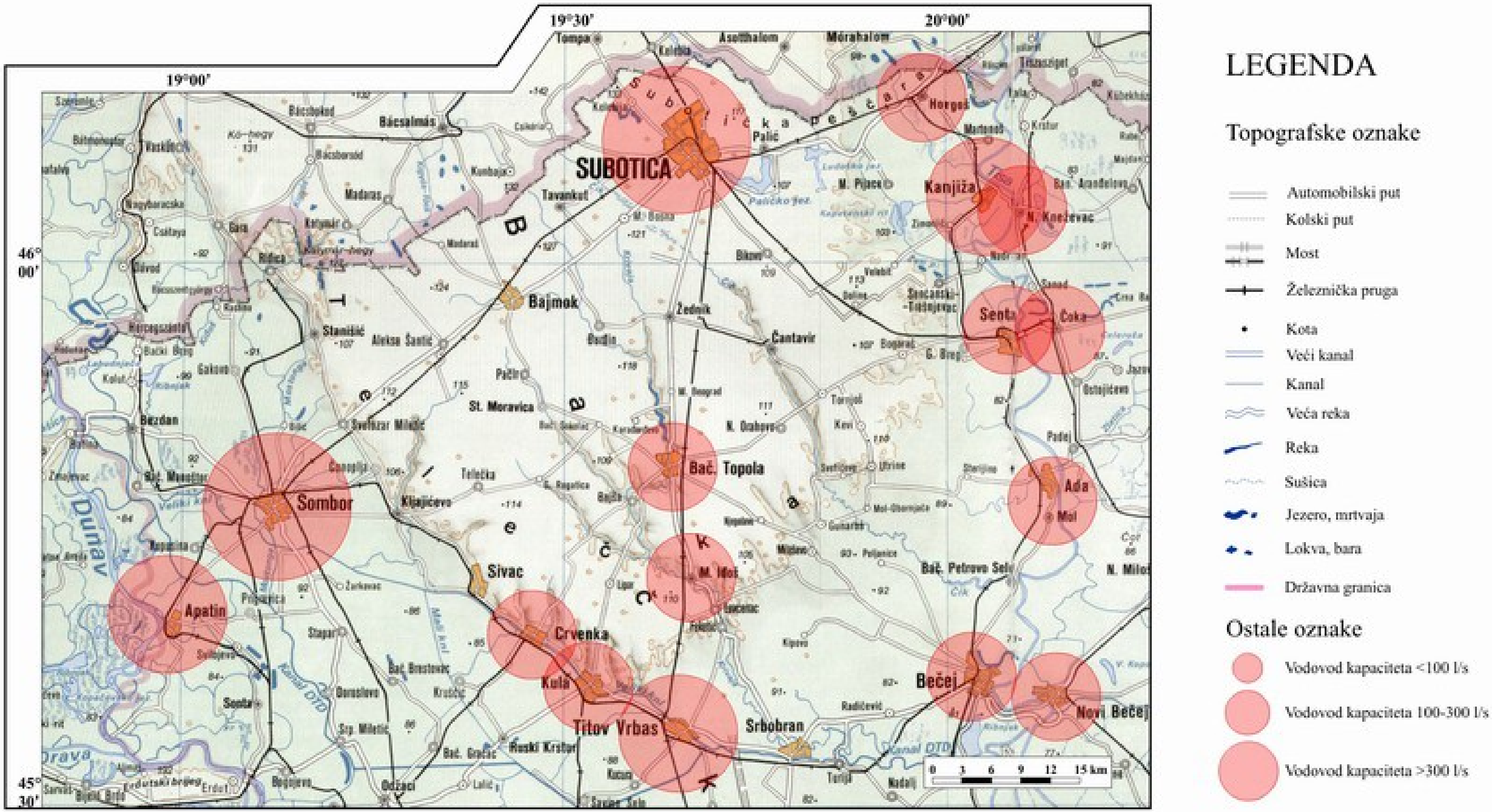
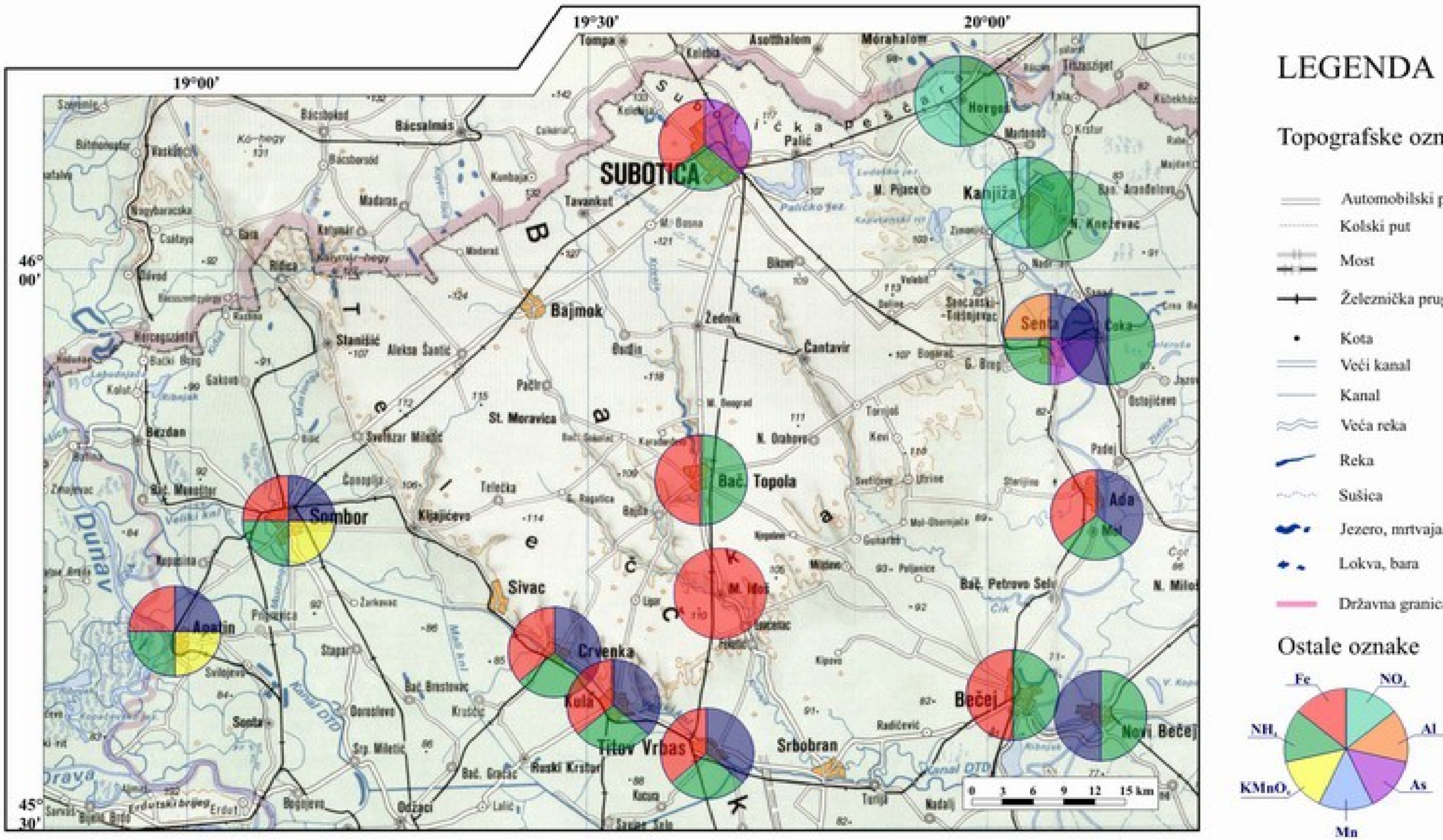
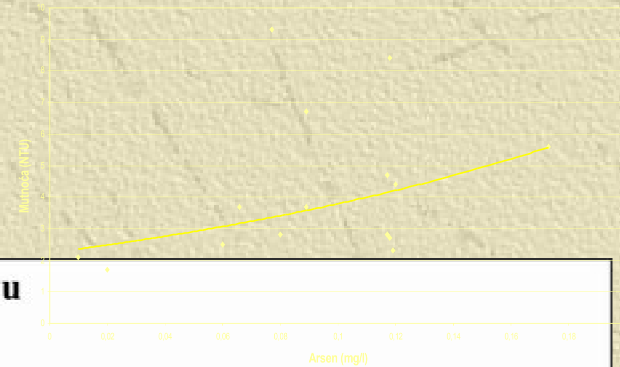


Prikaza povišenih sadržaja mikrokomponenti u podzemnim vodama na istražnom području 1 : 300 000





Karta prikaza hemijskog tretmana voda
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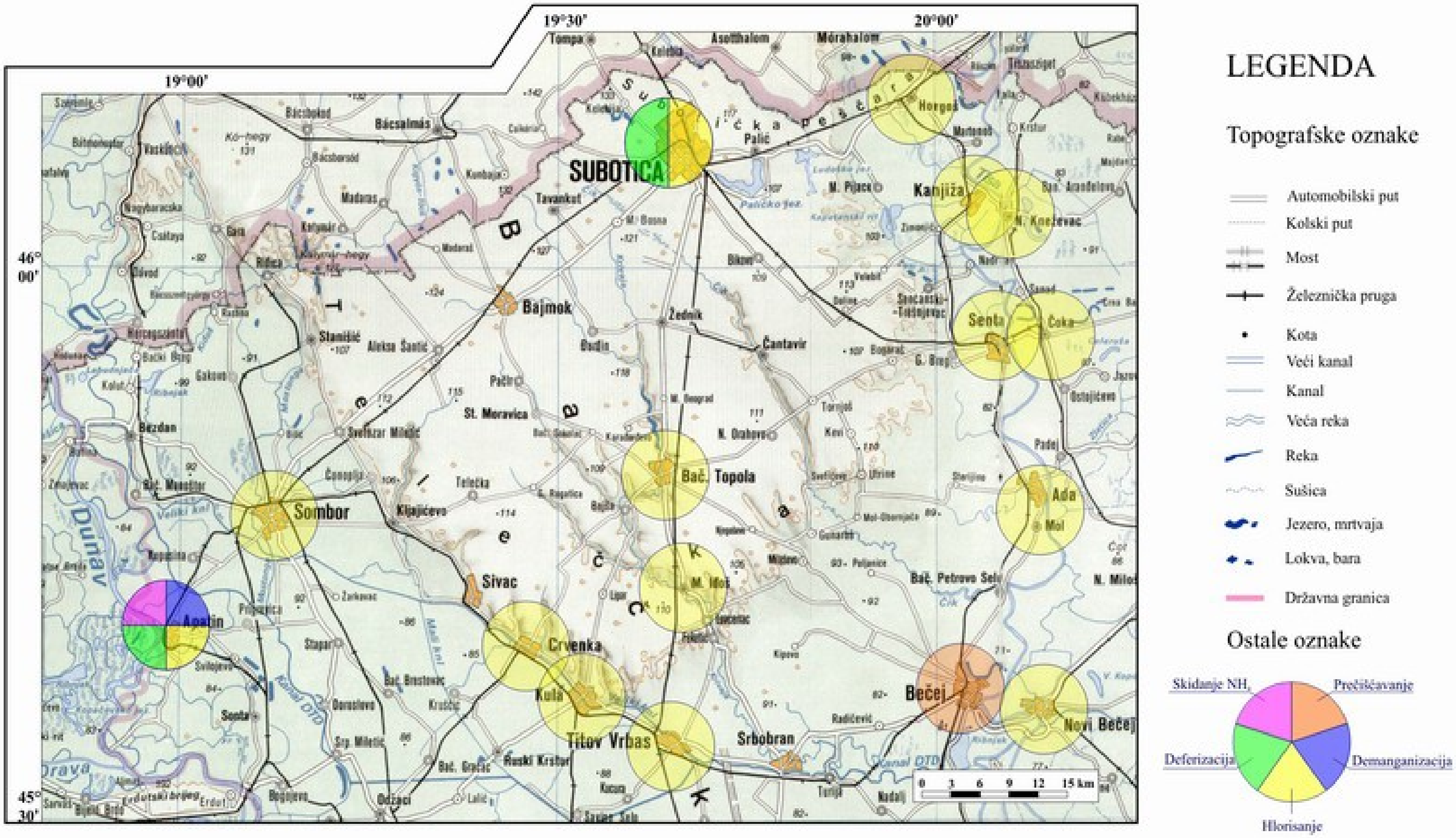
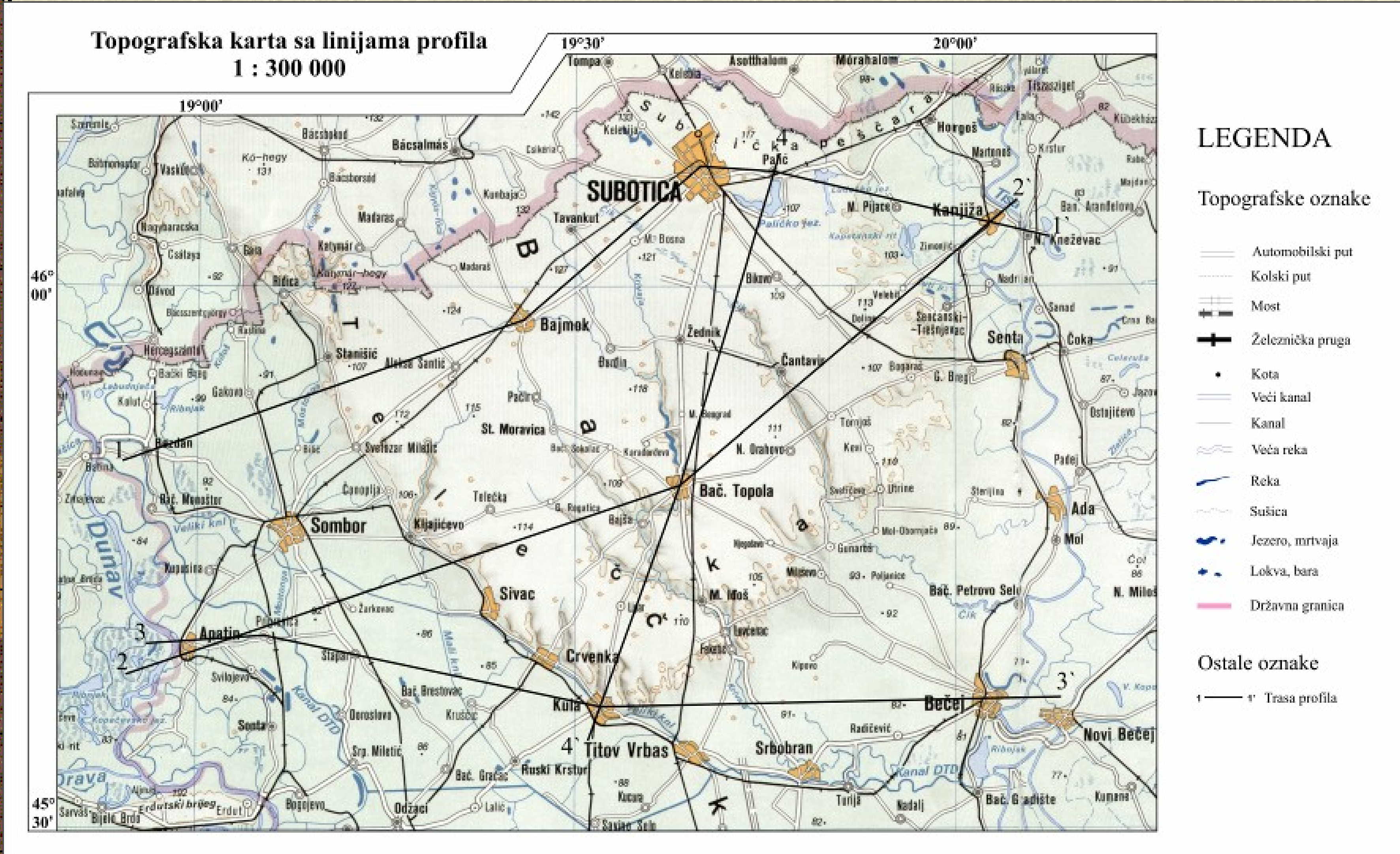
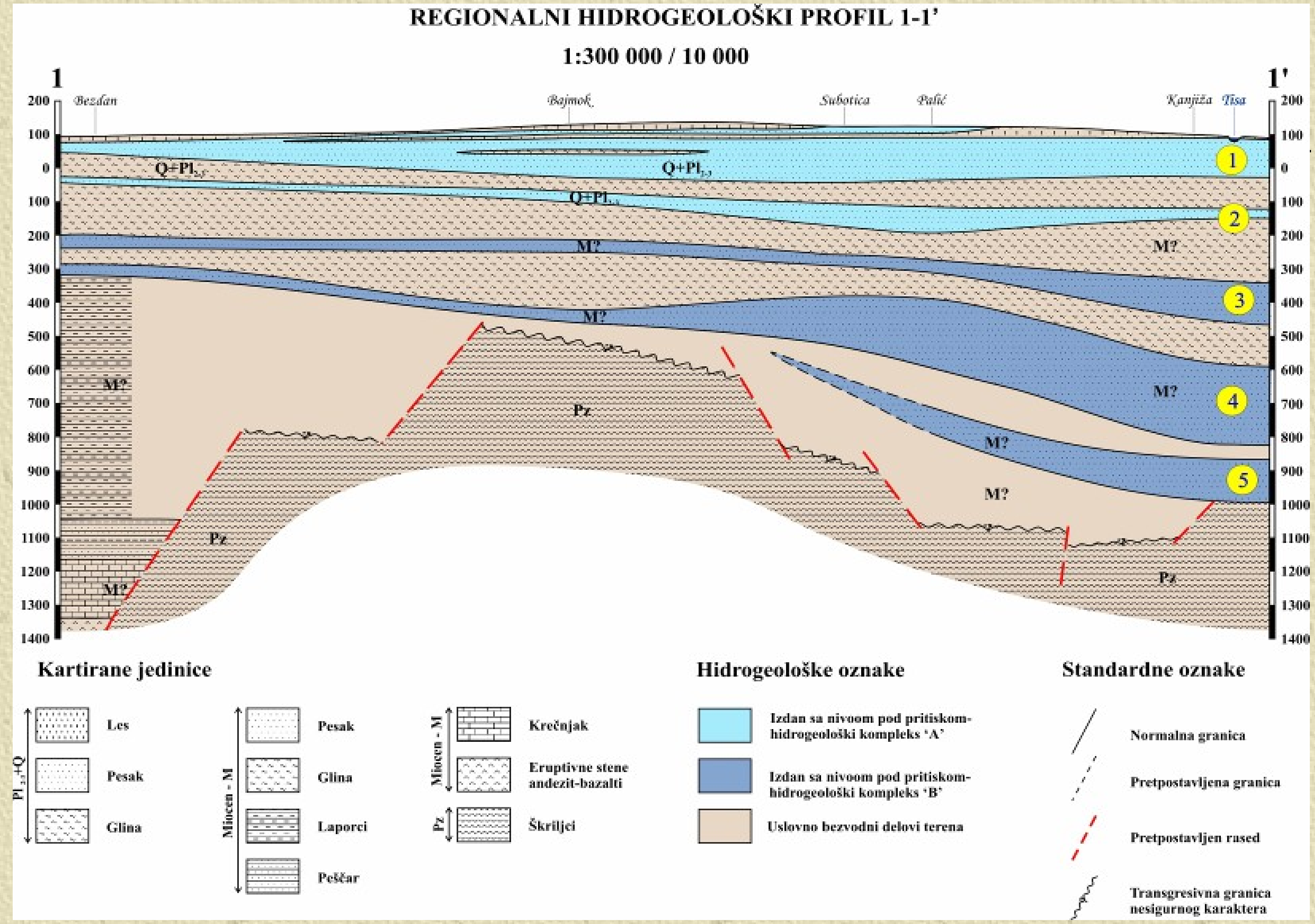


Towards HG Conceptual model

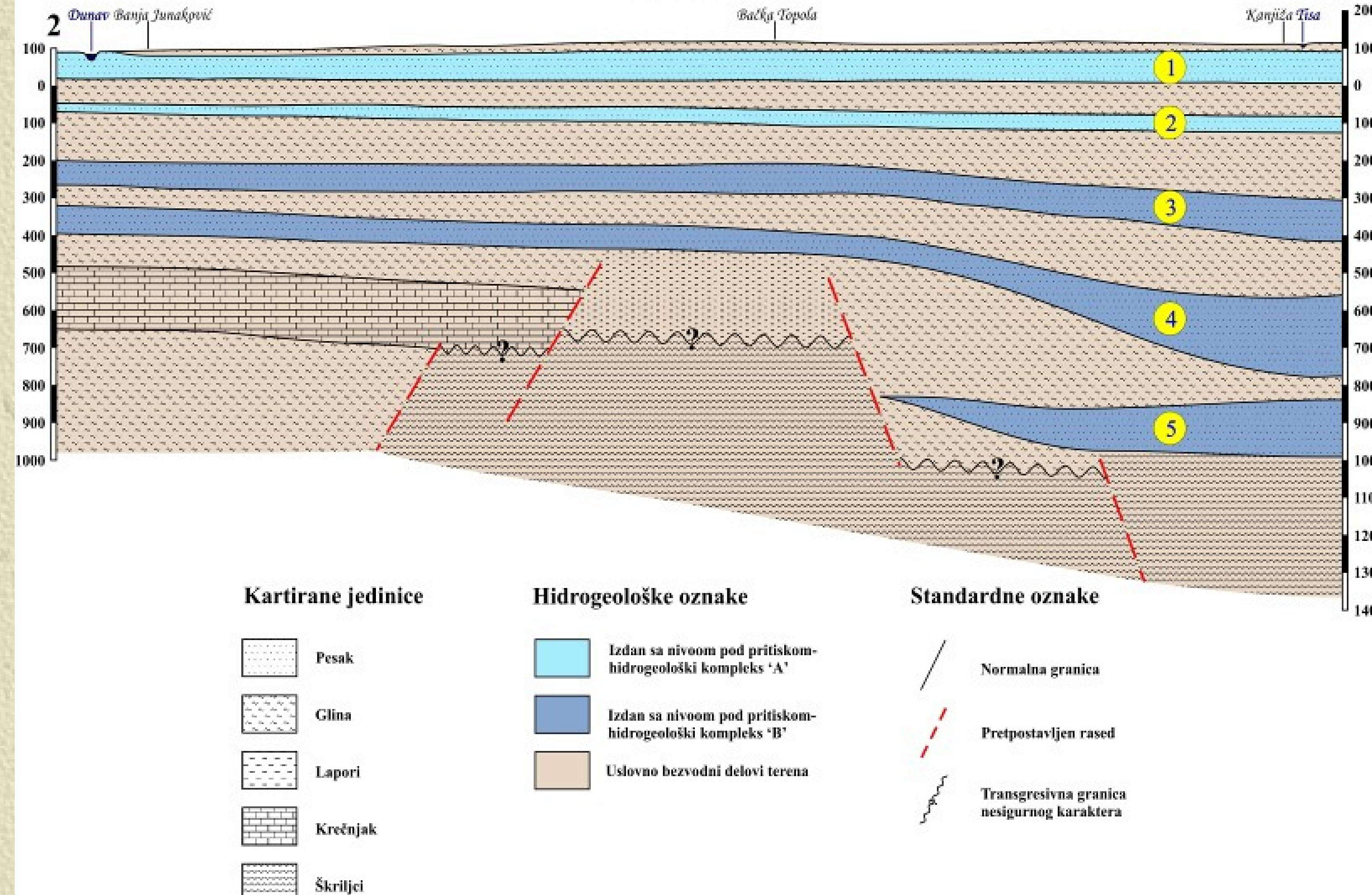


- **The conceptual hydrogeological model** includes 5 main aquifer layers to a depth of some 2500 m. The first two (Quaternary and Upper Pliocene), which are most prominent and characterized by the presence of fresh groundwater, are utilized mostly for drinking water supply and for irrigation.
- The deeper layers are also used in the water supply of some cities (e.g. Szeged) or for geothermal or balneotherapeutical purposes: thermal water is used for recreation and medical purposes in several spas in both countries, while geothermal energy is more efficiently used in Hungary. The number of wells that tap deeper aquifer layers with thermal waters is over 100 on the Hungarian side, while in Serbia there are some 15-20 such wells.


