Hydrogeochemical Characteristics of Develi Closed Basin (Kayseri-Turkey)

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Abstract: The Develi Closed Basin in Cenral Anatolia contains the Sultansazligi Marshes: a wetland area protected by the RAMSAR Convention. The aim of this study is to investigate groundwater pollution and groundwater quality of Develi Closed Basin. Groundwater samples were collected from the springs and wells at Develi Basin and analysed for chemical constituents. Based on the results; it is determined that concentrations of Na^{+}-Mg^{2+}-HCO_3^{-} are high at the groundwater of the north-eastern side of the basin and Ca^{+2} and HCO_3^{-} concentrations are high at the groundwater of the southern side of the basin. Also there is nitrate pollution at the groundwater at some locations of Develi Closed Basin.

Keywords: Groundwater chemistry, Develi Closed Basin, water quality

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Received: 27 october 2011 / Accepted: 29 november 2011
Published online: 30 december 2011

Riassunto: *Develi è un sottobacino chiuso del Kızılırmak River Basin (Basin no:15) all'estremità della città di Kayseri (Turchia). La quota media del bacino varia tra 1070-1150 m sul livello medio del mare. La Piana di Develi è centrale rispetto al Bacino Chiuso di Develi. L'area totale della piana di Develi è approssimativamente 800 km² mentre l'area di drenaggio del bacino è 3197 km². La piana di Develi ha una pendenza media del 2 %. La zona umida di Sultansazligi appartiene al Bacino Chiuso di Develi ed è una delle sette zone umide importanti della Turchia ed è il secondo, per importanza, habitat per volatili aquatici. La zona umida di Sultansazligi è inoltre conosciuta come una delle più importanti dell'Europa dell'Est e del Medio Oriente. Nella Regione Umida Sultansazligi sono presenti il Lago Yay, il Lago Col, le aree paludose Nord e Sud. I Laghi Col e Yay sono specchi d'acqua superficiali; il livello dell'acqua del Lago Yay è di circa 100 cm. e le coordinate della zona umida sono 38º.05 - 38º.40 Nord, 35º.00 - 35º.35 Est. Questa area umida è un'area di conservazione protetta dall'Accordo Anternazionale Ramsar. La zona umida di Sultansazligi nel Bacino Chiuso di Develi, è circondata dal Monte Erciyes (3916 m), del Monte Develi (2074 m), dal Monte Aladağlar (3373 m) e dal Monte Hodul (1937 m), rispettivamente in direzione nord, est, sud e ovest. Questo studio descrive le caratteristiche idrochimiche dell'acqua di sottosuolo nel Bacino Chiuso di Develi. Sono stati raccolti campioni d'acqua superficiali, campioni da 22 pozzi profondi e da 16 sorgenti, durante un arco di tempo di 3 anni (2003-2005) e su questi sono state eseguite analisi chimiche dal 12mo Direttorato Regionale Statale per le Opere Idrauliche. Secondo le analisi chimiche delle acque di sottosuolo è stato determinato che prevale un chimismo ad elevate concentrazioni di* Na^{+}-Mg^{2+}-HCO_3^{-} *nella zona nord est del bacino ed un chimismo ad elevate concentrazioni di* Ca^{+2} *e* HCO_3^{-} *nelle acque sotterranee del sud del bacino. Anche la contaminazione delle acque sotterranee è stata analizzata in questo studio, per esempio: la Sorgente Ilipinar e due pozzi nella zona di Calbalma mostrano elevate concentrazioni di boro in concomitanza di inquinamento da ammonio e nitriti in questi pozzi localizzati nel distretto di Yesilhisar. In più anche il parametro EC di questi campioni di acque di sottosuolo è risultato molto elevato.*

Introduction

Develi Plain is located at the center of Develi Closed Basin, its area is 800 km², slope of this plain is approximately 2%. Coordinates of Sultansazligi Wetland are 38º.05 – 38º.40 North and 35º.00-35º.35 East. Develi Closed Basin and Sultansazligi Wetland is shown in Figure 1. There are three dams (reservoirs) at Develi Closed Basin for irrigation purpose, namely; Agcasar, Kovali and Akkoy dams (DSİ, 1995; Gürer, 2004; Yıldız, 2007).

There are many previous studies on the hydrology and hydrogeology of Develi Closed Basin. There are hydrogeology reports about Develi Closed Basin prepared by Turkish State Hydraulic Works (DSI) (DSİ, 1995; DSI, 1970). (Gürer,2004; ENCON, 1999; Gürer et.al., 2005) are reports about groundwater investigations at Develi

 DOI 10.4409/Am-032-11-0032

Closed Basin. Yıldız (2007) is a PhD thesis about surface water-groundwater intrusion at Sultansazlığı Wetland. Erol (1999) is an article about geomorphology of Develi Closed Basin and (Göncüoğlu et.al., 1991; Dalay, 2000; Kaya and Yurdagül, 2001) are studies about geology of Develi Closed Basin.

Many groundwater sampling locations were selected in order to represent the whole groundwater quality of the basin so groundwater samples were collected from 22 wells and 18 springs for 3 years. Groundwater samples were analyzed at the water chemistry laboratory of the 12th Regional Directorate of Turkish State of Hydraulic Works at Kayseri City

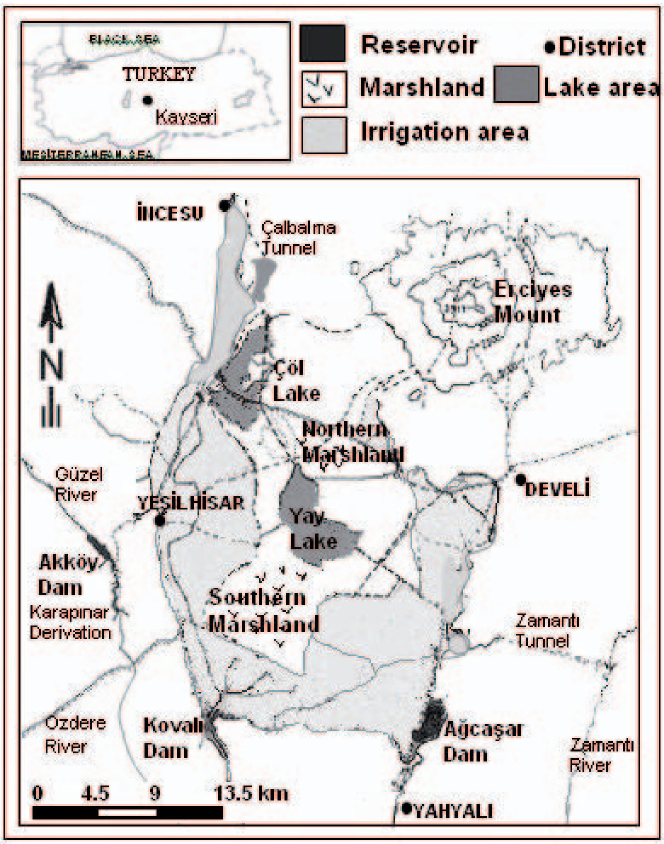

Fig. 1: *Location of Develi Closed Basin and Sultansazligi Wetland. (Modified from DSI, 1970)*