REGIONALNI HIDROGEOLOŠKI PROFIL 1-1'
1:300 000 / 10 000
1
1'
Bezdan
Bajmok
Subotica
Palić
Kanjiža
Tisa
Q+Pl
Q+Pl
Q+Pl
M?
M?
M?
M?
M?
M?
M?
M?
Pz
Pz
Pz
1
2
3
4
5
Kartirane jedinice
Les
Pesak
Glina
Pl+Q
Pesak
Glina
Laporci
Peščar
Miocen - M
Krečnjak
Eruptivne stene andezit-bazalti
Miocen - M
Škriljci
Pz
Hidrogeološke oznake
Izdan sa nivoom pod pritiskom-hidrogeološki kompleks 'A'
Izdan sa nivoom pod pritiskom-hidrogeološki kompleks 'B'
Uslovno bezvodni delovi terena
Standardne oznake
Normalna granica
Pretpostavljena granica
Pretpostavljen rased
Transgresivna granica nesigurnog karaktera

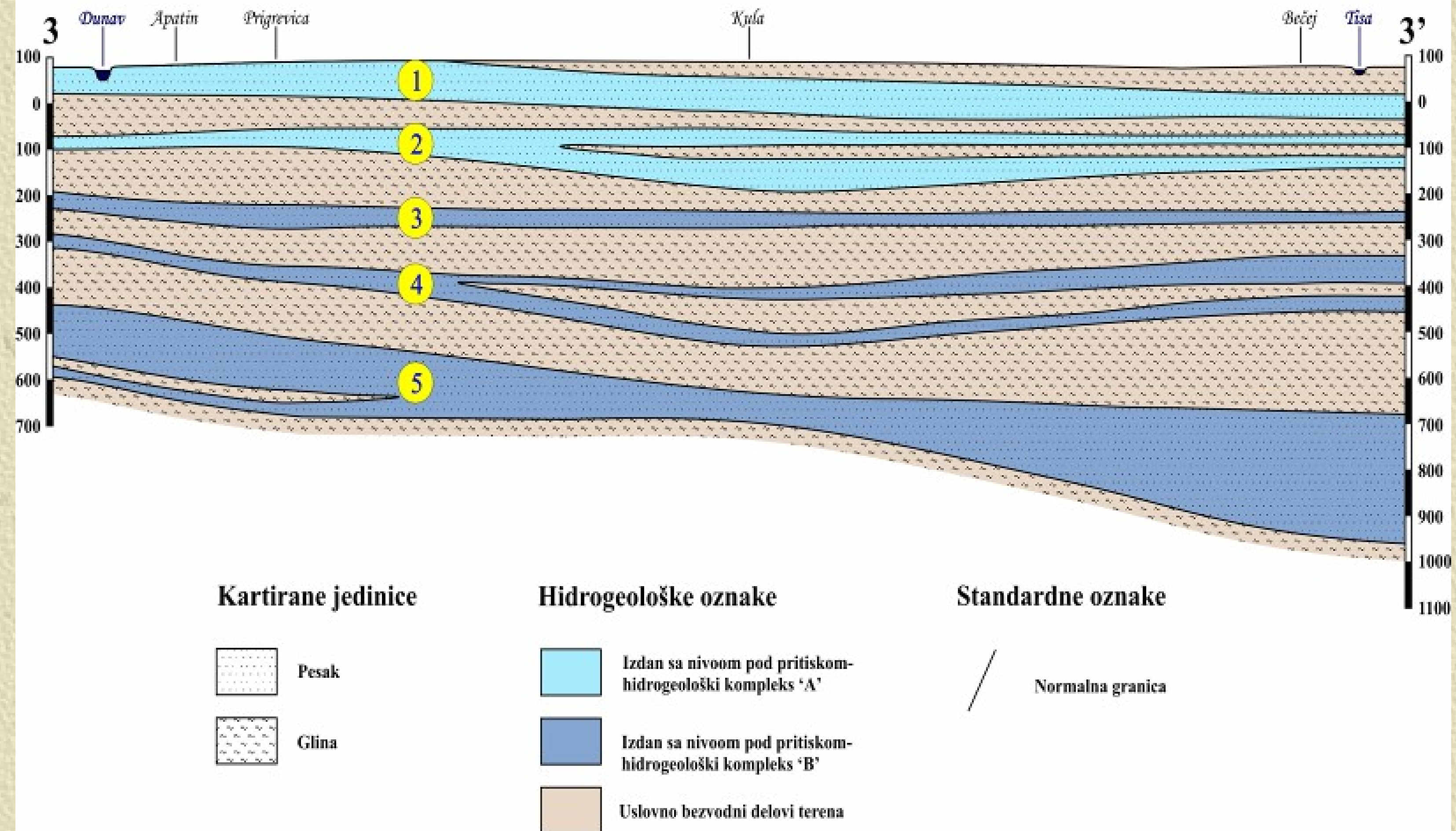
REGIONALNI HIDROGEOLOŠKI PROFIL 2-2'

1:300 000 / 10 000



REGIONALNI HIDROGEOLOŠKI PROFIL 3-3'

1:300 000 / 10 000



• **Processing Modflow has been used to forecast the effects of groundwater extraction under different scenarios for the next 15-20 years.**

•**The regional model covers the studied area of 135 km x 145 km. Discretization of the flow field is generated by primal cell dimensions of 1000m x 1000m, which are reduced in zones of groundwater sources to 125m x 125m. In total 642 100 cells**

•**The hydrodynamical model was conceived and built as a multi-layer model with ten layers (five water-bearing and five semi-permeable).**

•**Hydraulic parameters are approximated on the basis of provided documentation as representative values for the whole layer.**

•**Several problems had to be solved before completing the model: different reference systems, different geological nomenclature, missing transboundary aquifer maps, different well density, materials in native languages, deficient hydraulic parameters, absence of monitoring data out of the main sources, etc.**

1. Rainfall

Novi Sad	MESEC:	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
TEMPERATURA °C	Srednja maksimalna	2.5	5.7	11.5	17.2	22.2	25.2	27.2	27.2	23.7	18	10.3	4.5
	Srednja minimalna	-4.4	-2.3	1.2	5.8	10.6	13.6	14.7	14.2	11.2	6.3	2.2	-1.9
	Normalna vrednost	-1	1.5	6	11.4	16.6	19.6	21.1	20.6	16.9	11.5	5.9	1.2
RELATIV. VLAGA (%)	Prosek	85.5	80.9	72.9	68.4	67.9	69.8	67.2	68.6	72.2	74.6	82.7	86.6
PADAVINE (mm)	Sr. mesečna suma	37.8	34.8	40.7	46.8	56.9	82.5	61.2	55.3	35.9	34.8	45.9	44.2

Kikinda	MESEC:	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
TEMPERATURA °C	Srednja maksimalna	1.8	5.1	11.3	17.1	22.3	25.2	27.2	27	23.6	17.7	9.7	3.8
	Srednja minimalna	-4.7	-2.3	1.2	5.9	10.6	13.6	14.6	14.2	11	6.1	2	-1.9
	Normalna vrednost	-1.5	1.2	5.9	11.4	16.6	19.6	21.1	20.4	16.7	11.3	5.5	0.9
RELATIV. VLAGA (%)	Prosek	85.3	81.6	73.1	68.3	67.7	69.2	66.9	69.1	71.3	74.6	83.4	87
PADAVINE (mm)	Sr. mesečna suma	34	31.4	35.1	46.3	52.7	75.7	51.3	50.8	37.4	31.3	43.6	45.6

Sombor	MESEC:	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
TEMPERATURA °C	Srednja maksimalna	2,1	5,5	11,4	17,1	22,1	25,1	27,1	26,9	23,4	17,8	9,7	4,1
	Srednja minimalna	-4,8	-2,4	0,8	5,4	10,1	13,2	14,2	13,6	10,2	5,4	1,6	-2,2
	Normalna vrednost	-1,3	1,3	5,7	11,1	16,3	19,3	20,7	20,0	16,2	10,9	5,3	0,9
RELATIV. VLAGA (%)	Prosek	85,2	81,4	73,9	69,1	68,2	69,4	69,1	71,2	74,8	76,5	83,7	86,5
PADAVINE (mm)	Sr. mesečna suma	37,1	31,7	35,8	51,0	56,9	79,0	60,7	51,8	37,4	36,8	51,8	43,5

Palić	MESEC:	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
TEMPERATURA °C	Srednja maksimalna	1.7	5	10.7	16.5	21.7	24.8	26.9	26.7	23.1	17.3	9.3	3.7
	Srednja minimalna	-4.7	-2.3	1.3	6	10.7	13.7	15	14.5	11.1	6.1	1.8	-2.1
	Normalna vrednost	-1.6	1.1	5.6	11.1	16.3	19.4	21	20.2	16.5	11	5.2	0.7
RELATIV. VLAGA (%)	Prosek	85.7	81.2	73.3	67.6	67.5	67.2	65	67.8	71.5	75.1	83.3	87.1
PADAVINE (mm)	Sr. mesečna suma	35.6	31.3	33.7	42.7	55	73.9	56.7	54	36.4	27.7	46.3	46

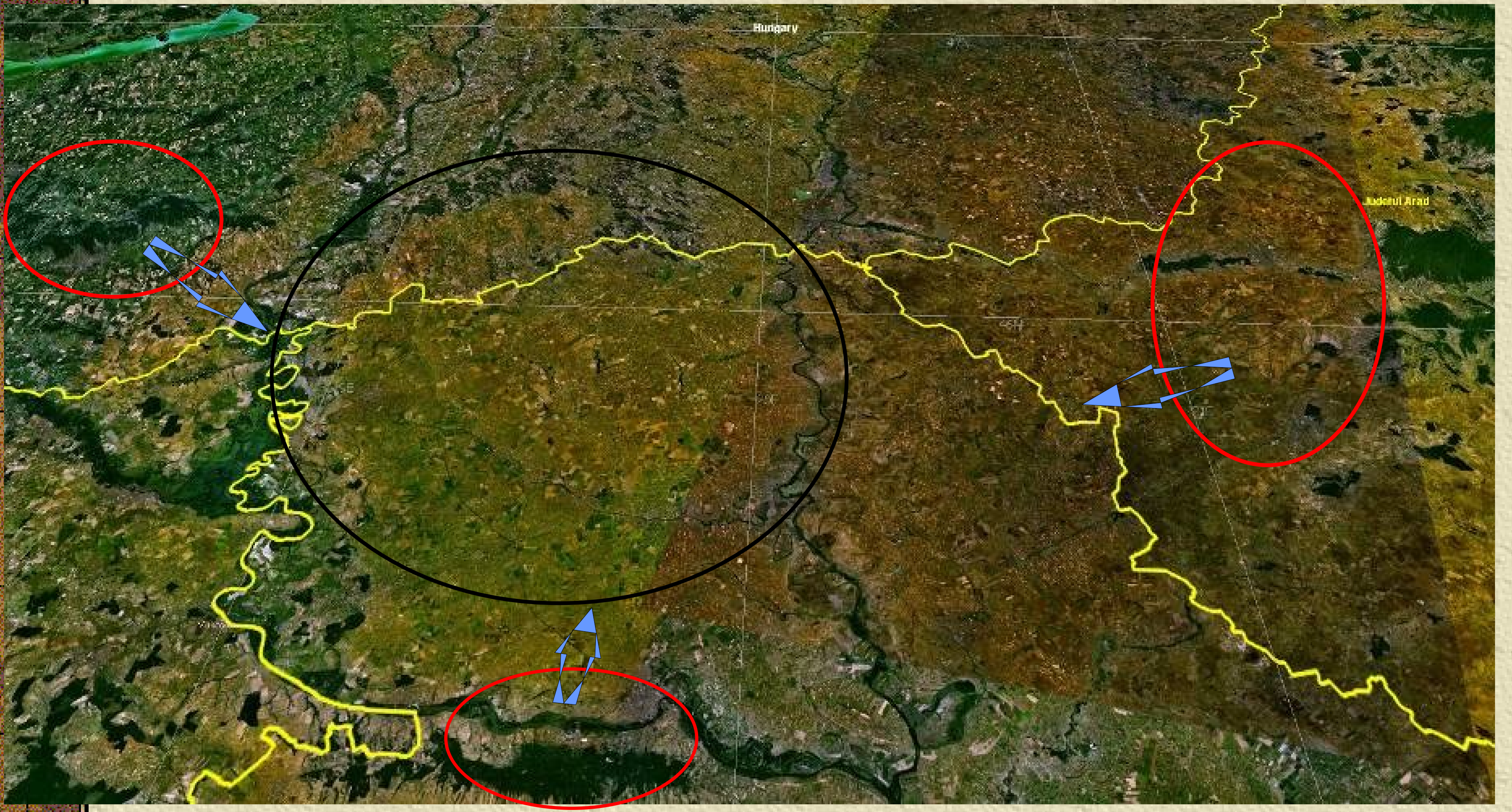
2. Danube and Tisza levels

Reka:	Dunav		Hidrološka stanica			Bezdan		period obrade 1946 - 2006 godina				
MESEC:	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Minimalna mesečna:	-63	-40	-14	-6	28	57	-20	-97	-86	-71	-77	-50
Srednja mesečna:	180	206	252	323	322	323	303	237	163	119	129	158
Maksimalna mesečna:	571	587	672	736	699	776	753	714	648	515	563	600

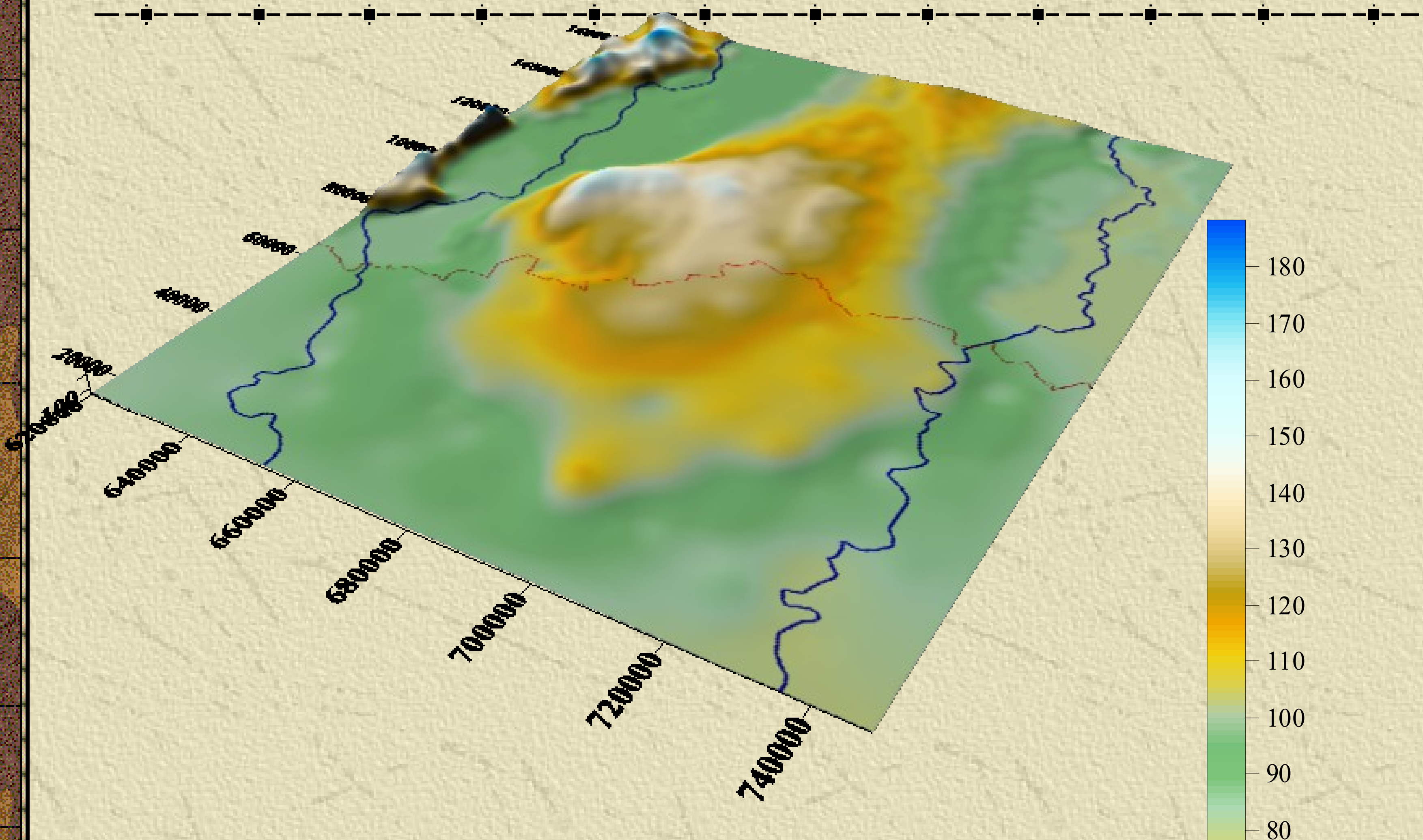
Reka:	Dunav		Hidrološka stanica			Bogojevo		period obrade 1946 - 2006 godina				
MESEC	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Minimalna mesečna	-25	12	33	55	80	100	28	-36	-40	-29	-30	-66
Srednja mesečna	209	232	281	358	365	368	345	281	209	168	179	200
Maksimalna mesečna	564	598	708	792	770	817	791	740	734	500	589	610

Reka:	Tisa		Hidrološka stanica			Senta		period obrade 1976 - 2006 godina				
MESEC:	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Minimalna mesečna:	92	154	156	179	203	164	151	206	144	86	81	146
Srednja mesečna:	277	297	373	475	408	324	289	275	255	253	264	271
Maksimalna mesečna:	672	764	831	926	884	698	626	714	492	507	663	649