Magmatic rocks such as basalt, andesite and tuff crop out at the northern and northwestern parts of Develi Closed Basin produced by the Erciyes Volcano. Aladaglar Mountains which are composed of karstified carbonate rocks are located at the south of the basin. The Aladaglar Massif is a large mountain range with the ages ranging from Devonian to Upper Cretaceous. Aladaglar nappes stacked together during the period between late Cretaceous and Eocene to form the massif, which is a part of the Alpine-Himalayan Orogeny in Turkey. Volcanic rocks also crops out at Develi Mountain which is located at the east of Develi Closed Basin. Develi Plain is a tectonic collapse plain filled by Quaternary alluvium, this plain filled both by the pyroclastic material released from surrounding volcanic centers and by the colluvial/alluvial material brought from the surrounding heights. Thickness of the alluvium layer increases and sediment particle size decreases while approaching to Sultansazligi Wetland (DSI, 1995; Gurer, 2004, Yildiz, 2007).Volcano-sedimentary rocks and ignimbrites outcrop at the western and eastern side of the basin (DSI, 1995; Bayari and Yildiz, 2011). Develi Tuff Formation and Sarica Formation (andesite and basalt) cover large area at Develi Closed Basin (Göncüoğlu et.al., 1991; Kara, 1997; Dönmez, et.al.,2003). Geology map of Develi Closed Basin and geological cross-sections of the basin are given in Figure 2 and Figure 3 respectively.

According to the hydrogeological studies at Develi Closed Basin such as (DSI, 1970) and (DSI, 1995); generally aquifer under the basin is unconfined aquifer (thickness about 100-150 m). While approaching to Sultansazligi Wetland, sediment particle size decreases to clay size. It is observed that only clay and silt are encountered at logs of the wells which are opened near the Southern Marshland of Sultansazligi (ENCON (1999). Average transmissibilities of the aquifer at the western side is 552 m^2/day, 100 m^2/day at the soutwestern side, 2574 m^2/day at the southern side and 1115 m^2/day at the western side of Develi Closed Basin. It is estimated that total inflow to the aquifer under Develi Closed Basin, is 90.582 x 10^6 m^3/year (Gürer,2004 ; Gürer and Yildiz, 2007). Reliable water abstraction volume from the aquifer was computed by Turkish State Hydraulic Works (DSI) as 65 x 10^6 m^3/year (DSI, 1995). Groundwater level observations from 1970 to 2005 are obtained from 12th Regional Directorate of State Hydraulic Works and groundwater contour maps are drawn. Figure 4 shows hydrogelogy map of Develi Closed Basin showing groundwater level, springs and wells.

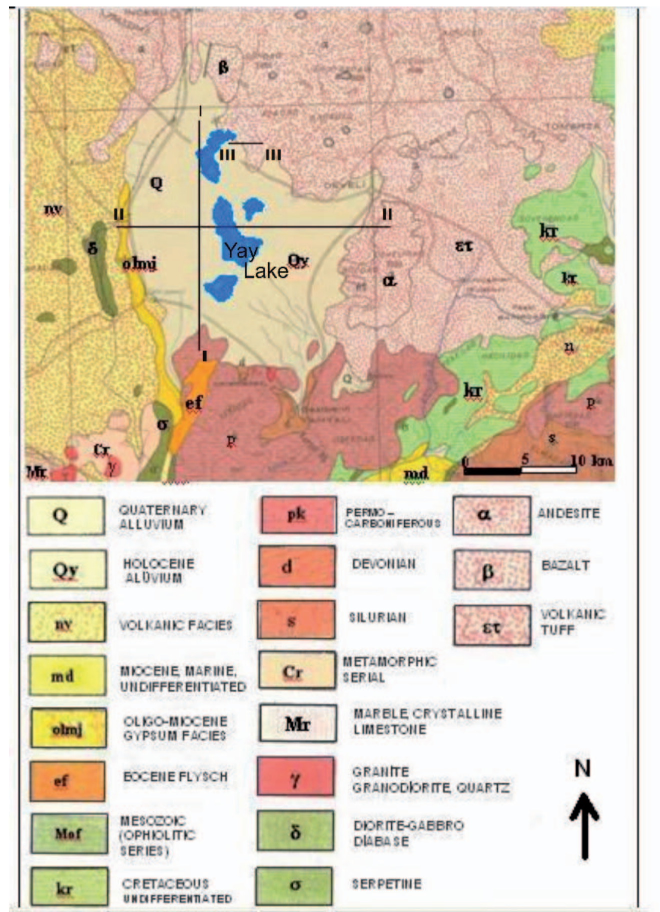

Fig. 2: *Geology map of Develi Closed Basin (modified from www.mta.gov.tr)*

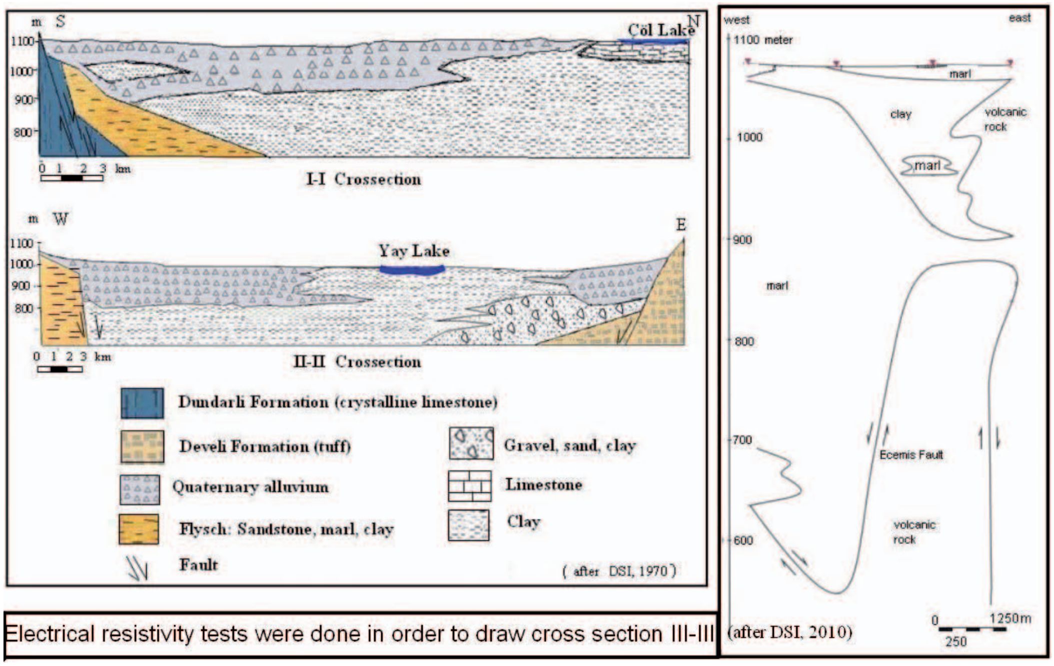

Fig. 3: *Geological cross-sections of Develi Closed Basin*

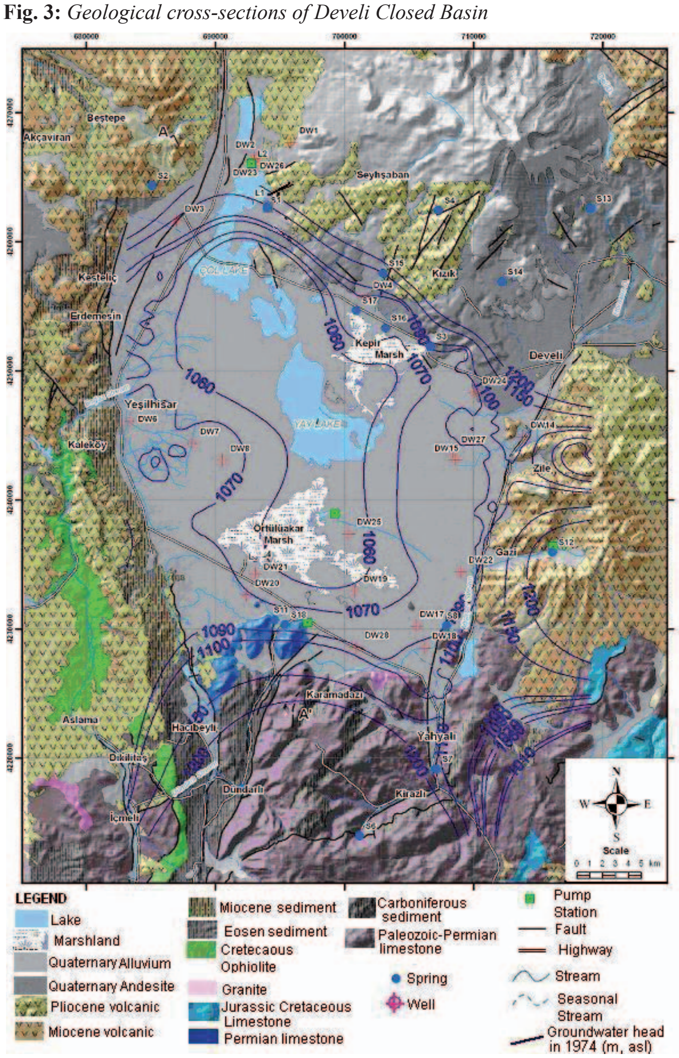

Fig. 4*: Hydrogeological map of the Develi Closed Basin with groundwater sampling. Locations (modified Bayari and Yildiz, 2011)*

Hydrogeochemical investigations at develi closed basin

Groundwater Sampling

Groundwater samples were collected from 22 deep wells and 18 springs (during 2003-2005) sampling locations are given at Figure 5. In situ analyses were made for the water temperature, EC and pH of the groundwater. Groundwater chemistry analyses were made at the chemistry laboratory of 12th Regional Directorate of DSI. Cation-anion concentrations (Na^{+}, K^{+}, Ca^{+2}, Mg^{+2}, Cl^{-}, SO_4^{-2}, HCO_3^{-}, CO_3^{-}), boron, nitrite, nitrate and ammonium concentrations and French Hardness of the groundwater samples were measured at the water chemistry laboratory. Water chemistry laboratory of the 12th Regional Directorate of Turkish State of Hydraulic Works at Kayseri City is a certificated laboratory; Turkish Quality Standards (TS 4531) and international ISO 14911, ISO 10304-1, ISO 14912 quality standards are used for the water chemistry analysis. Reliability analysis (electroneutrality) were also made in order to check the reliability of the analyses results in the content of this study. Additionally previously made groundwater chemistry analysis of Develi Closed Basin were also evaluated (previous DSI analysis made during 1999-2002 time period).

There are many springs at Develi Closed Basin. In the southern part of the basin, Dundarli Spring feed Kovali Reservoir and flows out from marble. Gozbasi, Yerkoy, Agcasar and Cinarpinar Springs feed Agcasar Reservoir and these springs flow out from limestone rocks. Kurbaga Springs (Buyuk Kurbaga- Kucuk Kurbaga) and Karaboga Spring drain the water of limestone at karstified Aladaglar Mountain. Soysalli, Ilipinar, Cayirozu, Kurpak and Elbiz Springs are located at the north of the basin. These springs drain the water of magmatic (basalt) rocks. Snow of Erciyes Mountain feed these springs. Table 1 shows the annual average, maximum and minimum discharges of these springs.