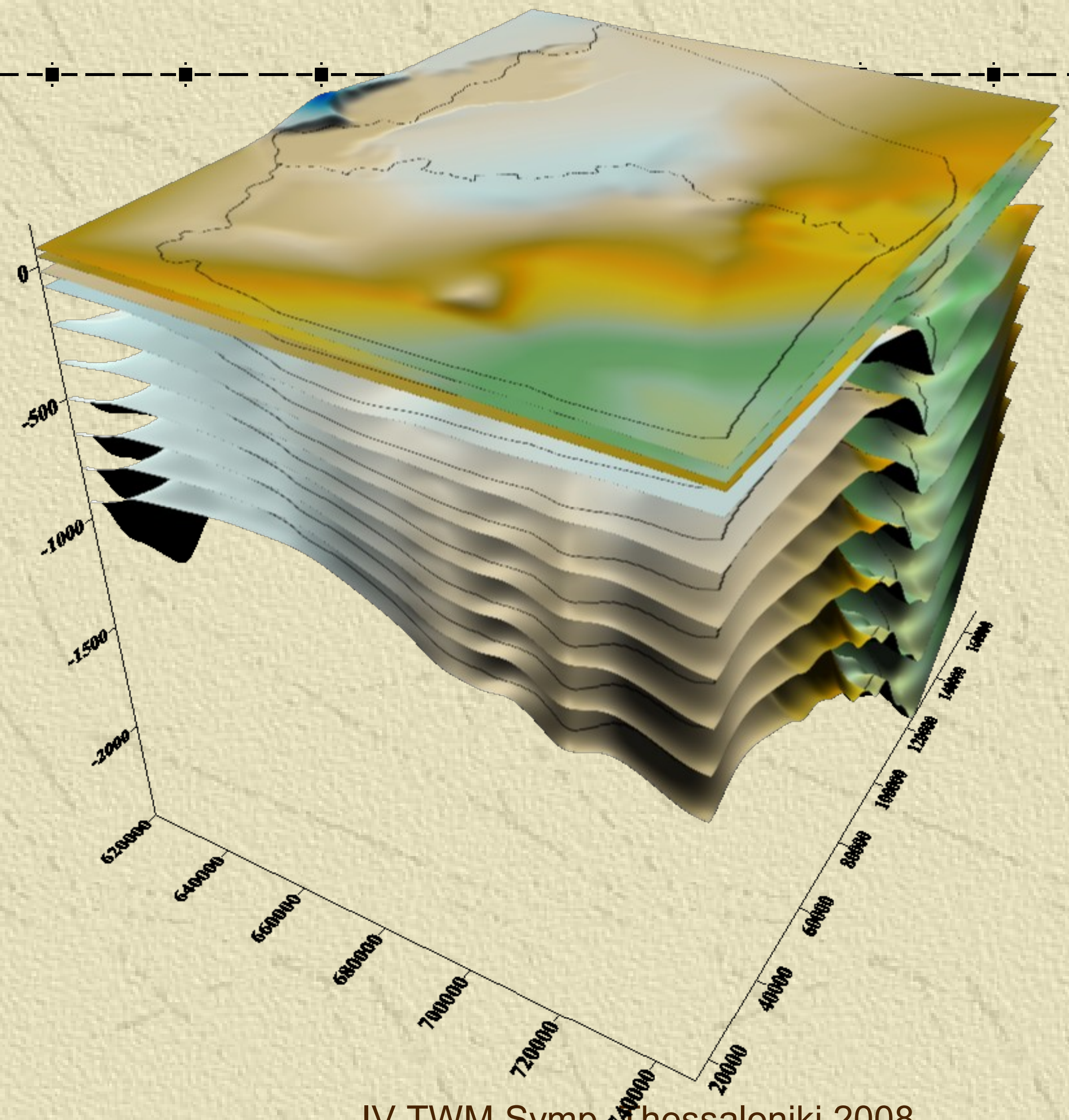
GHB (General Head Boundary)
(deeper layers recharge)



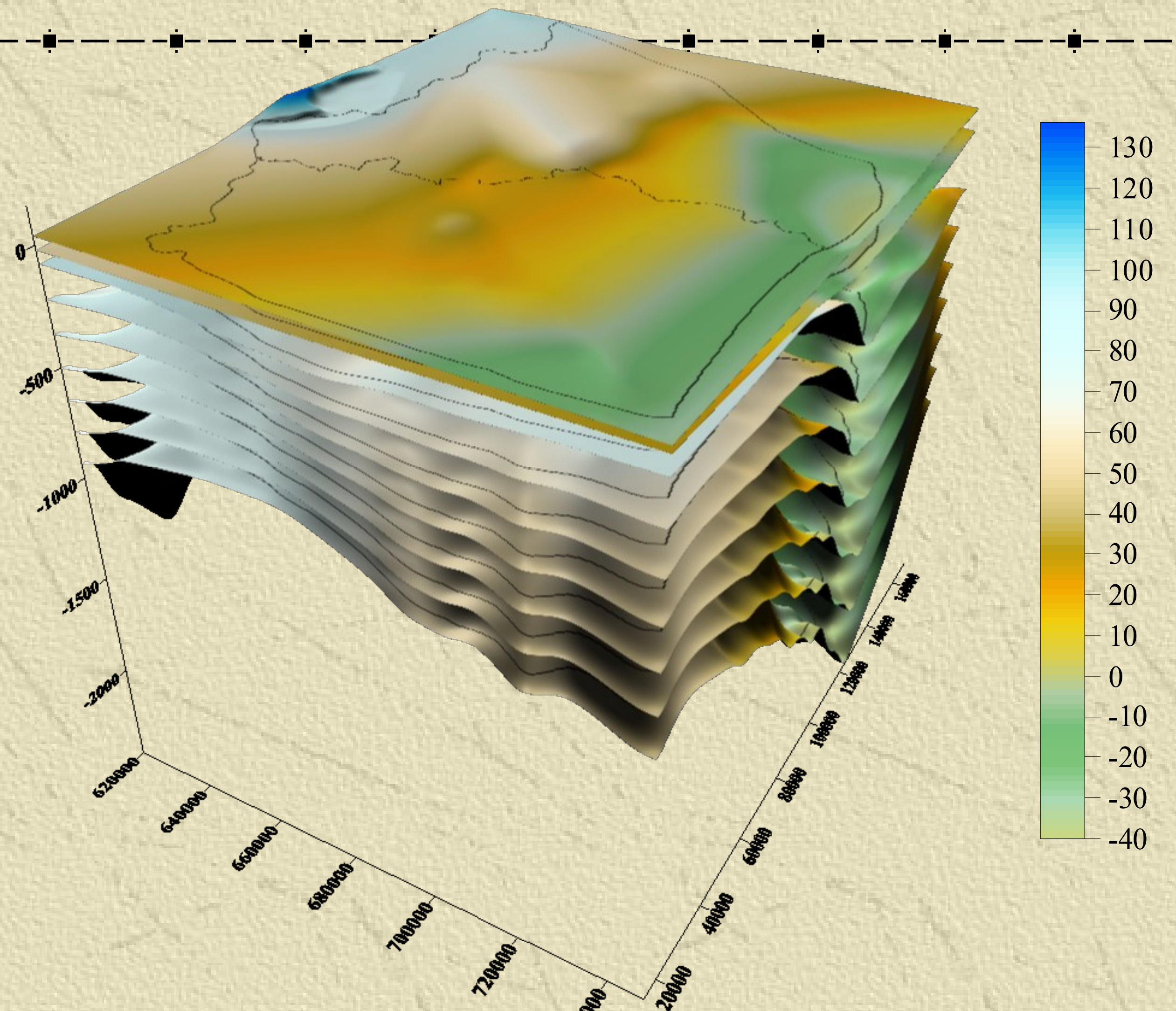
Terrain model



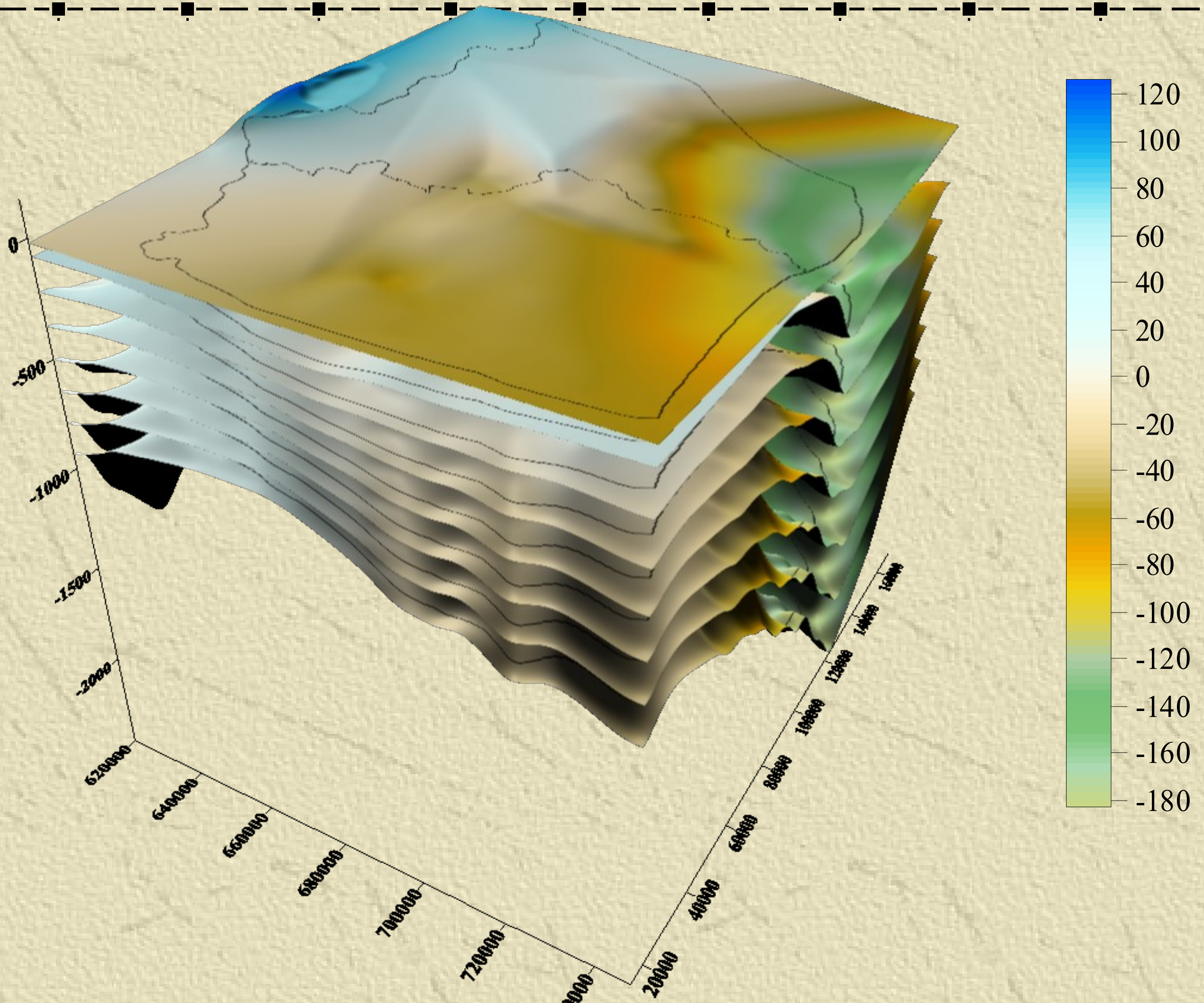
Aquifer surfaces (L2)



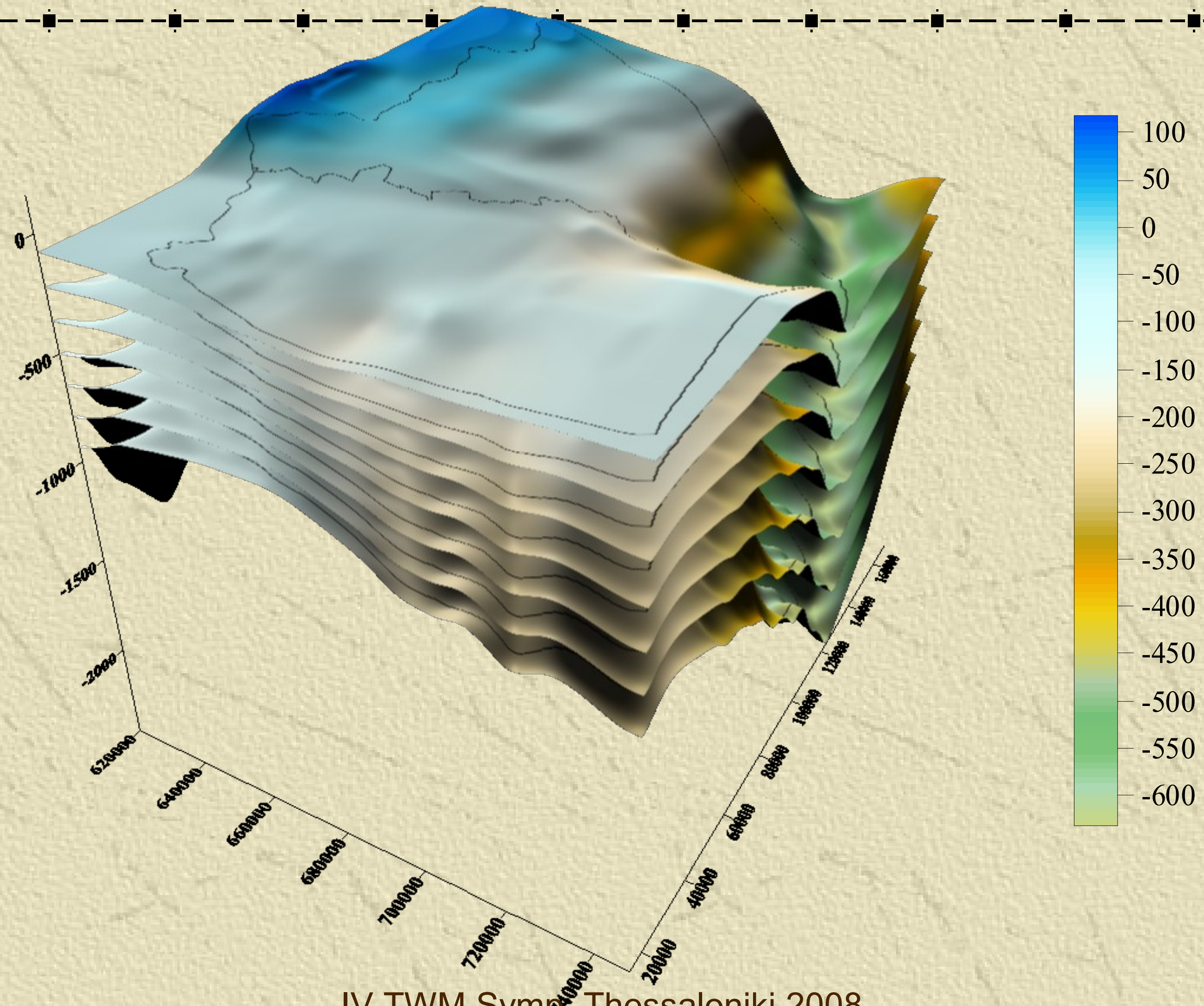
Aquifer surfaces (L3)



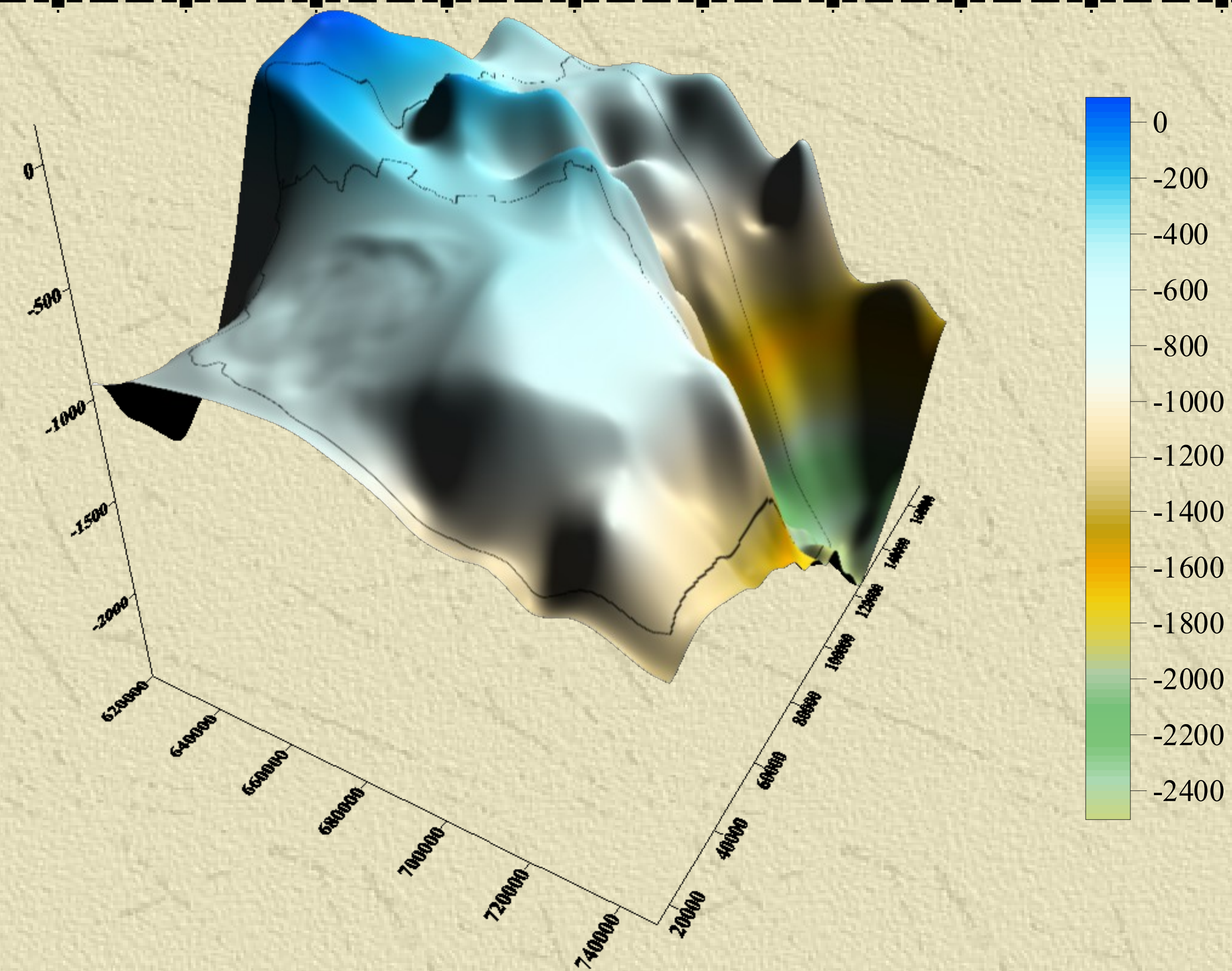
Aquifer surfaces (L4)



Aquifer surfaces (L5)