DOI 10.4409/Am-032-11-0032

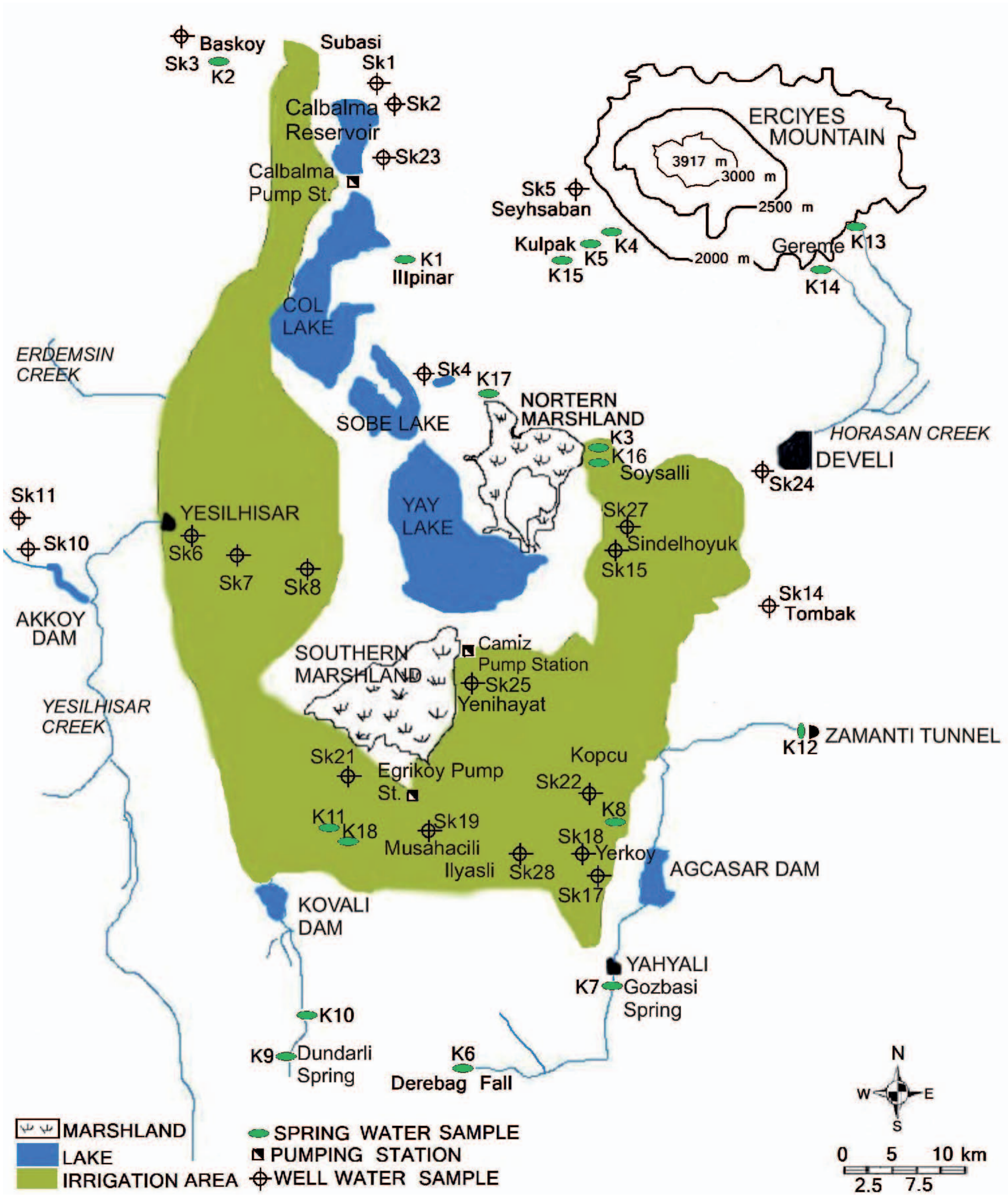

Fig. 5: *Locations of the groundwater samples*

Groundwater chemistry results of the water samples taken from the springs are given at Table 2 and groundwater chemistry results of the water samples taken from the deep wells are given at Table 3..

EC, nitrate and ammonium are higher than the standards of World Health Organization (WHO) and Turkish Standard Institution (TSE) at the water samples SK2 and SK23, According to Table 3; SK2 and SK 23 groundwater samples have high ammonium concentrations (0,722 mg/lt and 2,3 mg/lt respectively). Groundwater samples SK6 have have high ammonium concentrations (2.48 and 2.09 mg/lt).

Tab. 1: *Discharges of some springs at Develi Closed Basin (DSI, 1995)*

Spring name and groundwater sample code	Annual Q_{av} (m^3/s)	Annual Q_{MAX} (m^3/s)	Annual Q_{MIN} (m^3/s)
Cayirozu (K17)	0,14775	0,222	0,104
Karaboga (K8)	0,408167	0,449857	0,37542
Kurbaga (K11, K18)	0,051858	0,098	0,0105
Karapinar (K16)	0,421033	0,51075	0,3607
Soysalli (K3)	0,594561	0,6415	0,502
Ilipinar (K1)	0,037	0,047	0,031

Tab. 2: *Chemical analysis of the water samples taken from the springs in the study area*

Water Sample Location	pH	TDS mg/l	EC µS/cm	Na^+ mg/l	K^+ mg/l	Ca^{++} mg/l	Mg^{++} mg/l	Cl^- mg/l	SO_4^- mg/l	HCO_3^- mg/lt	CO_3 mg/lt	Hardness (oF)	NO_2 (mg/l)	NO_3 (mg/l)	NH_4 (mg/l)	Boron (mg/l)
K1	7,53	653	1179	155,87	7,8	27,86	19,08	236	2,88	203,2	0	14,8	0,003	2,97	0,11	3,2
K1	7,37	776	1134	163,69	10,9	46,49	21,27	275	11,5	246,52	0	30,35	0	5,89	0,22	3,6
K2	7,81	286	350	20,69	1,6	34,47	12,15	7,09	2,88	207,47	0	13,6	0,007	10,9	0,06	0,2
K2	7,72	311	329	25,75	2,7	33,07	13,61	6,03	9,13	219,67	0	13,85	0	13,51	0,13	0,1
K3	7,49	85	126	5,75	1,2	9,82	3,889	3,55	0,48	59,8	0	4,05	0	4,13	0,07	0,2
K3	7,37	91	123	7,36	1,6	8,216	5,347	4,61	6,24	57,969	0	4,25	0	5,71	0,16	0
K4	7,49	36	69	2,30	1,6	1,804	2,917	1,77	1,92	23,188	0	1,65	0,023	2,91	0,33	0,4
K4	7,77	61	80	3,45	2,0	10,02	1,215	2,13	6,24	37,222	0	3	0	7,58	0,15	0
K5	7,3	56	82	2,99	1,2	9,82	0,608	2,13	0,96	37,832	0	2,7	0	2,97	0,16	0,4
K5	7,82	63	76	4,14	1,6	8,216	2,309	1,77	7,2	37,832	0	3	0	0	0,08	0
K6	8,7	246	292	1,15	0,4	49,3	8,75	1,77	13	164,75	6,601	15,9	0,01	2,15	0,25	0,6
K6	8,3	204	221	0,46	0,0	41,08	7,292	0,35	6,72	145,23	4,201	13,25	0	4,12	0,15	0,1
K7	7,9	325	381	1,61	0,8	64,13	11,42	2,48	30,3	215,4	0	20,7	0,01	6,56	0,2	0,6
K7	7,96	229	252	0,92	0,0	46,89	6,805	1,77	12,5	160,48	0	14,5	0	4,92	0,17	0,2
K8	7,38	506	653	25,98	1,6	87,98	15,31	44,7	36	293,51	0	28,25	0,033	9,04	0,165	0,6
K8	7,6	513	624	30,81	2,0	85,17	16,28	48,9	43,7	286,18	0	27,95	0	12,1	0,2	0,2
K9	7,95	135	227	0,69	0,0	41,28	7,899	5,67	1,44	1,8306	75,61	13,55	0	5,63	0,26	0,1
K10	8,05	218	284	1,15	0,4	44,49	6,198	1,42	5,28	161,09	0	13,85	0,003	5,32	0,12	0,4
K10	8	229	251	0,69	0,0	47,29	6,805	1,06	11,5	161,09	0	14,6	0	8,2	0,12	0,1
K11	7,85	443	594	23,68	2,0	67,94	19,44	37,2	49	244,08	0	24,95	0,049	14,97	0,308	0,6
K11	7,66	360	601	32,88	2,3	65,13	21,87	33,7	2,88	68,953	132	25,25	0	10,85	0,34	0,4
K12	8,23	84	123	3,91	1,6	11,62	4,496	1,42	1,44	53,087	6,601	4,75	0	2,76	0,2	0,4
K12	8,37	71	129	6,67	1,6	10,22	6,562	4,61	3,84	2,4408	33,9	5,25	0	4,16	0,17	0
K13	7,32	27	45	2,30	1,2	1,002	3,038	3,55	14,4	1,8306	0	1,5	0	3,83	0,14	0
K14	7,66	43	59	4,14	1,6	2,004	3,038	1,06	8,65	21,967	0	1,75	0	1,13	0,13	0
K15		57	79,2	4,38	1,8	7,14	2,38	1,63	2,52	36,852	0		0	3,35		0
K16	6,6	172	224	21,15	4,7	12,02	7,292	10,6	11,5	103,73	0	6	0		0	0
K17	6,7	472	710	108,05	11,7	20,04	13,37	156	9,61	152,55	0	10,5	0		0	0
K18	7,1	622	876	34,25	2,7	76,15	41,32	46,1	123	299	0	36	0		0	0

DOI 10.4409/Am-032-11-0032

Tab. 3: *Chemical analysis of the water samples taken from the wells in the study area.*

Water Sample Location	pH	TDS mg/l	EC µS/cm	Na^+ mg/l	K^+ mg/l	Ca^{++} mg/l	Mg^{++} mg/l	Cl^- mg/l	SO_4^- mg/l	HCO_3 mg/lt	CO_3 mg/lt	Hardness (F)	NO_2 (mg/l)	NO_3 (mg/l)	NH_4 (mg/l)	Boron (mg/l)
SK1	7,98	116	189	14,71	1,2	5,411	8,628	19,9	0,4803	65,902	0	4,9	0,003	4,05	0,089	0,2
SK2	8,26	3800	6605	1046,04	117,3	116,6	69,88	1549	326,12	565,05	9,601	57,85	0,023	8,11	0,722	13,7
SK3	7,9	412	496	26,44	3,9	53,91	16,53	14,2	6,2439	291,07	0	20,25	0,01	10,76	0,105	0,6
SK3	7,49	415	472	30,35	4,7	49,3	17,5	13,8	9,606	289,85	0	19,5	0	12,09	0,02	0,2
SK4	7,39	140	206	19,77	2,0	8,818	6,684	17,4	0,4803	85,428	0	4,95	0,003	2,45	0,05	0,3
SK 5	7,5	652	1274	17,24	9,8	54,91	22,48	220	2,4015	325,85	0	22,95	0,043	2,24	0,19	4,1
SK 6	7,11	1645	1834	68,97	15,6	231,3	85,43	95,4	55,715	1093,5	0	92,85	0,01	28,88	2,48	1,8
SK 6	6,89	1723	1756	95,41	9,8	211,4	102,7	133	108,07	1063	0	95	0	31,51	2,09	1,3
SK7	7	1124	1358	62,99	7,8	152,7	53,59	78	43,707	723,7	0	60,15	0,01	12	0,86	1,3
SK7	6,73	1259	1382	97,71	9,0	150,9	61,86	122	60,038	756,65	0	63,1	0,007	7,8	0,83	1,4
SK8	8,3	650	1025	70,81	7,0	64,73	34,76	103	49,951	308,15	10,8	30,5	0	19	0,23	1,3
SK8	7,52	738	1000	94,26	7,0	70,94	35,97	147	81,171	302,05	0	32,5	0,003	23,74	0,21	1,4
SK10	8,17	265	386	10,12	1,6	53,51	4,375	14,2	11,047	164,75	5,401	15,15	0,007	17,68	0,064	0,5
SK11	8,46	164	223	5,98	1,2	32,26	3,16	4,25	0,4803	112,89	5,401	9,35	0,003	10,59	0,076	0,4
SK11	8	254	223	8,74	1,2	47,29	5,833	3,19	17,291	170,86	0	14,2	0	14,2	0,06	0,3
SK14	7,54	480	719	22,07	1,2	91,98	14,58	30,5	149,37	171,47	0	28,95	0,007	9,3	0,211	0,6
SK14	7,59	599	780	63,68	3,5	85,17	20,54	77,3	208,93	138,52	0	29,7	0,046	2,76	0,344	0,1
SK15	7,15	319	465	28,74	4,7	31,86	18,23	45,4	12,488	178,18	0	15,45	0,013	6,91	0,24	0,5
SK15	6,8	432	617	55,87	9,4	32,06	23,09	81,5	22,574	207,47	0	17,5	0		0	0
SK17	7,9	267	275	2,53	0,4	55,11	6,684	3,19	15,37	183,67	0	16,5	0,01	5,76	0,1	0,1
SK18	7,8	422	488	3,68	0,4	88,98	9,844	5,67	29,298	283,74	0	26,25	0,036	9,7	0,8	0,6
SK18	7,6	333	476	3,68	0,4	28,26	6,076	7,45	23,054	265,44	0	9,55	0	11,5	0,23	0
SK19	8,23	616	730	63,68	3,1	58,12	30,5	28,4	62,439	366,12	4,201	27,05	0,233	0,13	0,38	0,3
SK19	7,8	551	643	60,23	3,9	57,11	7,656	34	57,636	329,51	0	17,4	0	0	0,31	0,1
SK20	7,5	627	836	52,88	2,3	84,77	25,64	70,2	68,203	323,41	0	31,7	0	6,96	0,26	1,2
SK20	7,63	485	698	59,31	3,9	67,13	6,562	56,7	46,589	244,08	0	19,45	0	4,52	0,39	0,7
SK21	8,53	340	441	29,89	1,2	30,06	23,7	25,5	22,094	207,47	0	17,25	0,138	3,61	0,77	0,2
SK21	8,01	363	425	37,93	2,0	32,46	21,75	55	10,086	204,42	0	17,05	0,086	0,12	0,68	0
SK23		1744	3010	354,90	29,1	149,5	62,35	621	122,93	404,35	0		0	10,62	2,3	0
SK24		260	323	22,12	4,6	30,13	12,47	16,2	9,95	165,38	0		0	7,87	0,42	0
SK25		5401	8240	1641,82	63,3	99,33	124,8	1925	940,52	606,36	0		0	16,09	0	0
SK29	7,2	852	1240	112,65	23,5	58,12	48,61	163	110,47	335,61	0	34,5	0		0	0
SK28	7	426	570	17,24	2,0	60,12	23,09	14,2	48,03	262,39	0	24,5	0		0	0
SK30	6,26	155	214	17,01	3,1	0	0	7,09	5,7636	122,04	0	8	0		0,06	
SK31	6,84	157	218	18,85	5,5	0	0	8,51	7,6848	115,94	0	6,6	0		0,2	0,1