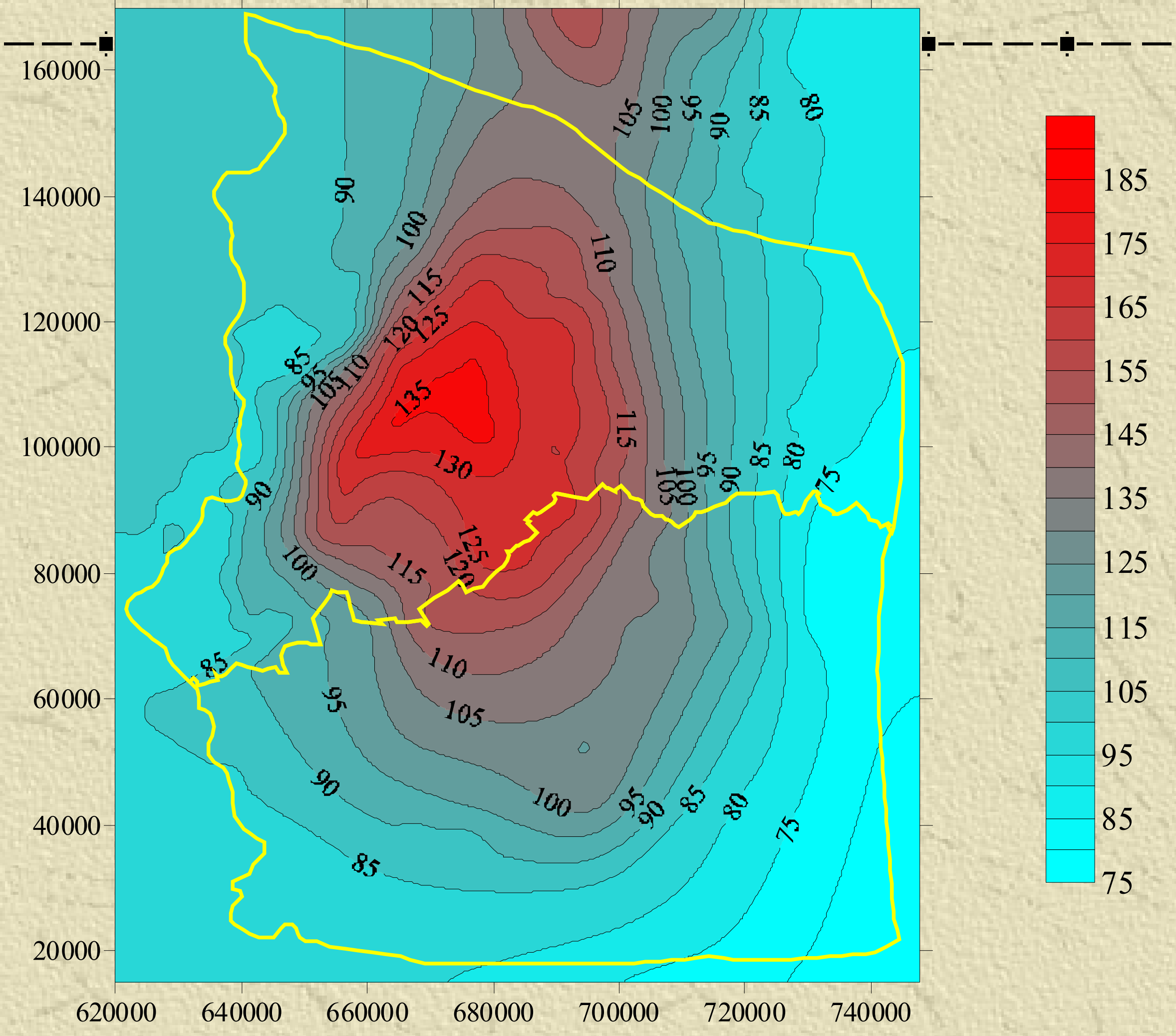
Upper Pannonian surface



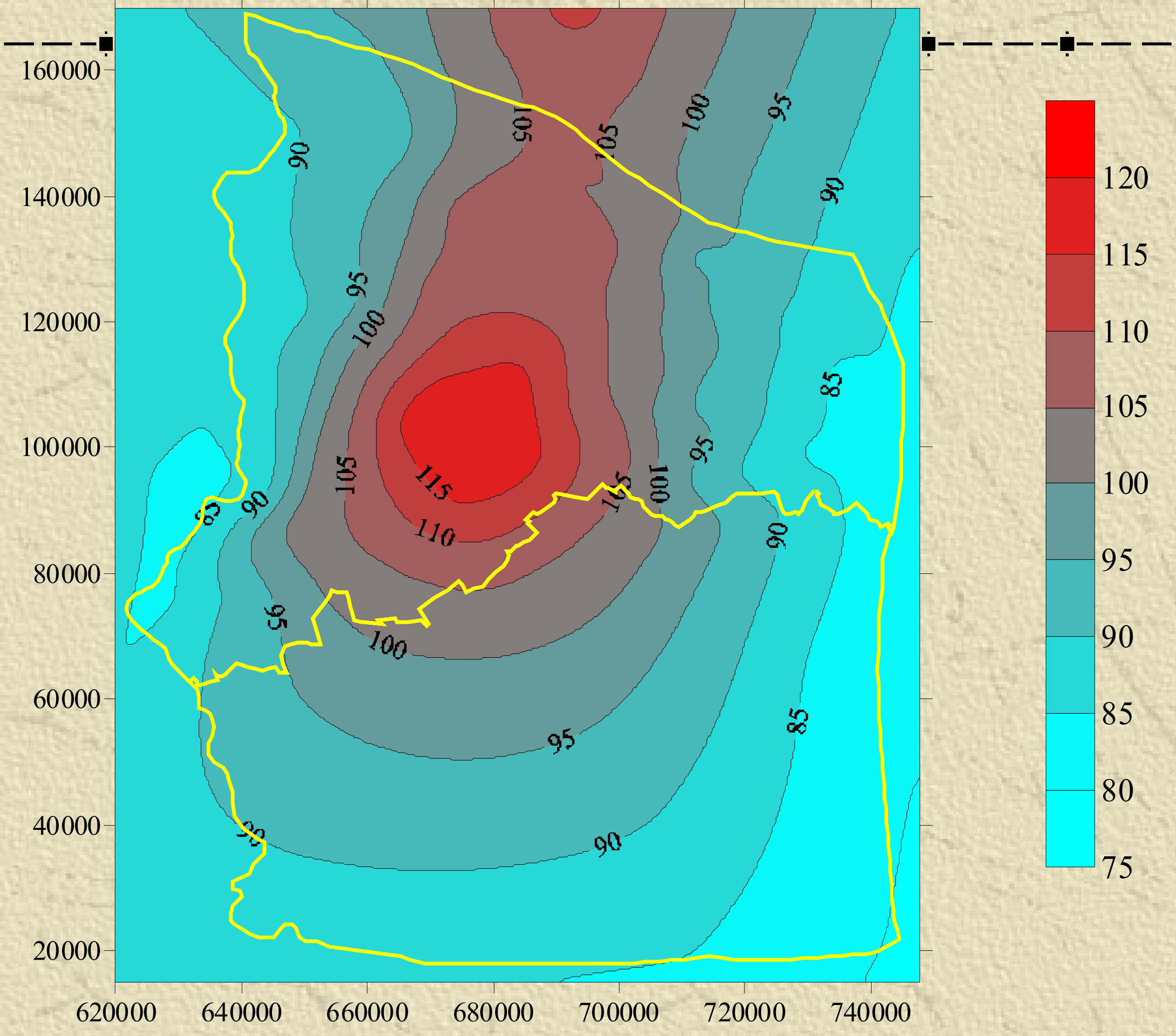
Average hydraulic parameters

Layer	Kh (m/day)	Kv (m/day)	Porosity
1	4	0.004	0.1
2	2	0.004	0.2
3	0.015	0.0002	0.1
4	10	0.4	0.2
5	0.05	0.0005	0.05
6	5	0.5	0.15
7	0.05	0.001	0.05
8	5	0.5	0.15
9	0.05	0.001	0.05
10	5	1	0.15

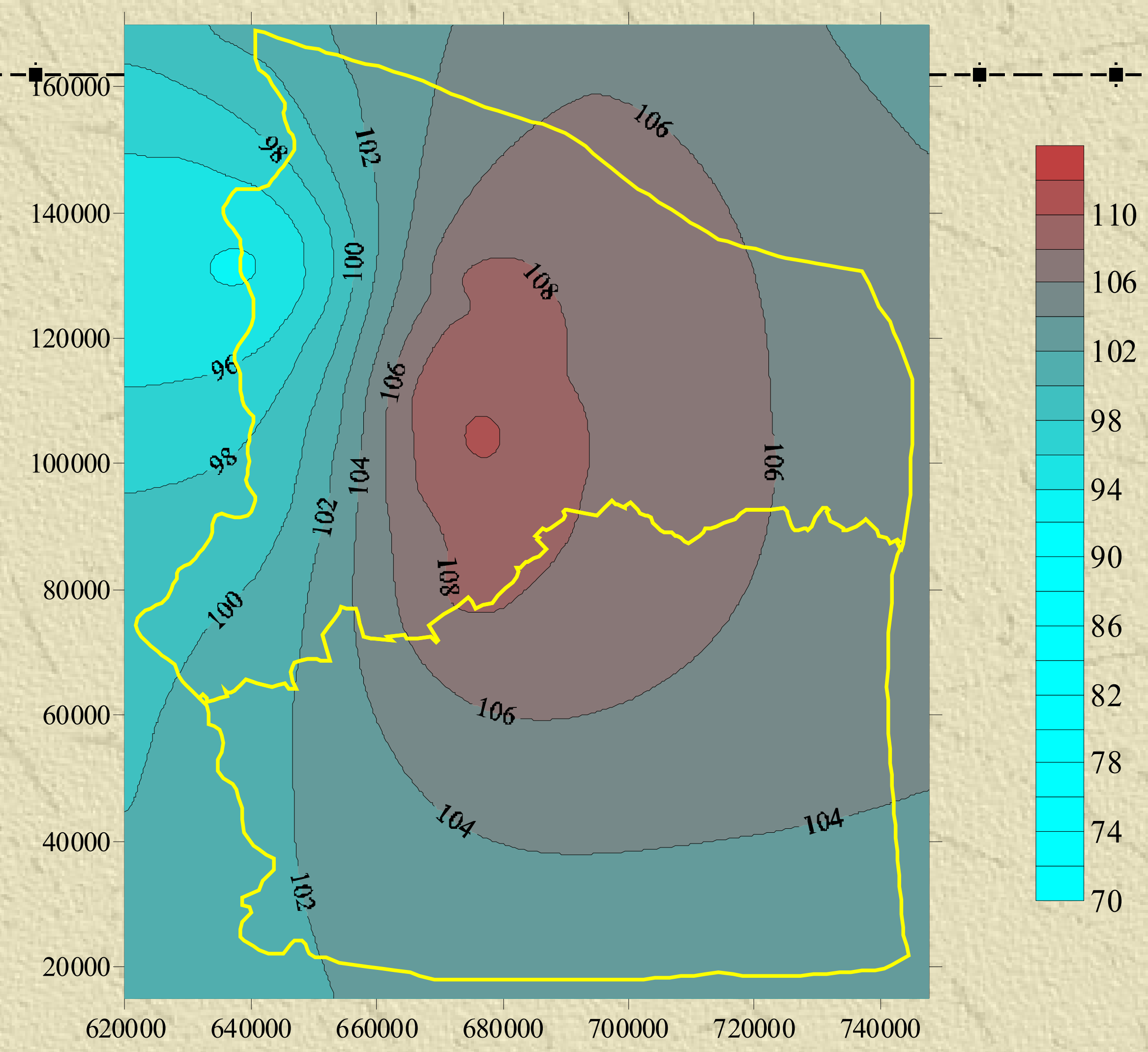
Water levels (L1-L2)



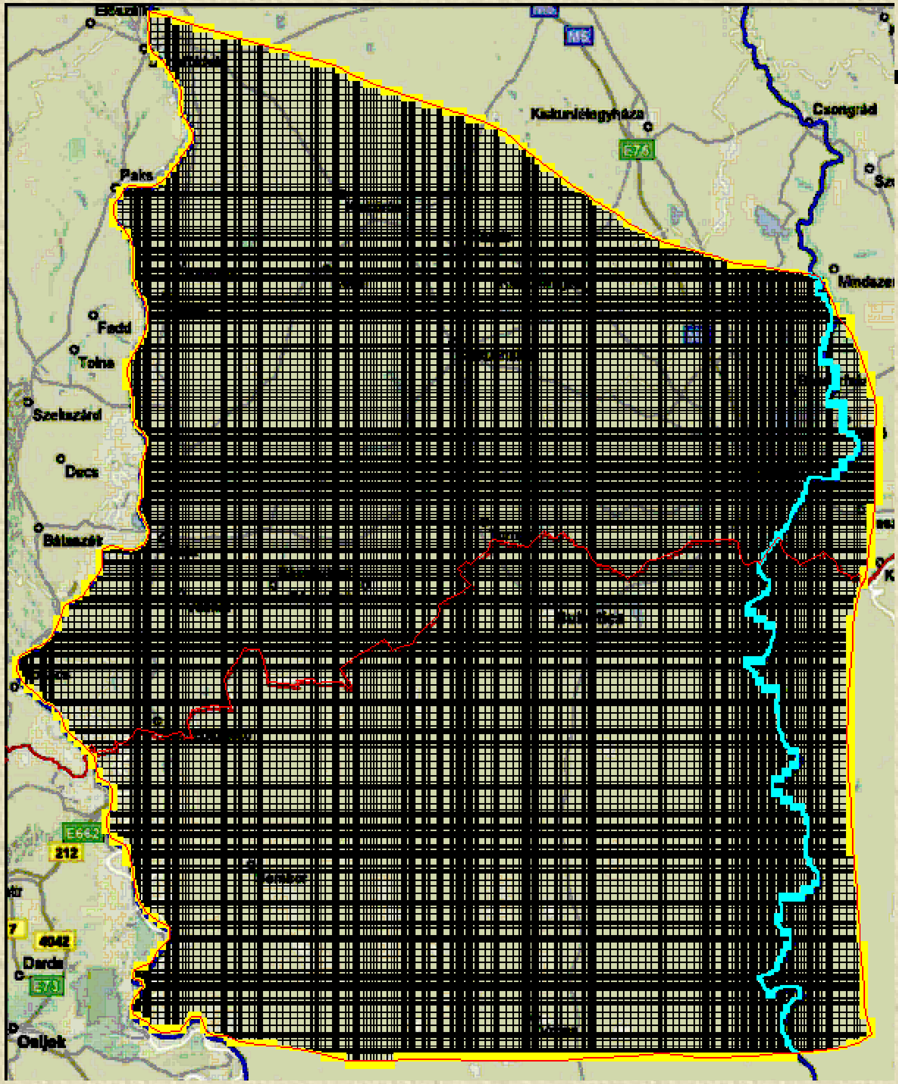
Water level (L4)



Water level (L10)

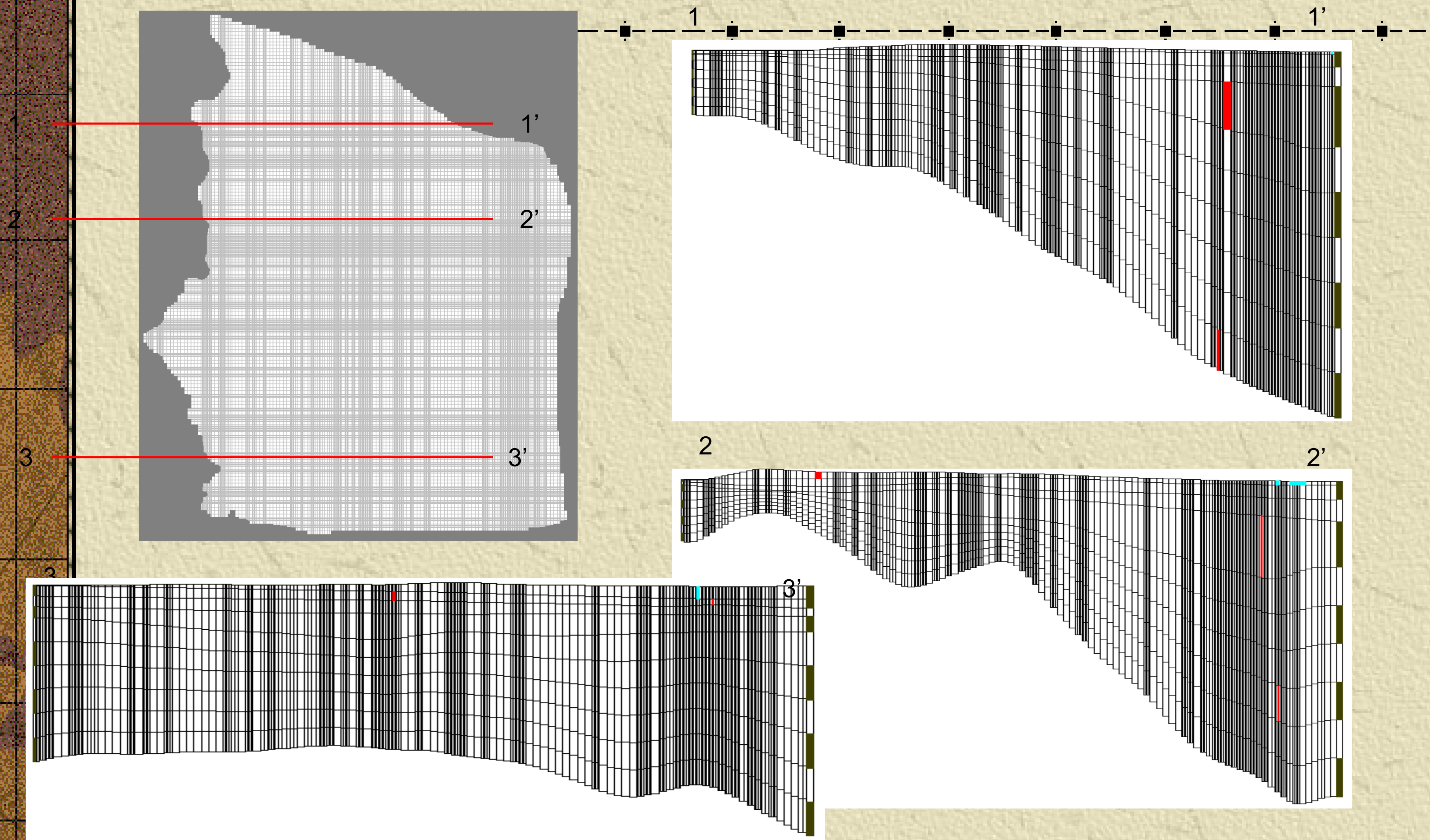


Mesh size and refinement

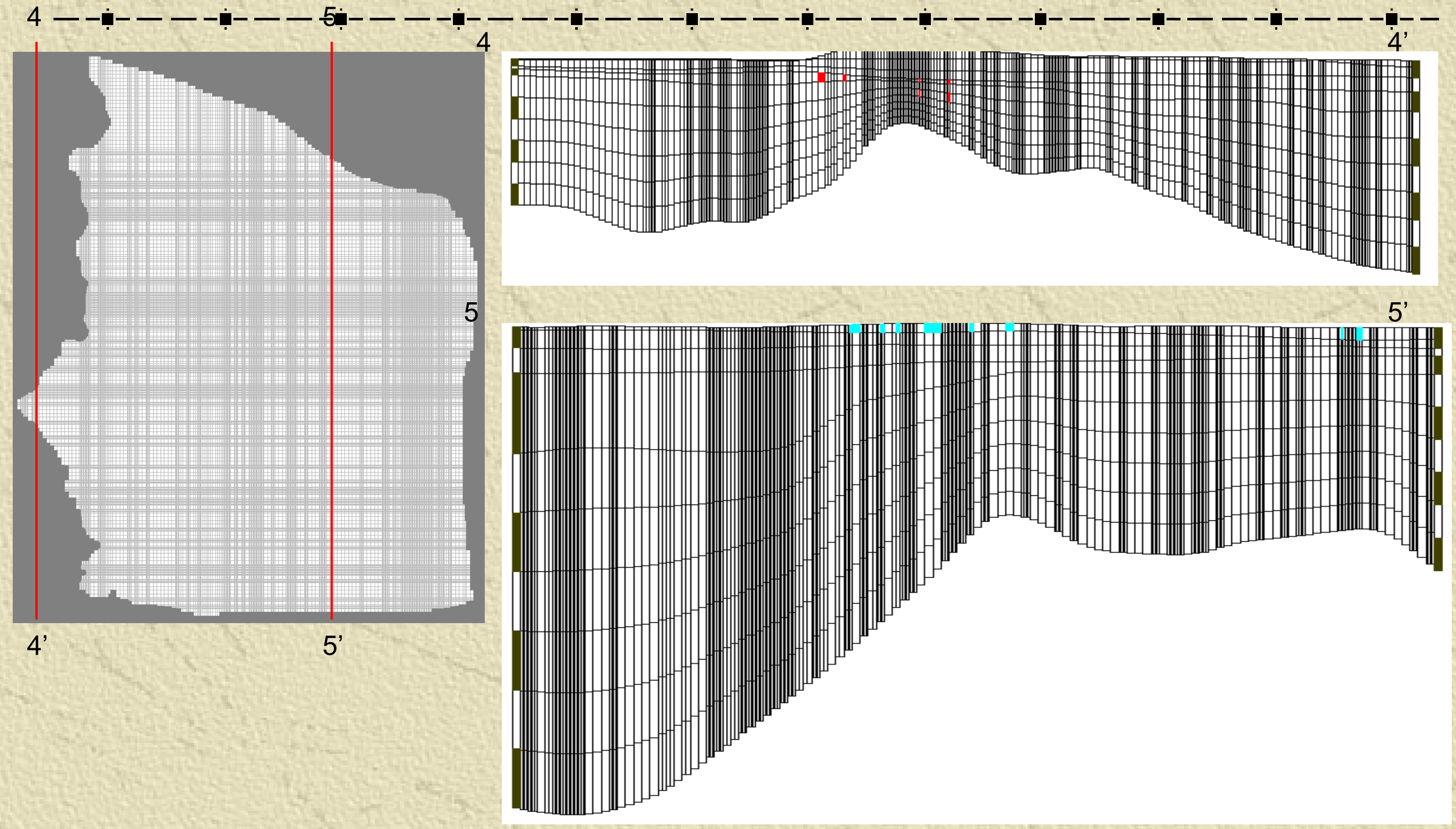


MODFLOW grid

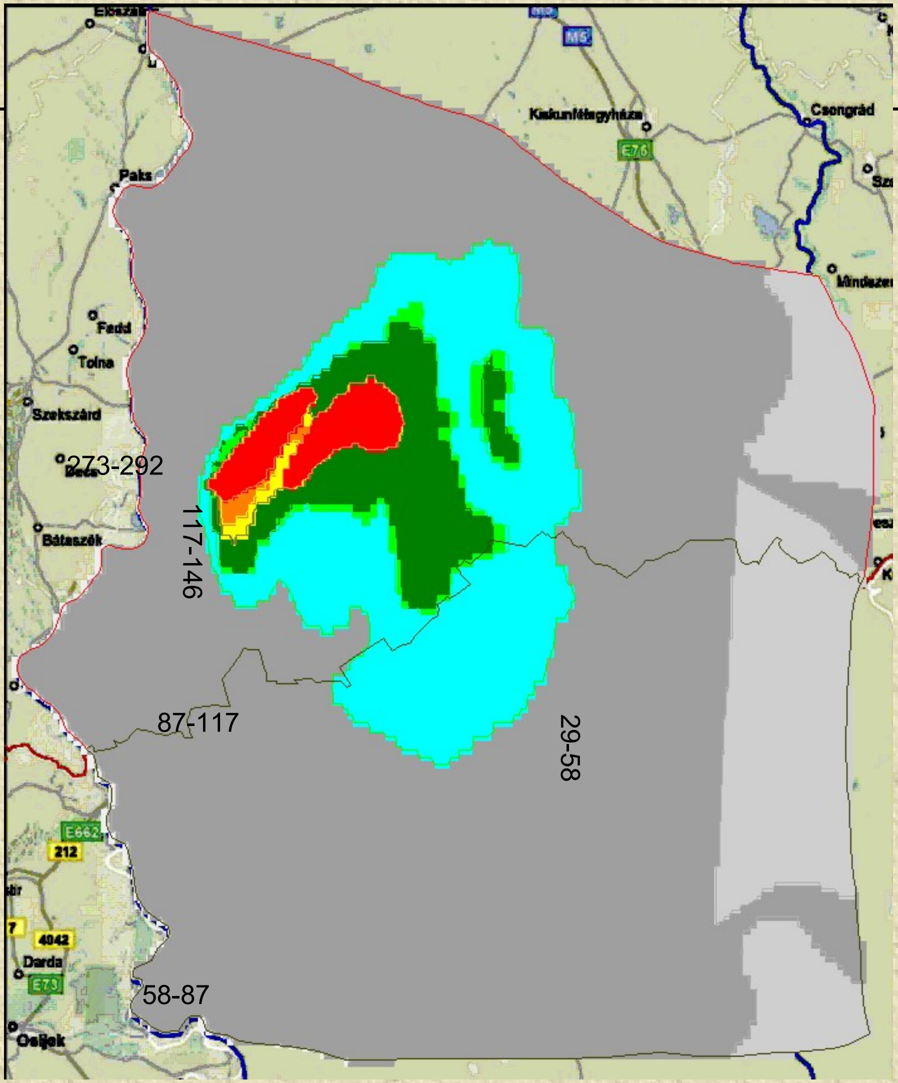
Horizontal cross sections



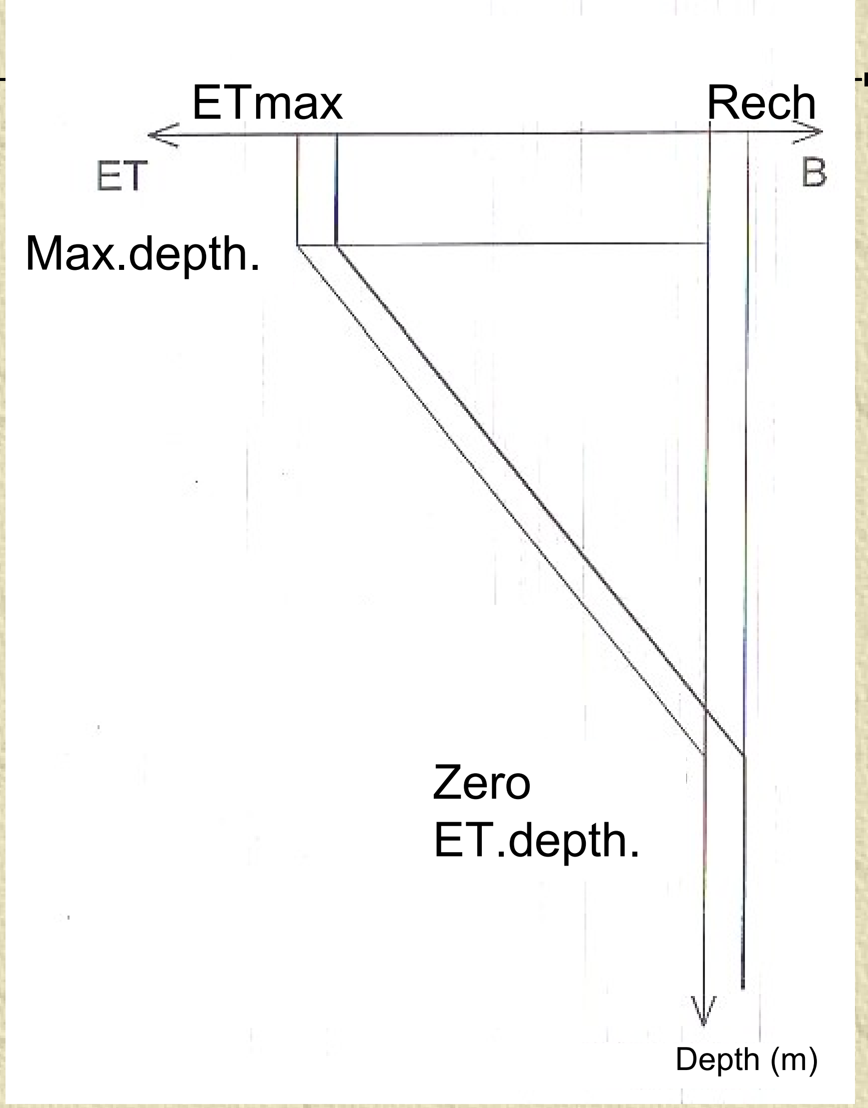
MODFLOW grid
Vertical cross sections



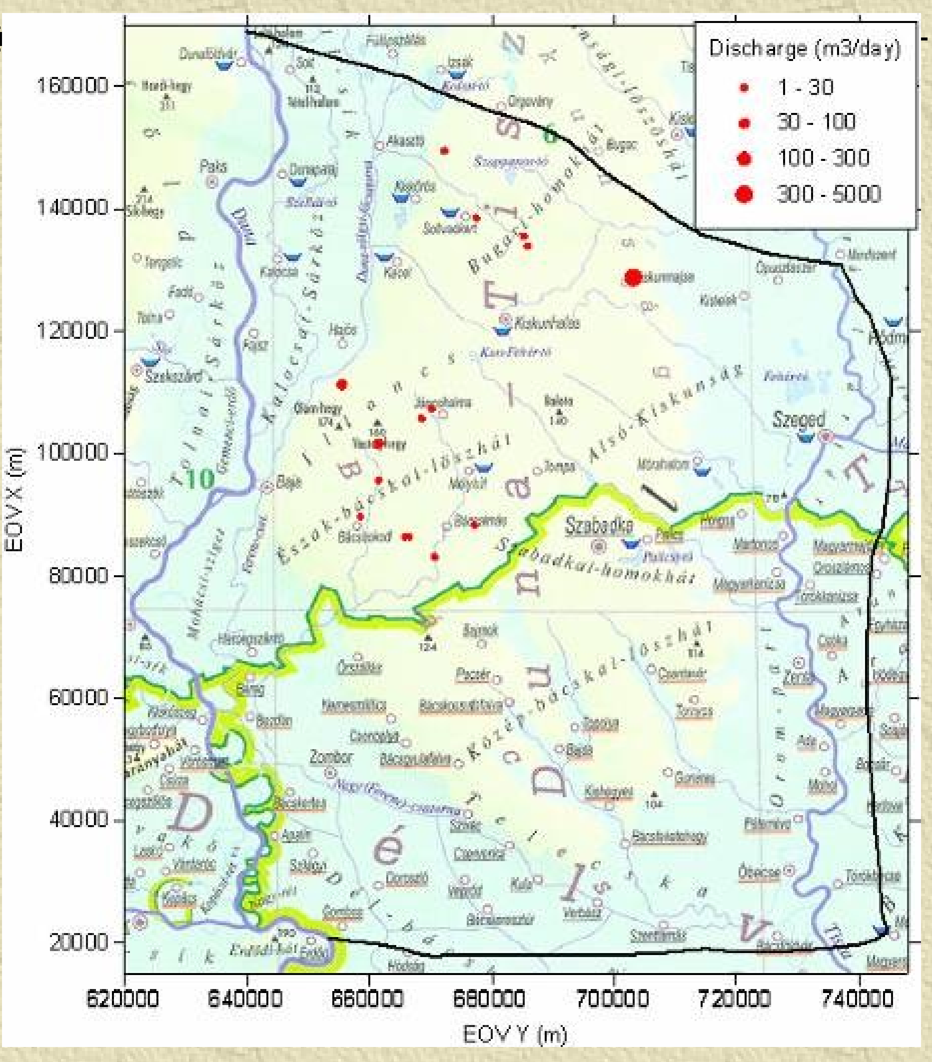
Recharge rates



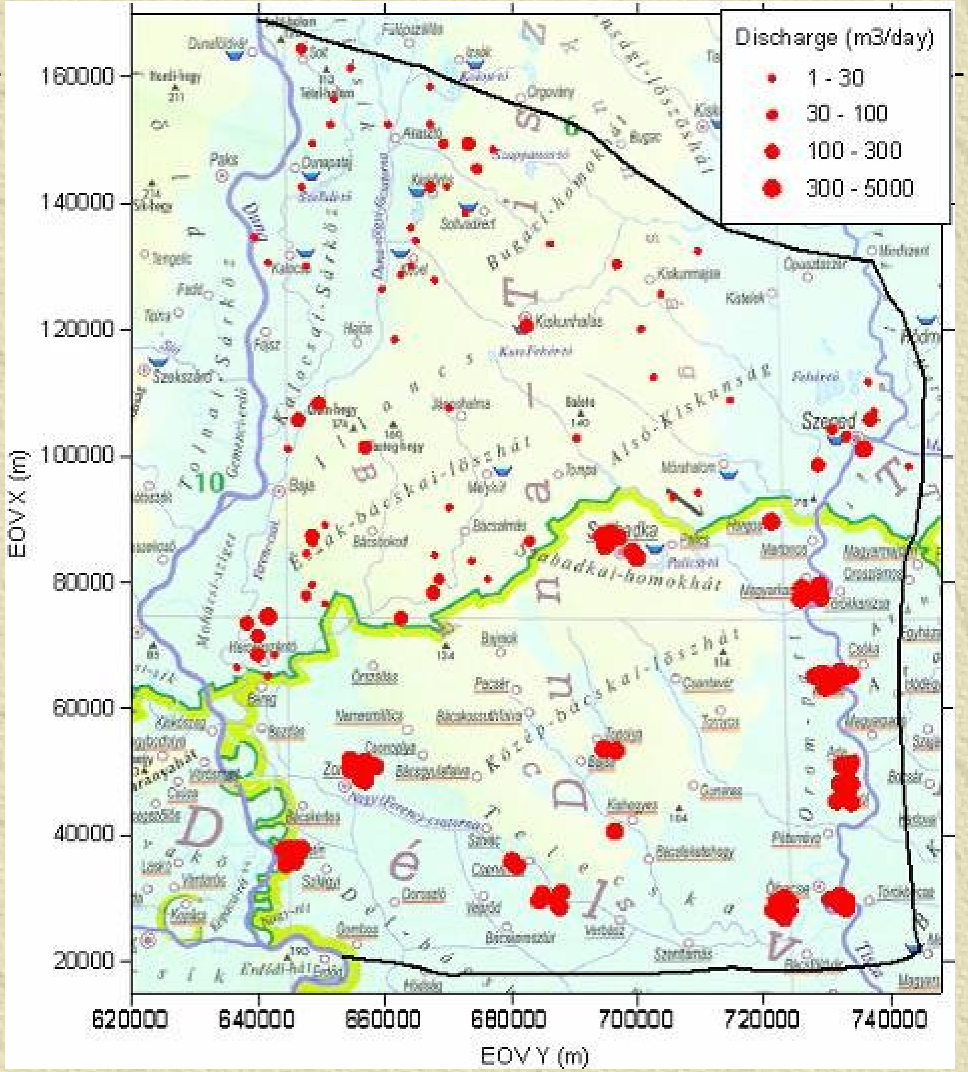
Evapotranspiration



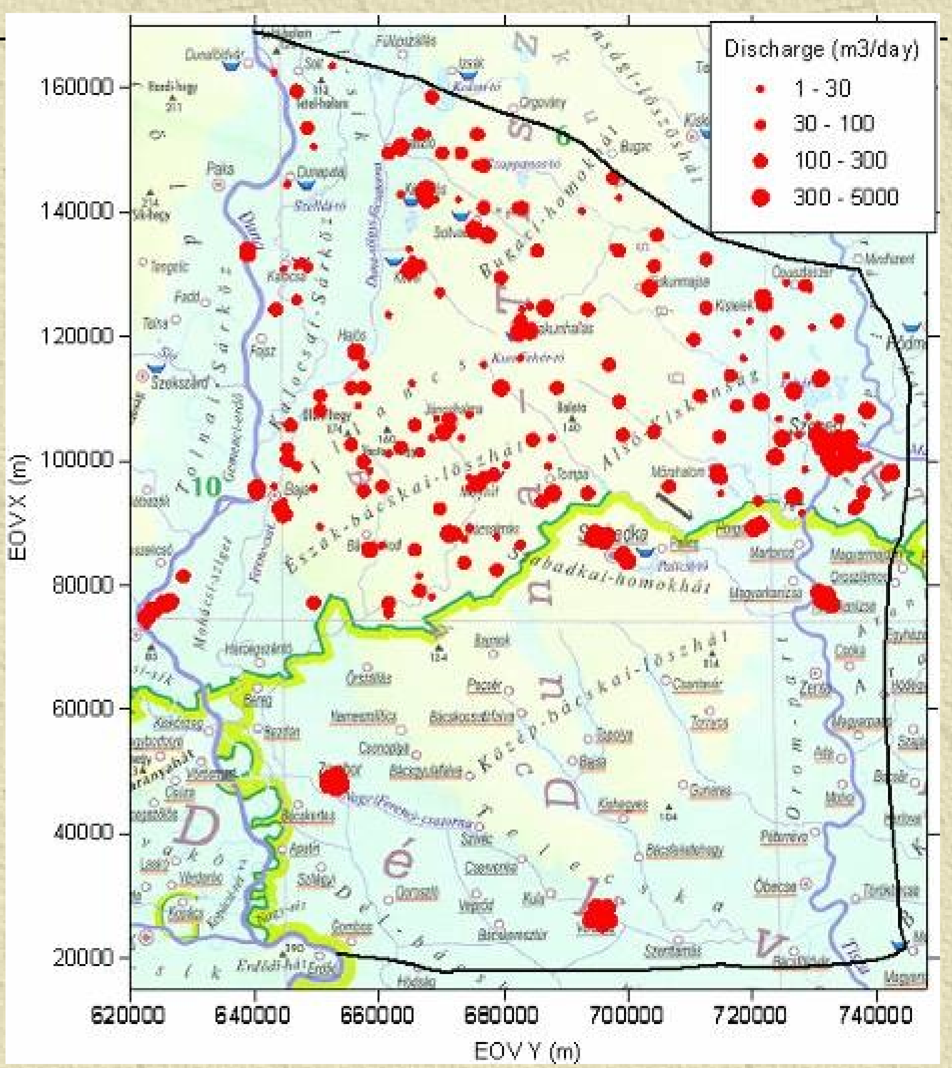
Discharge from L1



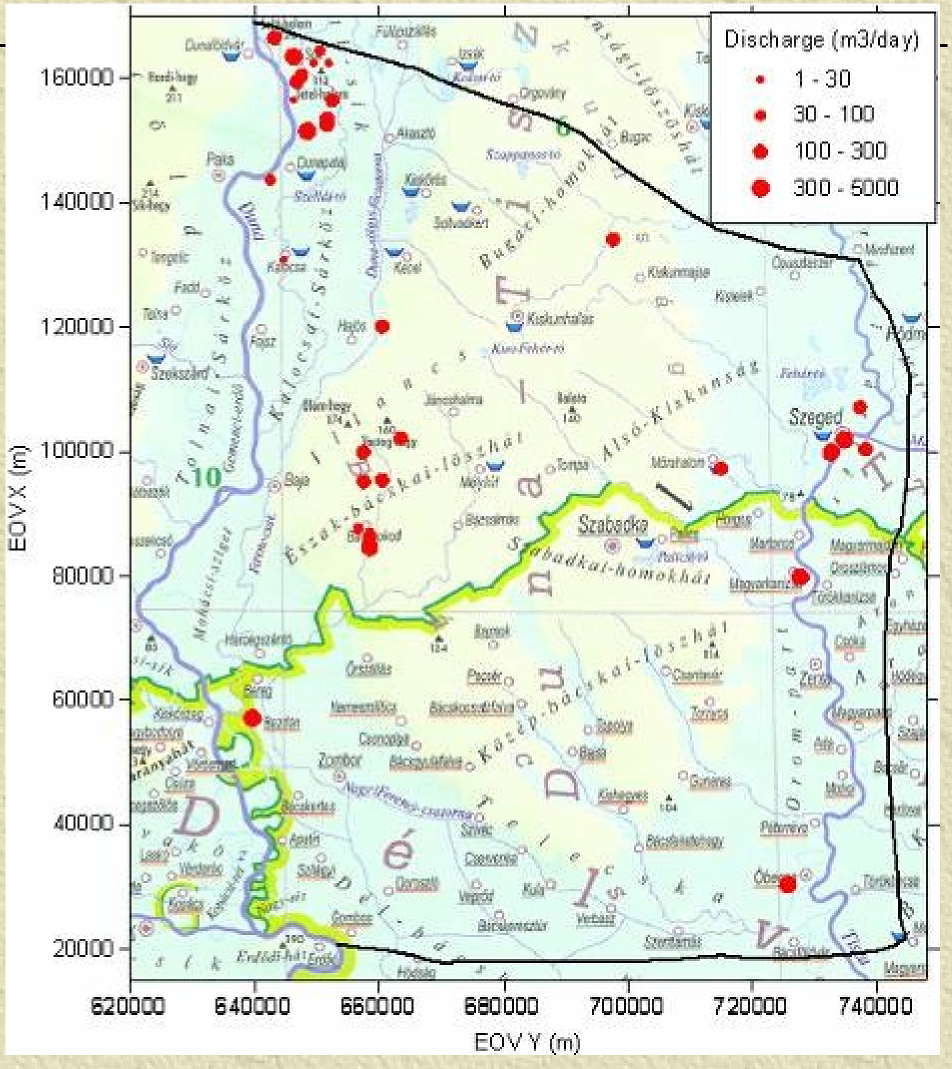
Discharge from L2



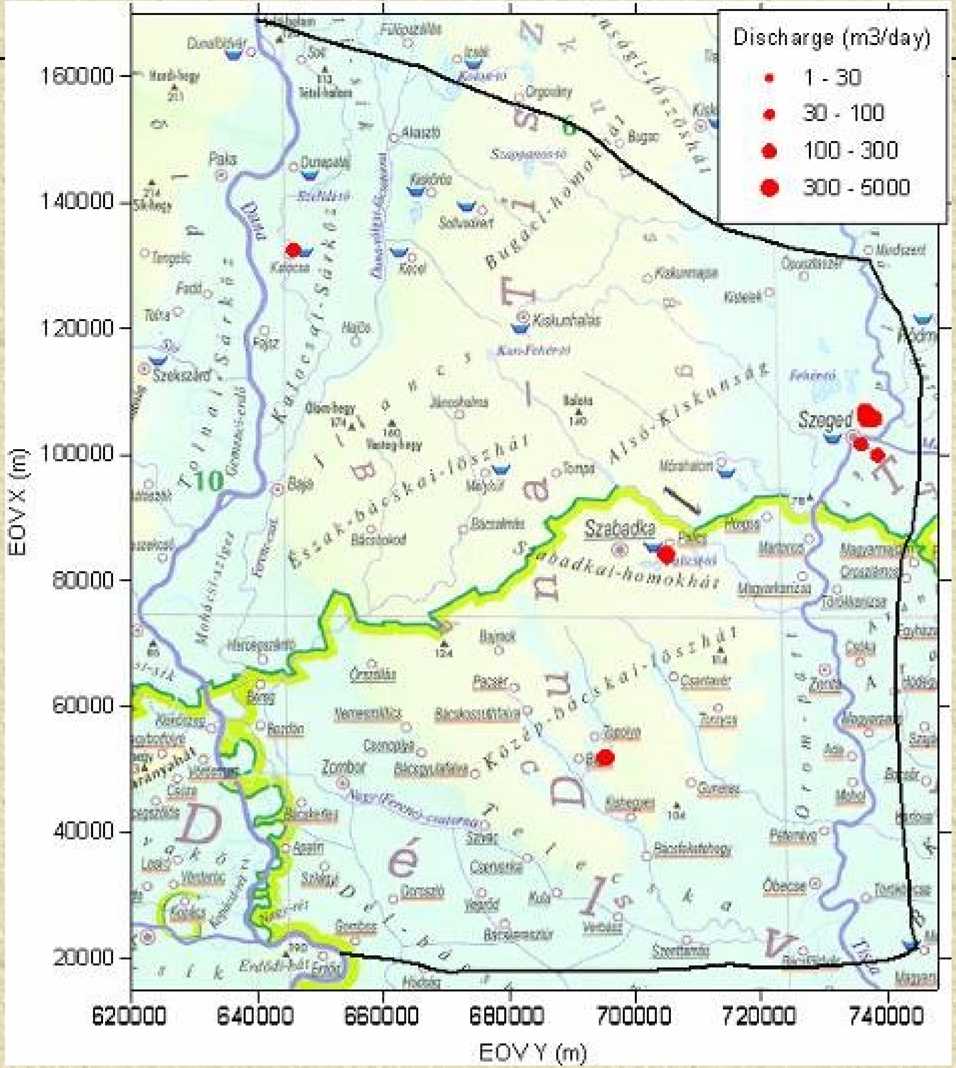
Discharge from L4



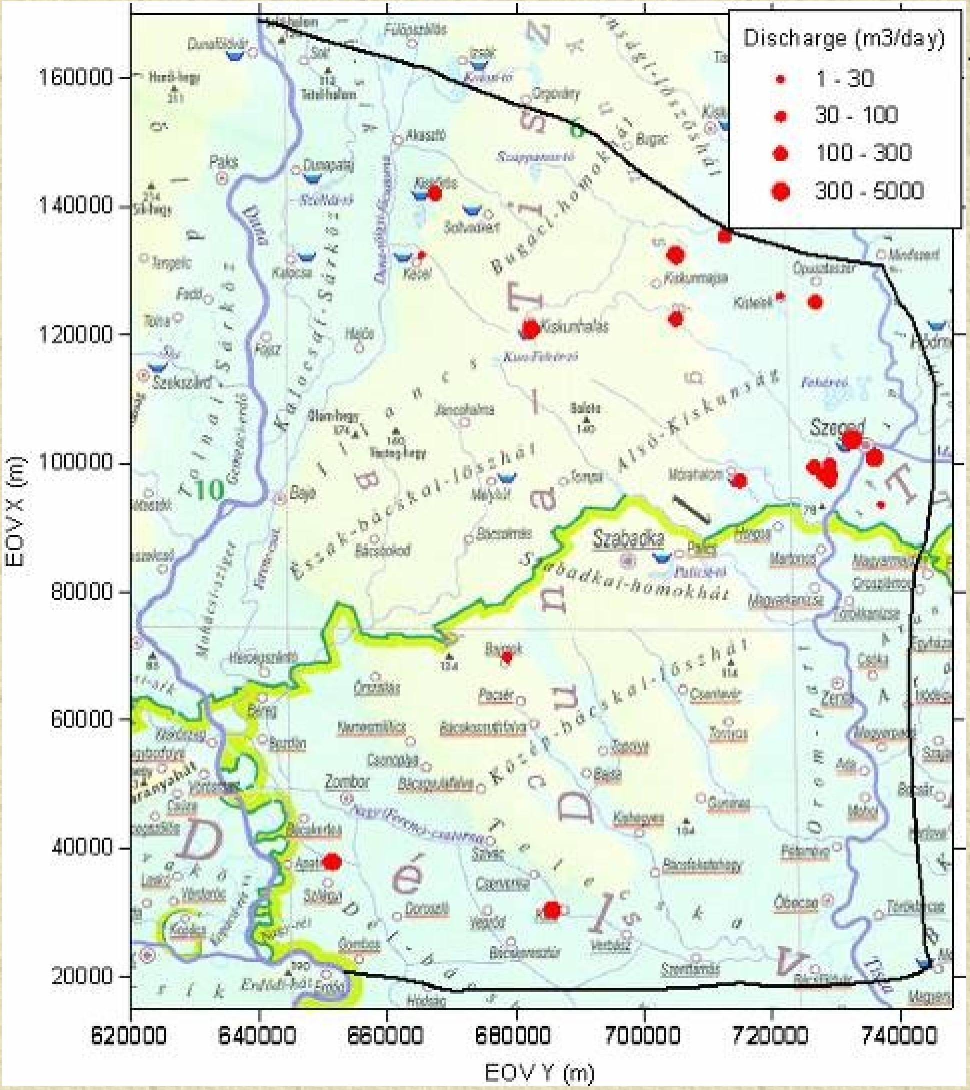
Discharge from L6



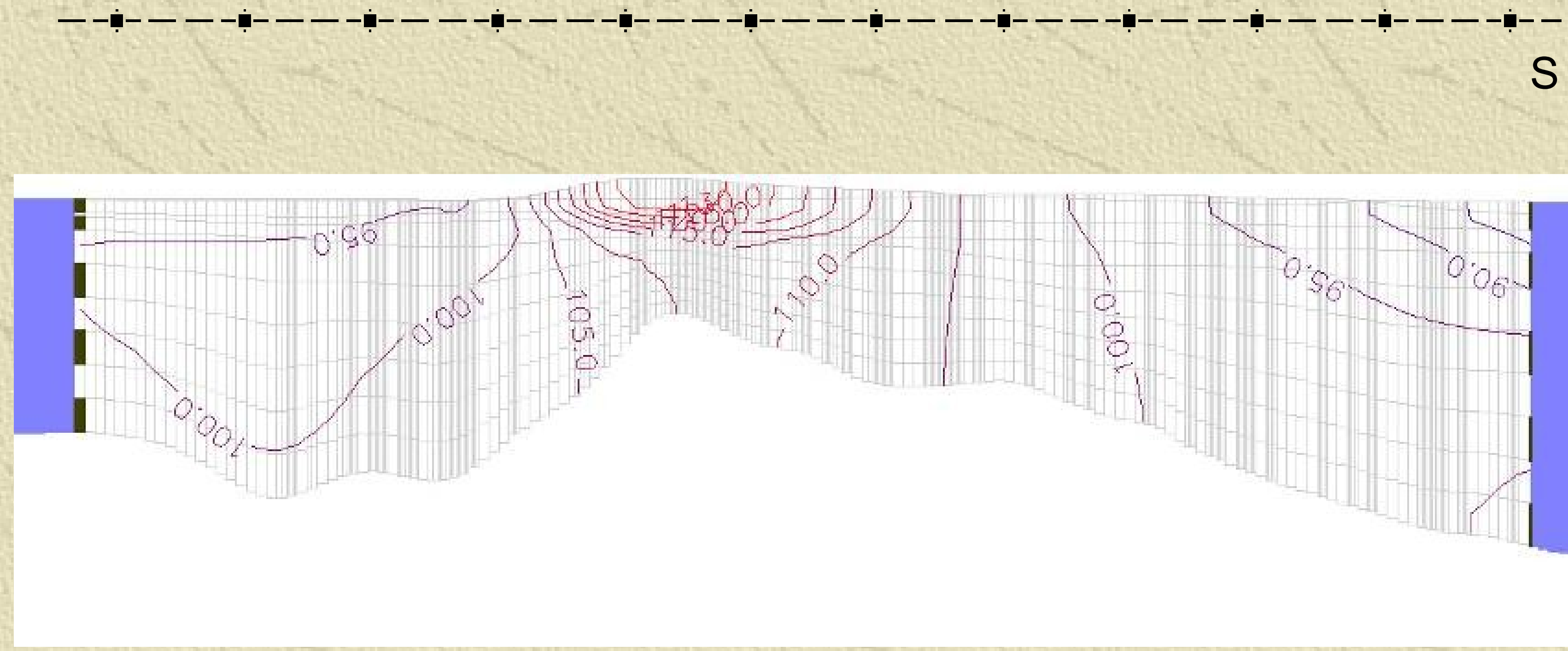
Discharge from L8



Discharge from L10

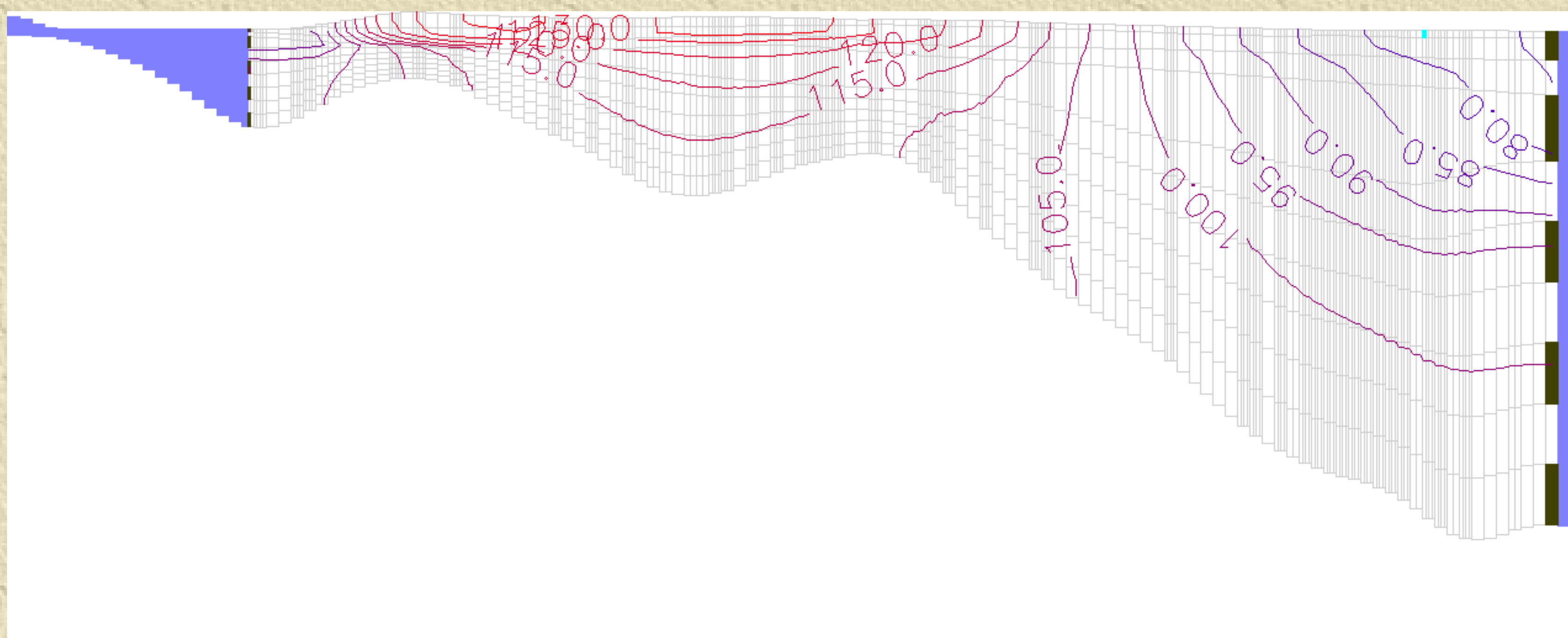