TDS: Total dissolved solids; EC:Electrical conductivity

Hydrochemical facies

Hydrochemical evolution of groundwaters along their flowpath can be defined as: cation concentration order of shallow groundwater is: $Ca^{+2}>Mg^{+2}>Na^{+}>K^{+}$, cation concentration order of deep groundwater is $K^{+}> Na^{+}> Mg^{+2}> Ca^{+2}$ and anion concentration order of the shallow groundwater is: $CO_3^- + HCO_3^- > SO_4^- > Cl^-$ and finally anion concentration order of the deep groundwater is $Cl^- > SO_4^- > HCO_3^- + CO_3^-$.

Ca/Mg and Ca/Na ratios at the shallow groundwater are greater than Ca/Mg and Ca/Na ratios at the deep groundwater. Additionally, litology of the aquifer affects the chemical characteristics of the groundwater for example Ca and HCO_3 concentrations are high at the groundwater flowing in the limestone layer and Na concentration is more than the other elements at the groundwater which is flowing in the magmatic rock such as andesite or basalt. As an addition; SO_4 and Na concentrations are more than the other elements at the groundwater which is flowing in the clay stone or gypsum (Unsal and Çelik 2008).

Ca/Na, Ca/Mg and SO_4/Cl ratios of the groundwater samples taken from the springs and deep wells are depicted in Figure 6. Groundwater samples taken from the springs: K6, K7, K9 and K10 have high Ca/Na and SO_4/Cl ratios because these springs drain the water of limestone layers and these springs are the result of shallow circulation. Additionally groundwater samples taken from the wells: SK10, SK11, SK23, SK17 and SK18 have high Ca/Na ratio, these wells can