Calculated GW flow regime in a N-S cross section



Calculated GW flow regime in a W-E cross section

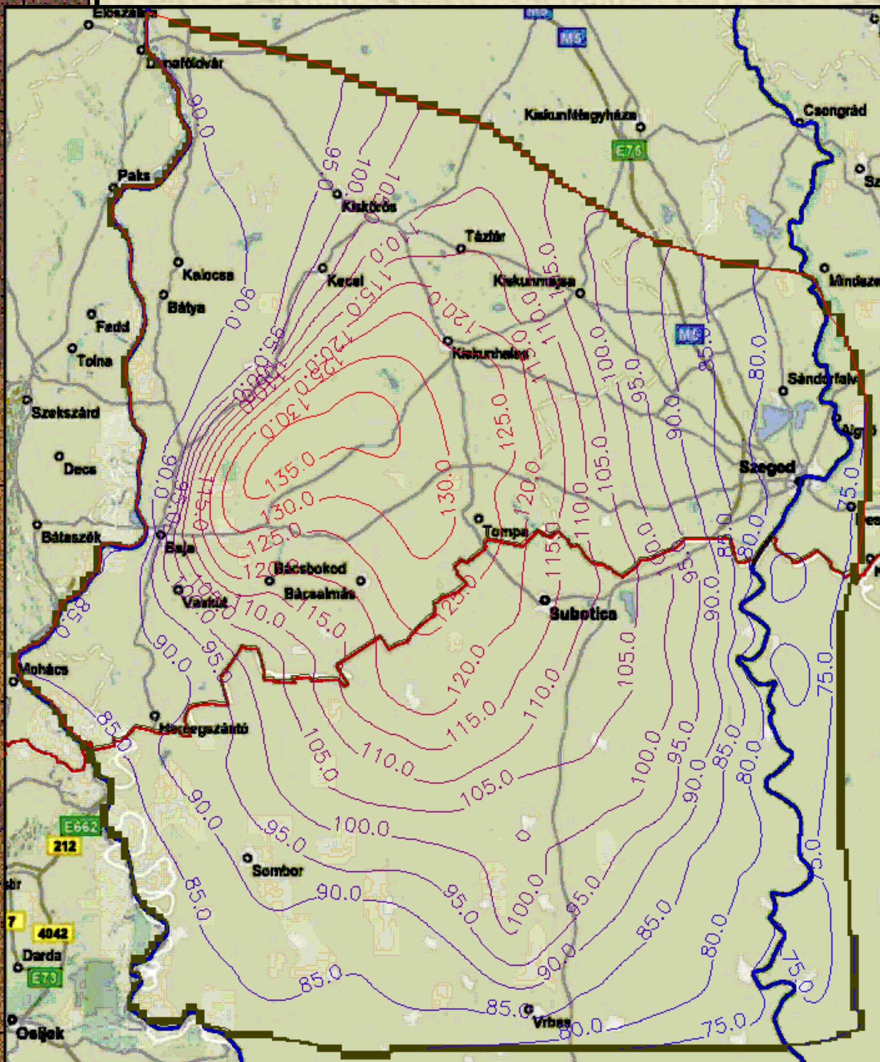
W E

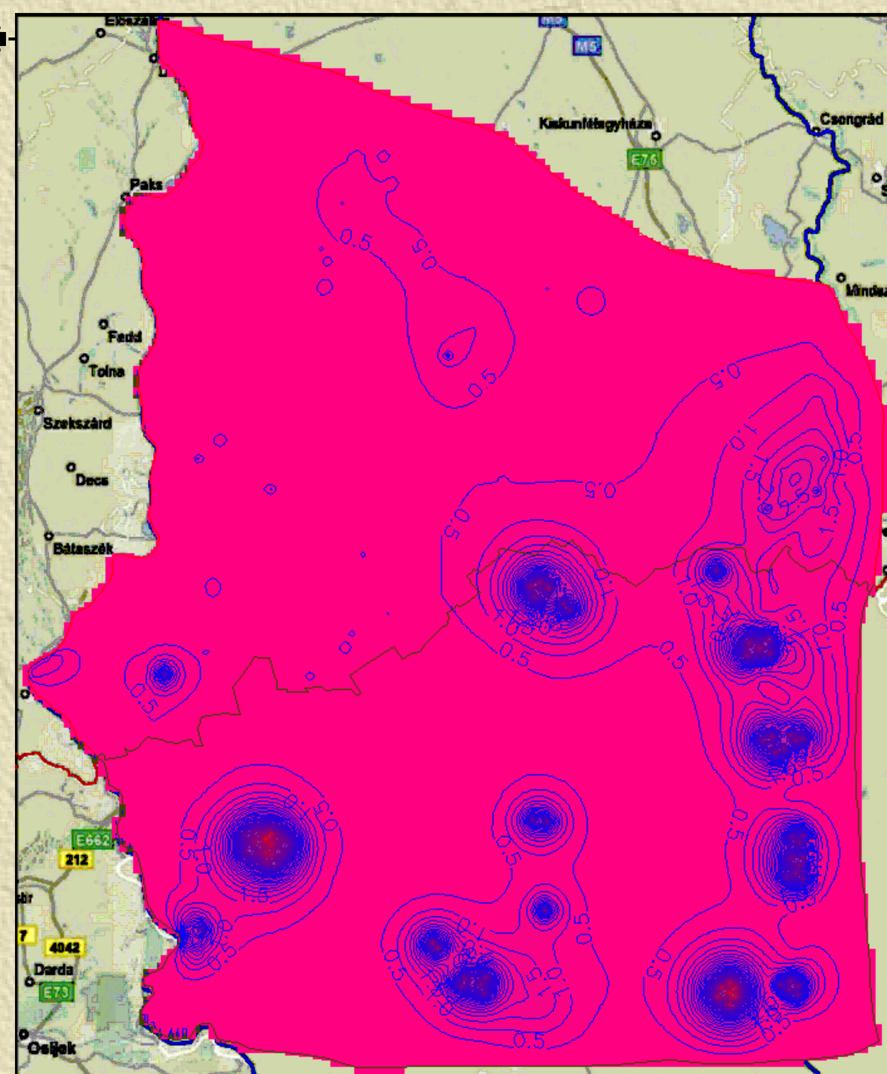


Scenarios

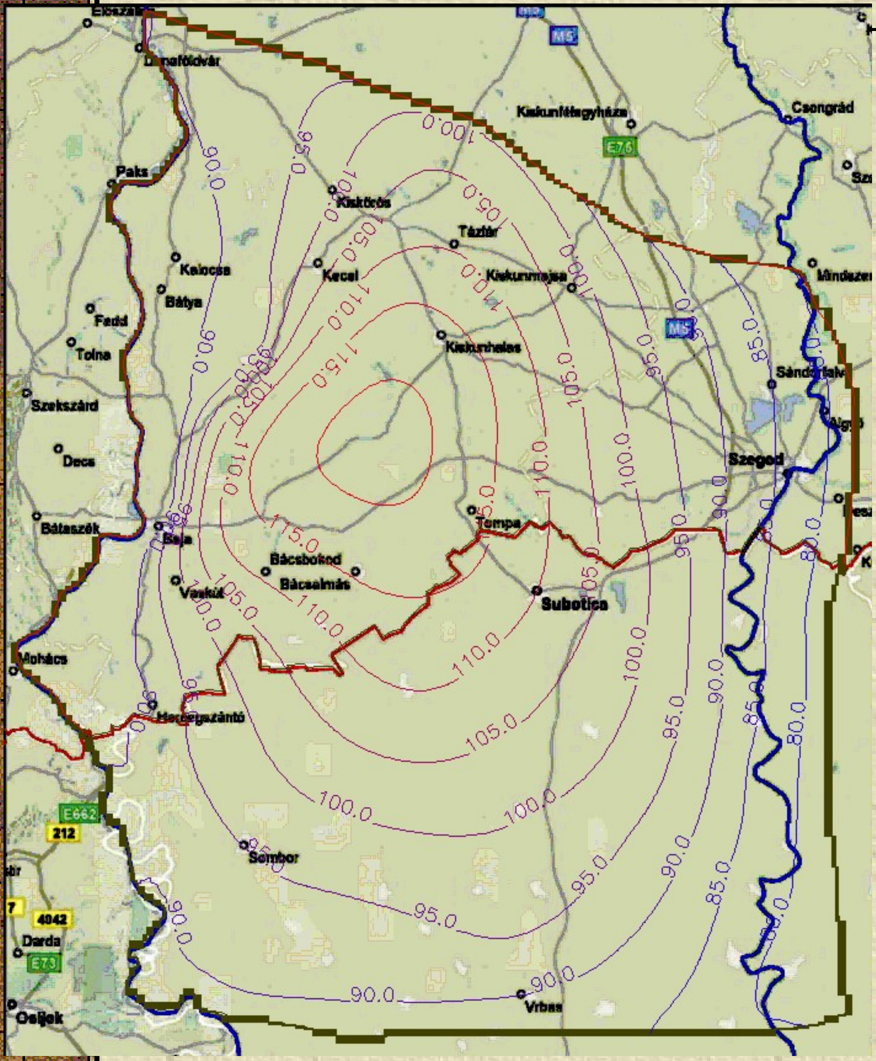
Scenarios		Recharge	Artificial recharge	Well production rates
Name	Features			
A1	Base model primary steady state flow model	Normal	-	-
A2	Base model with wells	Normal	-	Normal
B	Effect of climatic change (worst case)	Reduced -20%	-	Normal
C	Effect of climatic change (safe case)	Reduced -10%	-	Normal
D	Modeling art. recharge	Normal	Yes	Normal
E	Prediction 1	Reduced -20%	-	HU:+10%
F	Prediction 2	Reduced -20%	-	HU: +10% SRB: - 15%

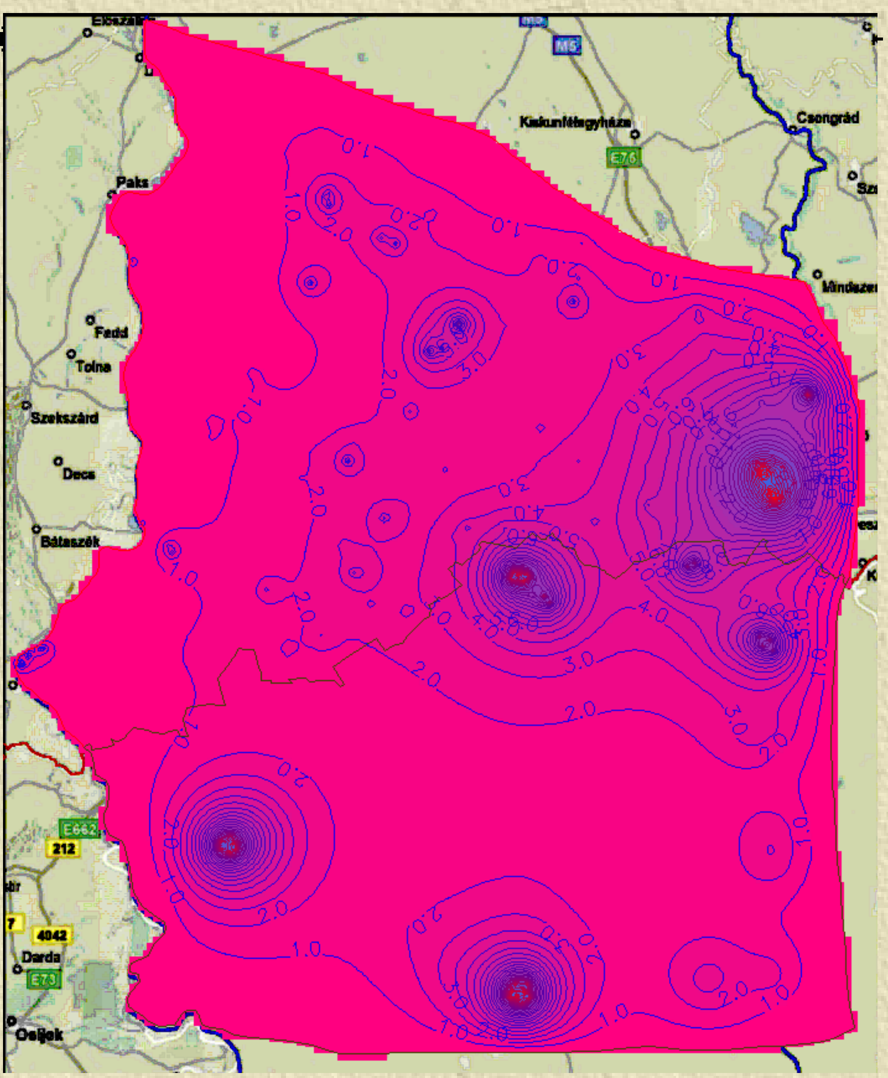
Head distribution and drawdown – 2nd layer – basic model





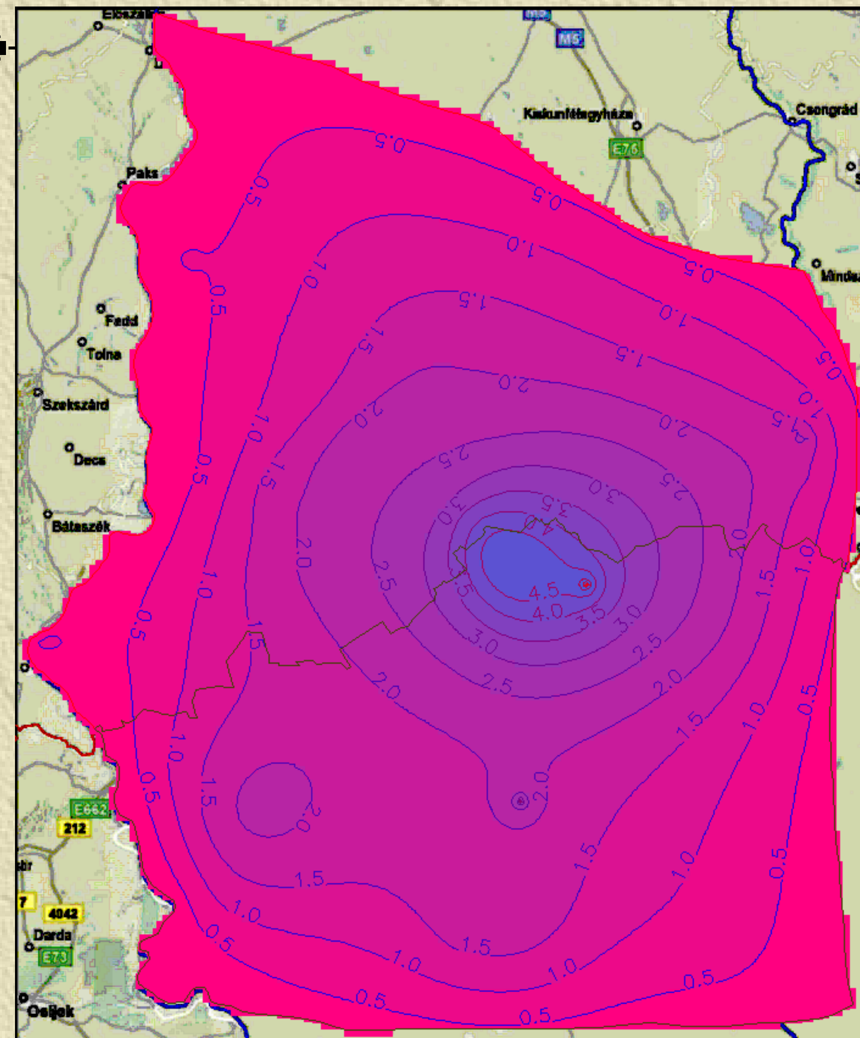
Head distribution and drawdown – 4th layer – basic model





Head distribution and drawdown

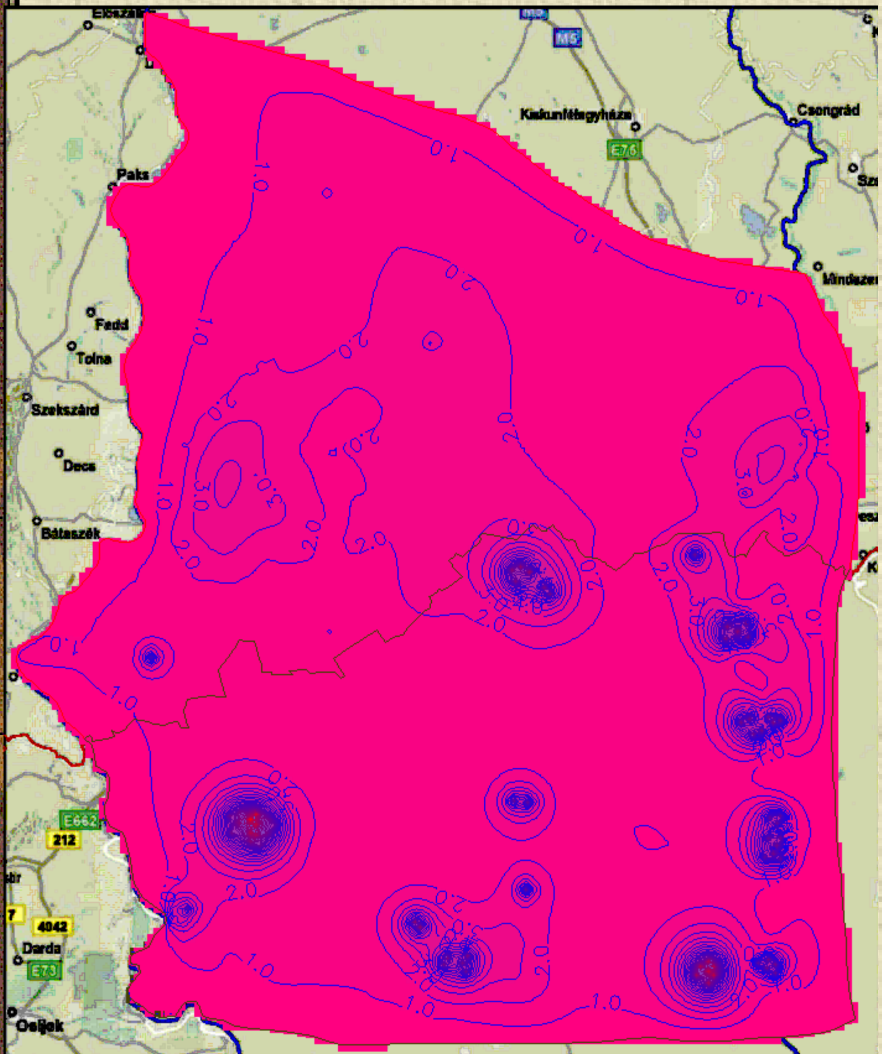
– 8th layer – basic model

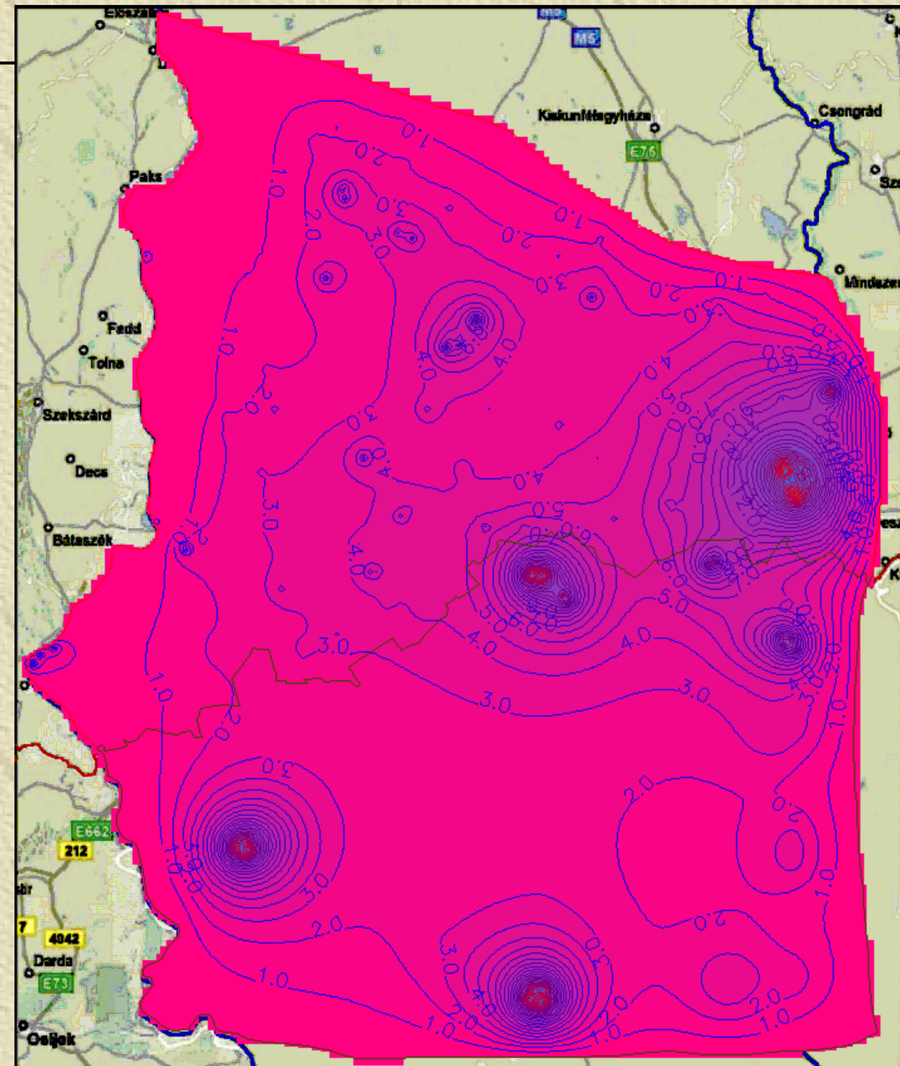


Drawdown in the 2nd & 4th layer

„B” scenario

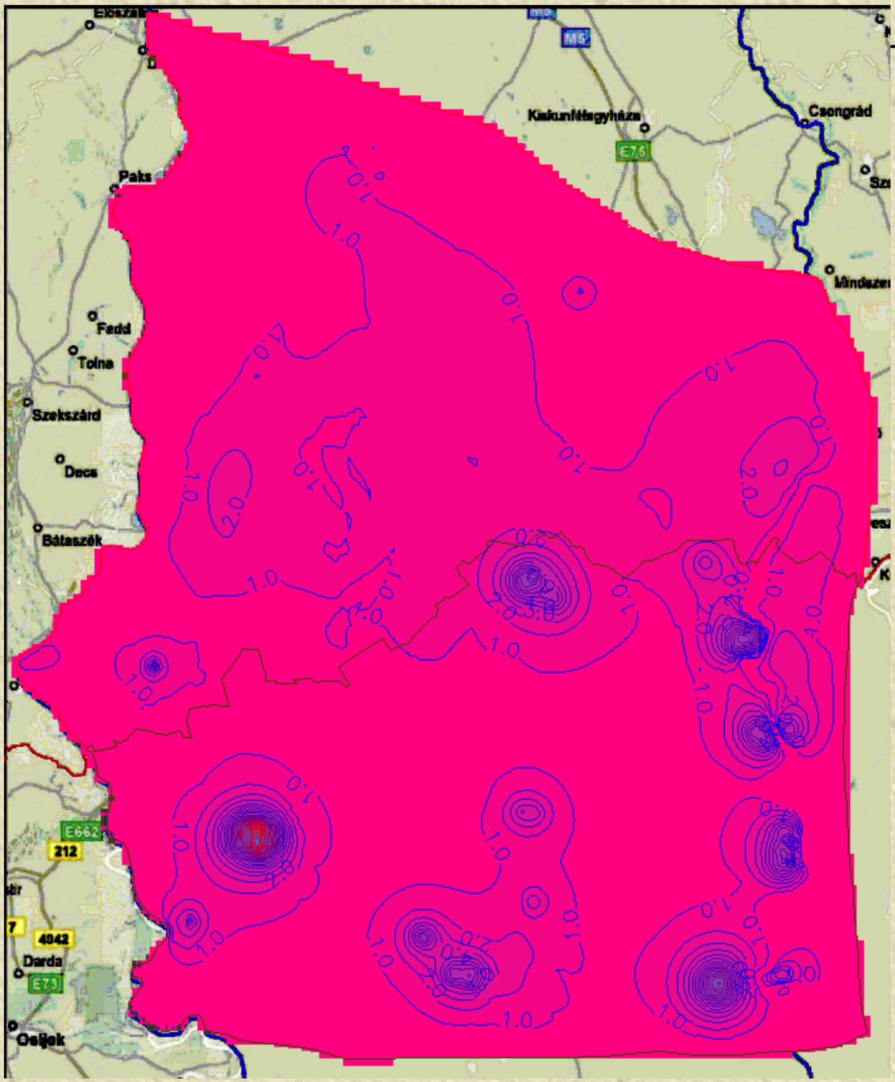
Reduced recharge rates of 20%
for the same exploitation rate
on both sides (worst case scenario)