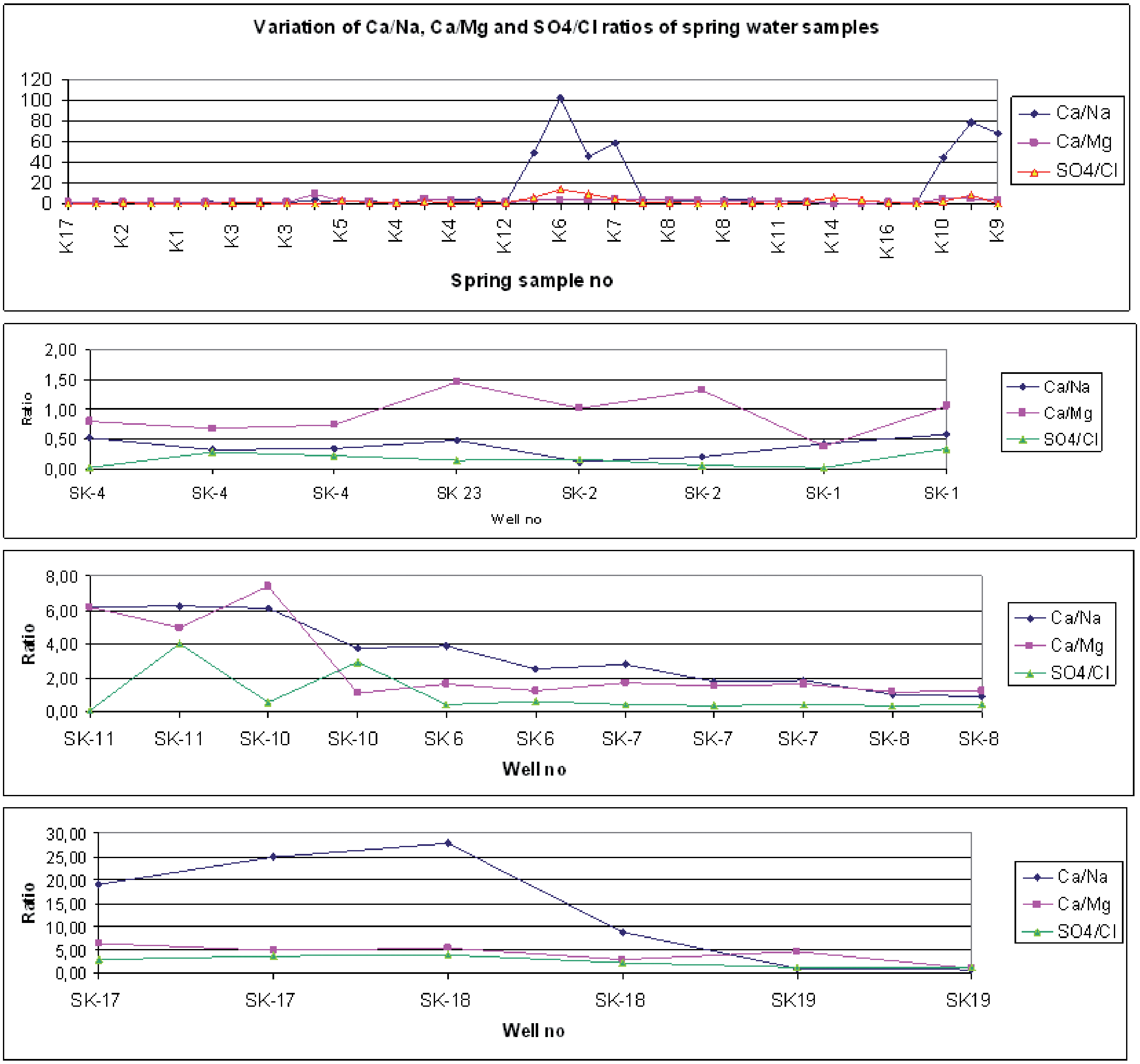

Fig. 6: *Ca/Na, Ca/Mg ve SO_4/Cl ratios of the groundwater samples.*

have shallow circulated groundwater.

Figure 7 shows Piper diagrams of the water samples which were collected at Develi Closed Basin. According to Piper diagrams it can be said that these groundwater samples have high concentrations of carbonate and bicarbonate. Bicarbonate concentration is high at the water samples which had been collected at the southern part of Develi Closed Basin because there is inflow through the aquifer from the limestone layers of Aladaglar Mountains (Yildiz, 2007).

Water samples which were collected at the northern side of Develi Closed Basin (SK1, SK2, SK5 water samples taken from the deep wells, Ilipinar, Cayirözü and Soysalli Springs), contain high concentrations of Na^{+} and Mg^{+2} cations because groundwater flows in the magmatic and volcanic rocks such as basalt, andesite and tuff. Derebag, Gozbasi, Dundarli, Karaboga and Kurbaga Springs which are located at the south of Develi Closed Basin, contain high concentration of Ca^{+2} and HCO_3^{-}, because these springs drain the water of the limestone layers.