Drawdown in the 1st layer

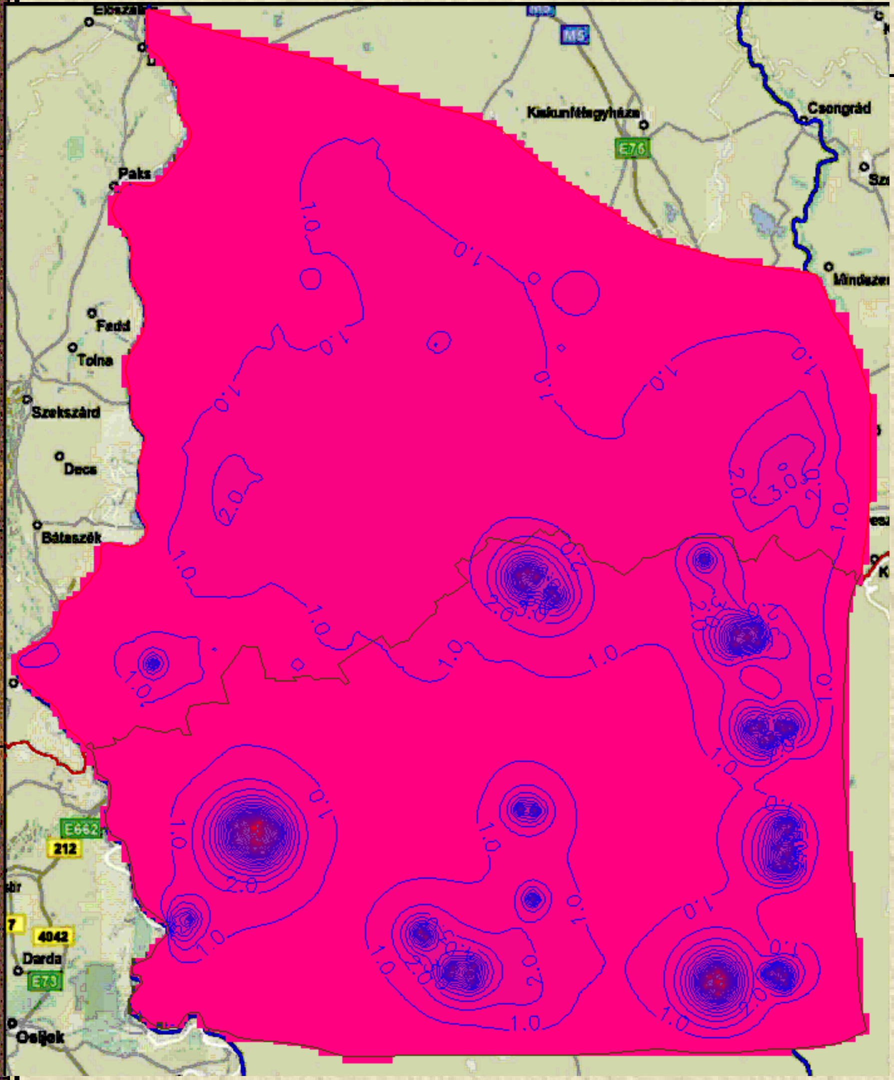
„C" scenario

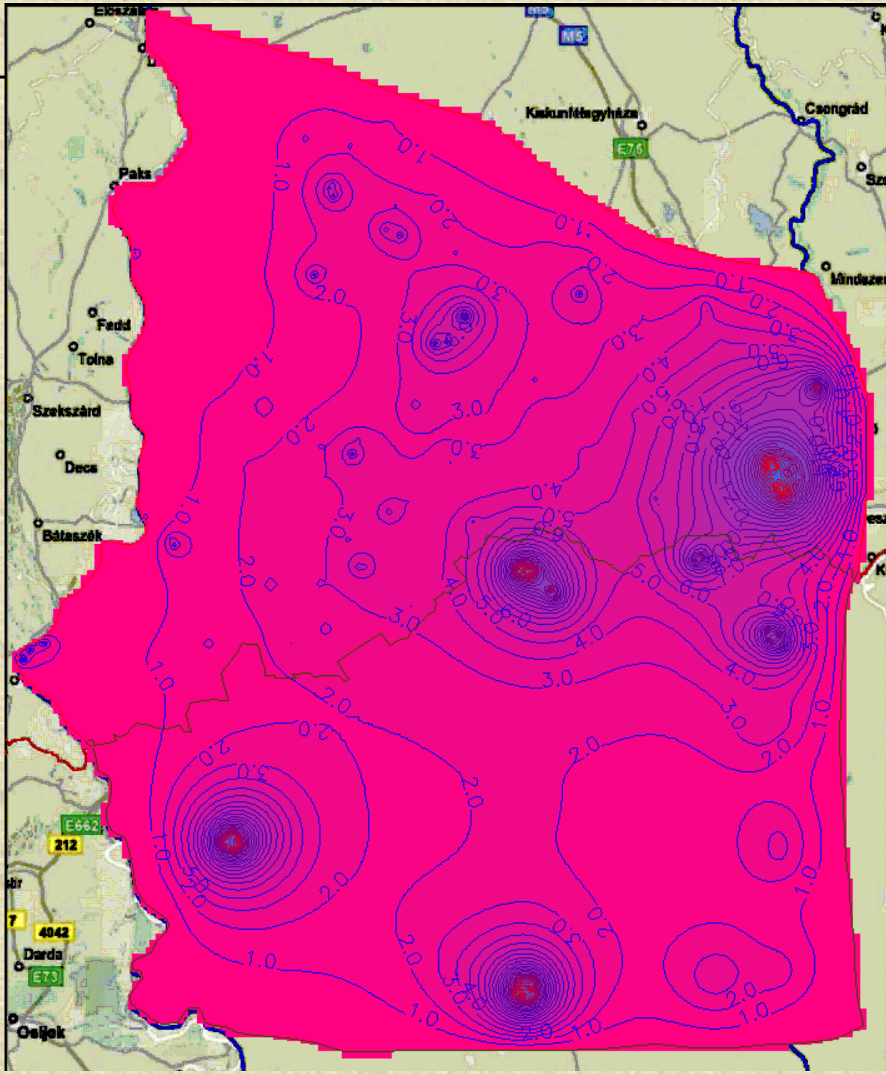


Reduced recharge rates of 10% for the same exploitation rate on both sides

Drawdown in the 2nd & 4th layer

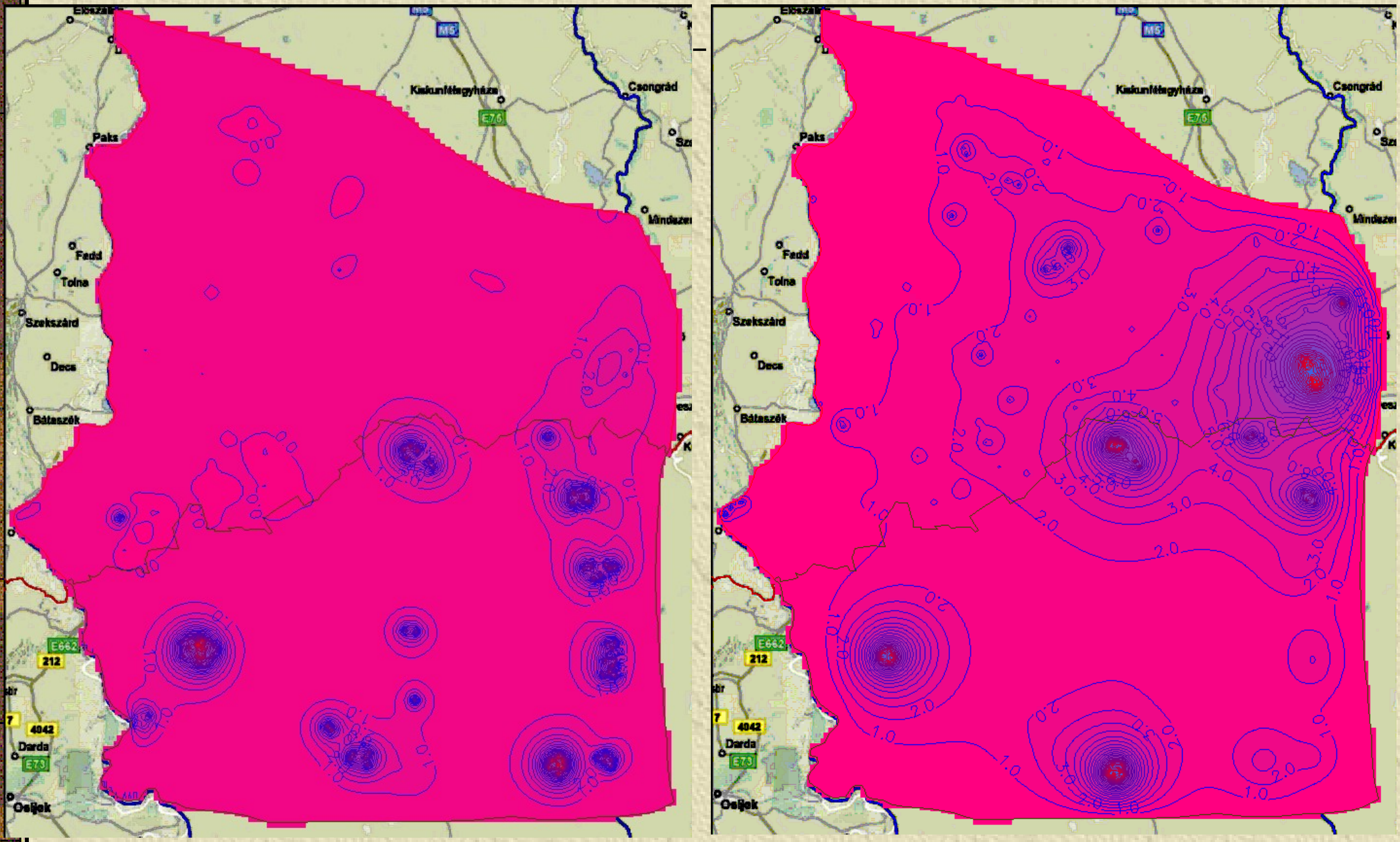
„C" scenario





Drawdown in the 2nd & 4th layer

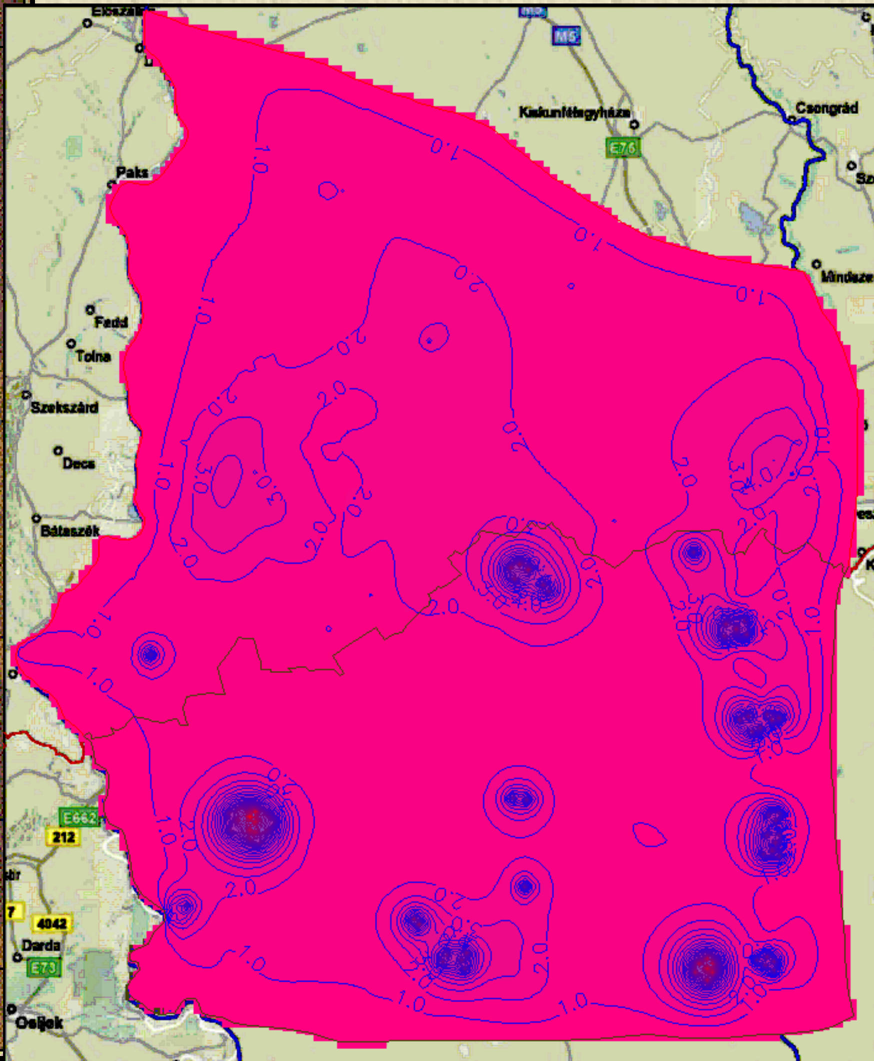
„D” scenario

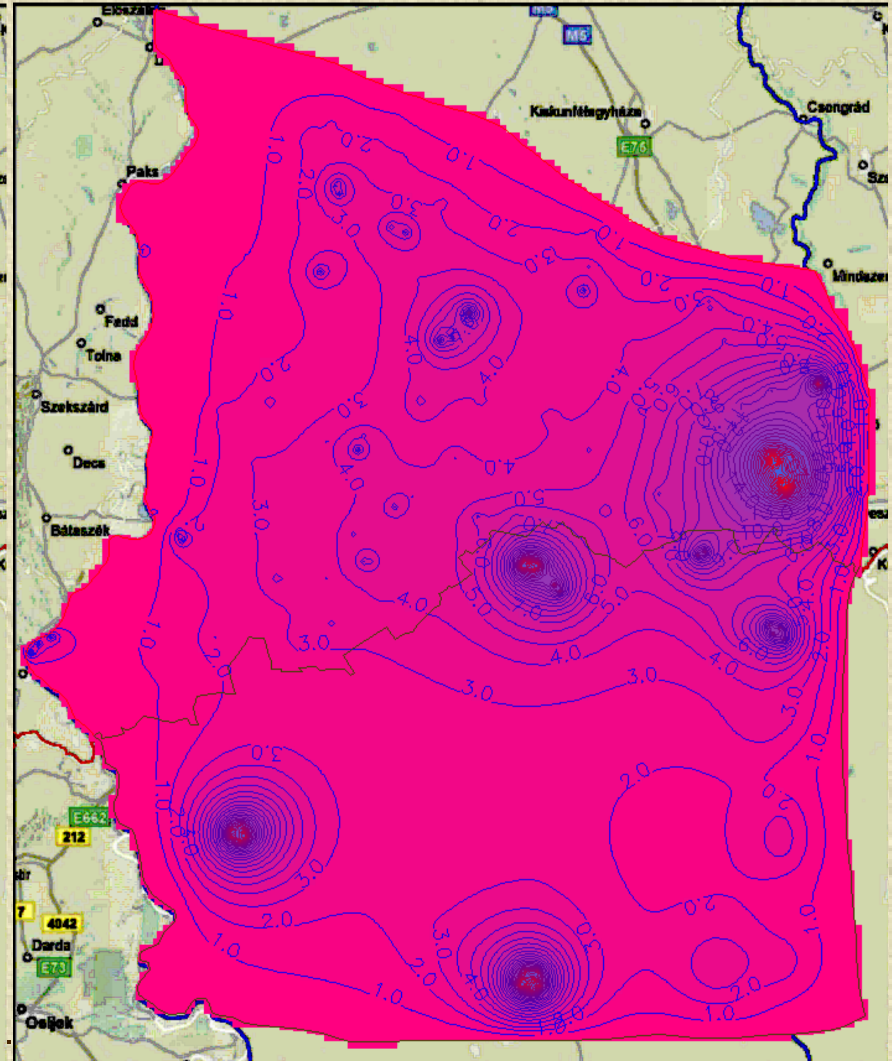


Drawdown in the 2nd & 4th layer

„E” scenario

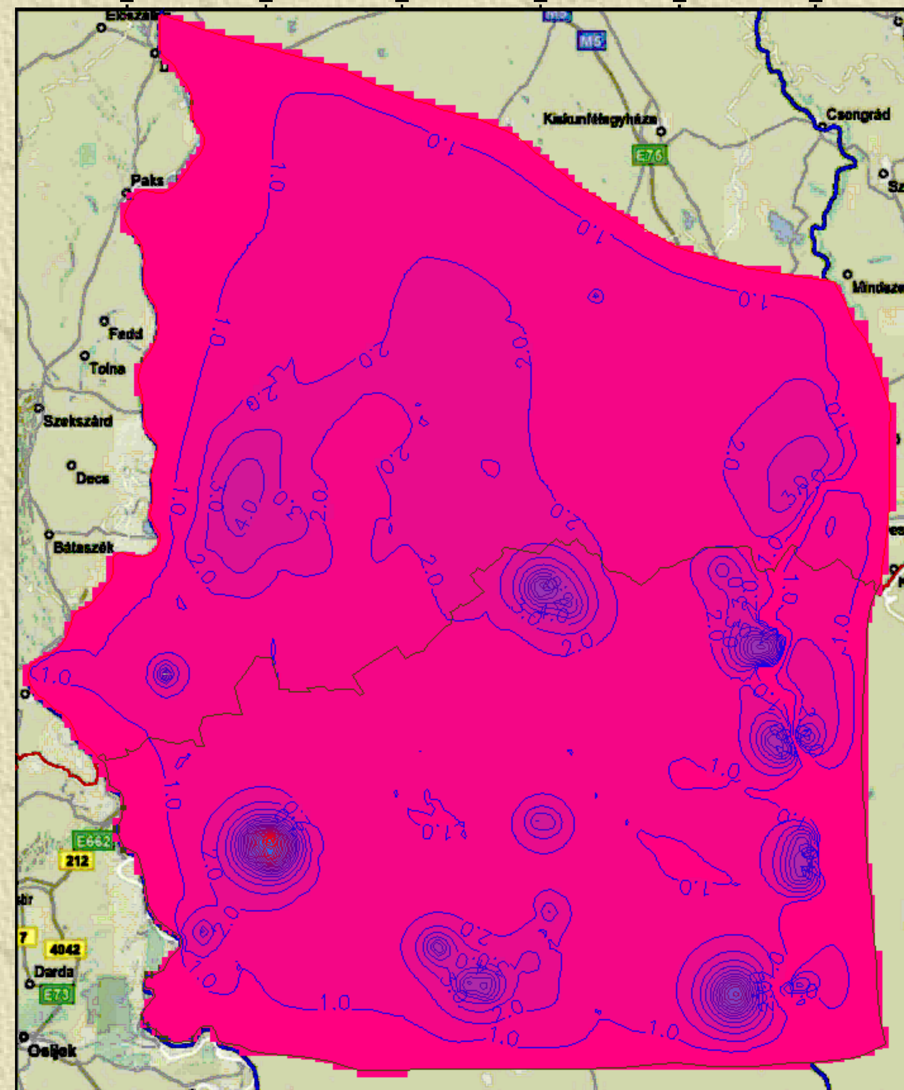
Reduced recharge rates of 20%
for the same exploitation rate
on both sides & Hungarian wells production incresed
10% (worst case scenario)





Drawdown in the 1st layer

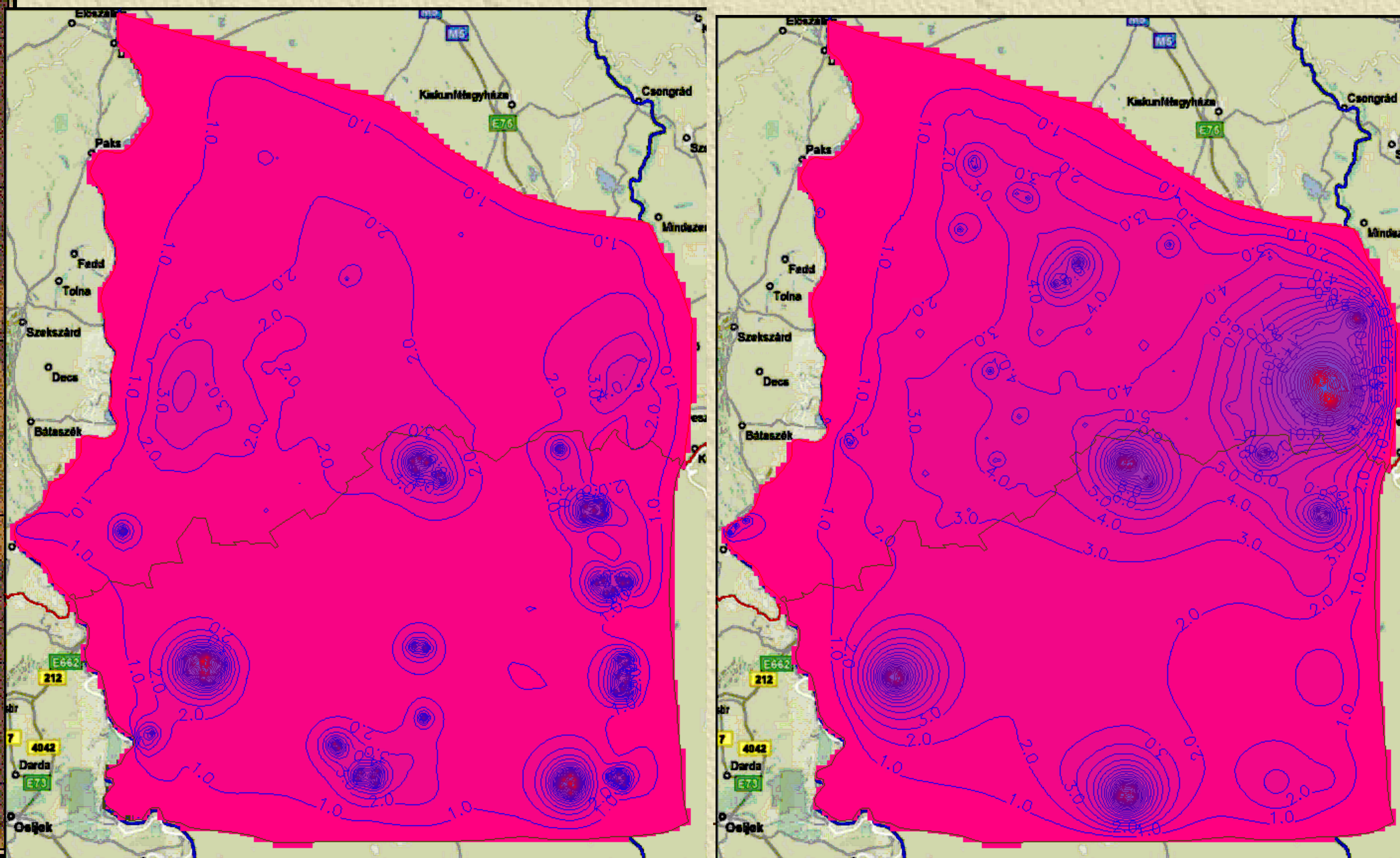
„F” scenario



Reduced recharge rates of 20% for the same exploitation rate on both sides
& Hungarian wells production increased 10%
& Serbian wells production decreased 15%

Drawdown in the 2nd & 4th layer

„F” scenario



Cumulated Water-Budget

	Recharge (Thm³/d)	ET. (Thm³/d)	Art. Rech. (Thm³/d)	GAP (Thm³/d)	Wells (Thm³/d)	Tisza (Thm³/d)	Duna (Thm³/d)	Chanals (Thm³/d)
Basic Model	**2,433**	**-2,123**	**0**	**310**	**0**	**-63**	**-145**	**-103**
Basic Model & wells	**2,433**	**-1,946**	**0**	**486**	**-430**	**-5**	**-88**	**-87**
Basic Model & wells Rech. * 0,8	**1,946**	**-1,587**	**0**	**359**	**-430**	**11**	**-48**	**-57**
Basic Model & wells Rech. * 0,9	**2,190**	**-1,768**	**0**	**422**	**-430**	**3**	**-70**	**-71**
Basic Model & wells + Art. Rech.	**2,433**	**-1,961**	**20**	**472**	**-430**	**-5**	**-89**	**-90**
Basic Model Rech. * 0,8 Hu-well 110%	**1,946**	**-1,582**	**0**	**364**	**-445**	**12**	**-48**	**-57**
Basic Model Rech. * 0,8 Hu-well 110% SRB-well 85%	**1,946**	**-1,600**	**0**	**346**	**-405**	**4**	**-54**	**-58**

Over exploitation?

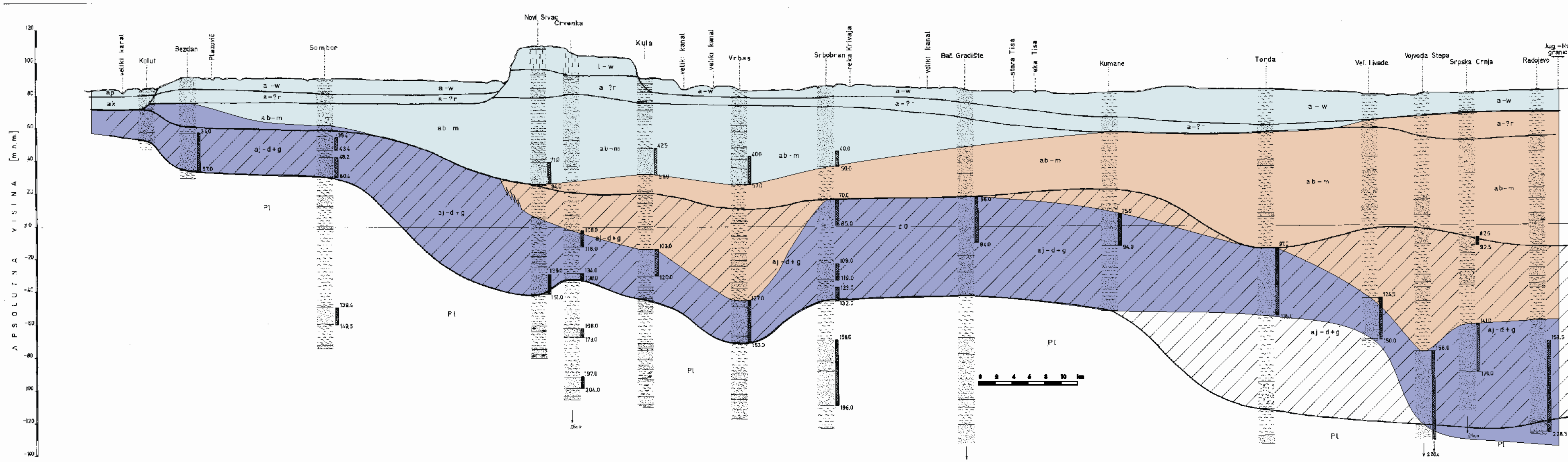
- It is assumed that the aquifer recharge potential, mostly through infiltrated rainfall and flow from remote areas, is enabling the **replenishment of some 60-90% of the current extraction rate** (depending on the area and the distance from the sources). There are some indications of regional drawdown; thus **many wells which were previously artesian today are characterized by a static groundwater table lower than 10m below the surface in the vicinity of the main sources.**

Evaluated solutions:

- Regional water supply system for Backa from Danube alluvium (possible source location is upstream of Apatin)
- **Waterworks would be centralized at municipality and regional level.**
- **Existing sources would remain functional as integral part of future water supply systems.**
- **Complex water treatment should be introduced.**
- **River bank filtration should be applied.**
- **Artificial recharge can also be introduced to support riverbank filtration.**
- **During transition and after the construction of a new system : Ensure sustainable use, GW monitoring, reduce losses in distributive system, introduce PPP and increase water taxes**

WEST

EAST



"FIRST"AQUIFER

SEMI-PERVIOUS DEPOSITS

BASIC WATER-BEARING COMPLEX

Conclusions and recommendations

- The cooperation of Hungarian and Serbian experts is essential for current and future water management and the sustainable development of Hungarian – Serbian transboundary aquifer. The common work within the frame of the SUDEHSTRA project which has helped very much to strengthen the collaboration between the experts involved and create an ambience for inventive future work on the development and protection of precious groundwater resources in the region.

- The main project goal on both sides was to move towards sustainable water management, which is regularly a long, difficult and complex process. Thus, within the applications and from the beginning of the project it was perceived that a 12-month duration would not be sufficient to ensure a quick impact and to improve the situation immediately. However, it can be said with certainty that an adequate foundation for environmentally safe water management has been successfully structured and should be continuously evaluated and closely monitored after the formal end of the project.

3 Workshops conducted in Szeged and in Palic from both countries' presentations

Workshop in Palic for the representatives from local waterworks;

- A very important project component included the encouragement of measures for the rational use of water resources, their ecological protection and monitoring. This was addressed through the preparation and delivery of promotion leaflets and other material to the end-users.

Thanks for your attention!