DOI 10.4409/Am-032-11-0032

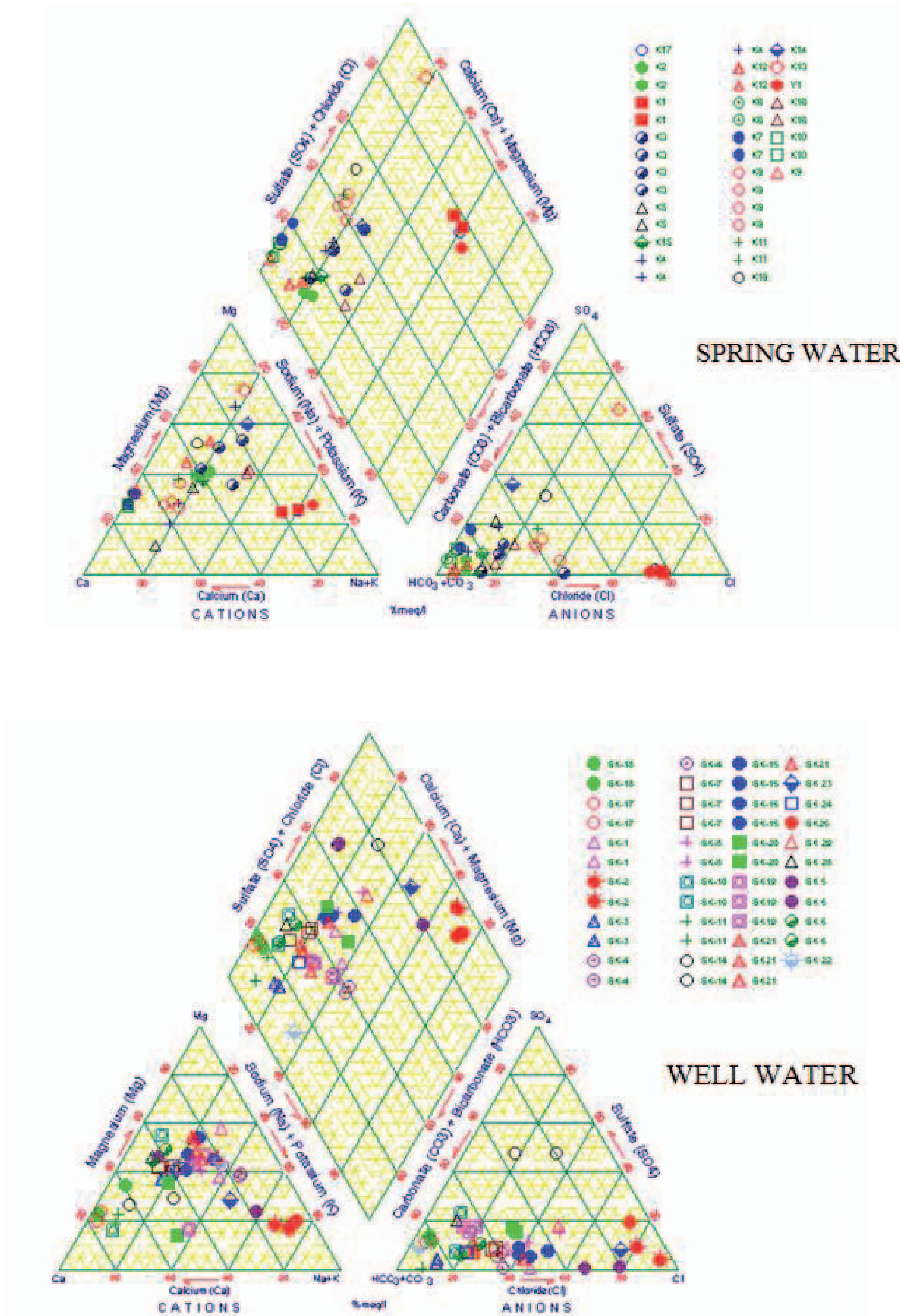

Fig. 7: *Piper diagrams of the groundwater samples.*

Saturation indices with respect to calcite, aragonite, gypsum, anhidrite and dolomite are calculated for the groundwater samples taken from the springs and wells of Develi Closed Basin. Saturation index values are shown at Figure 8. When Figure 8 is examined it is determined that groundwater samples taken from the wells are saturated with respect to dolomite, calcite and aragonite but undersaturated with respect to gypsum and anhydrite. For example spring water samples K11 and K9 (these springs flow in the limestone layers) are saturated for calcite, aragonite, dolomite and anhidrite but these samples are not saturated for gypsum. Additionally K12 spring water sample (this spring drains the water of basalt) is saturated for calcite but not saturated for aragonite, dolomite, gypsum and anhidrite.

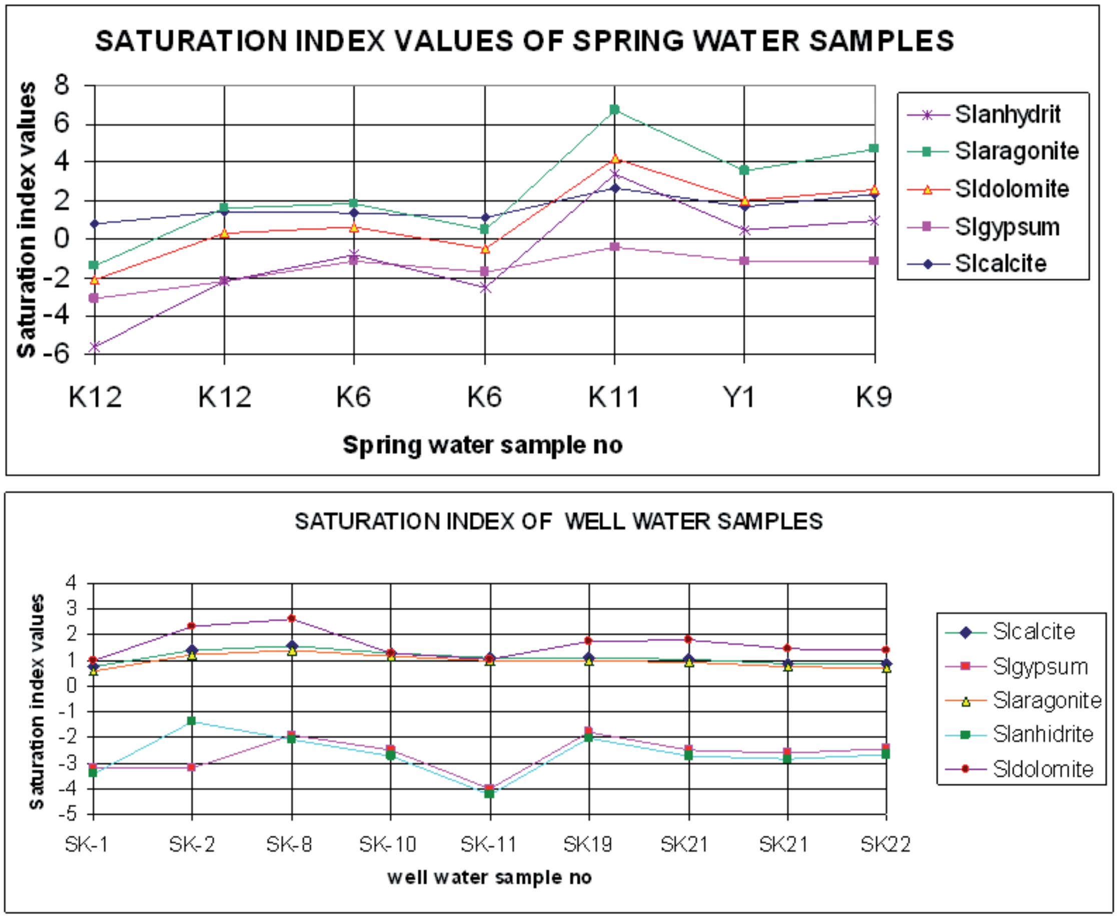

Fig. 8: *.Saturation index values of the groundwater samples*

Ionic composition variation graph for the spring water samples is shown in Figure 9. According to Figure 9; it can be said that groundwater sample (K1) taken from Ilipinar spring has high concentration of SO_4, Cl, Na and K. Because this spring is located near Ecemiş Fault (*see Figure 3 cross section III-III and Figure 5*) and drains water of magmatic and volcanic rocks such as andesite, basalt and tuff. According to the order of the ion concentrations of this spring; it can be said that Ilıpınar Spring drains deep circulated groundwater. Groundwater samples K6, K7, K8, K9, K10 and K11 taken from the springs; which are flowing in the limestone layers, have high concentrations of Ca, HCO_3 and CO_3 ions so these springs drain shallow circulated groundwater.

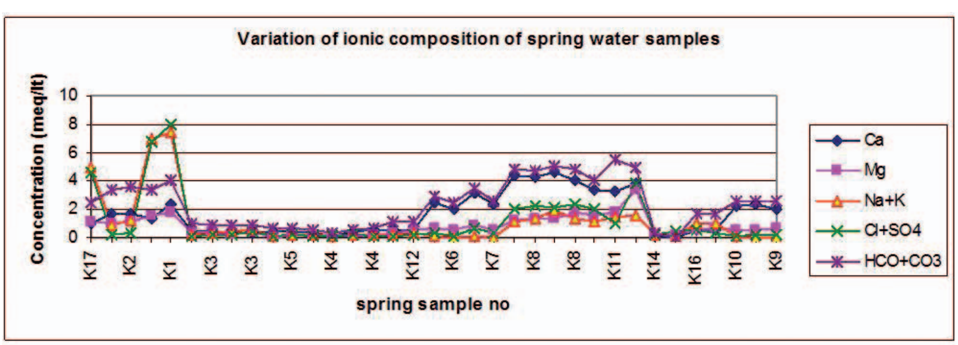

Fig. 9: *.Ionic composition of the spring water samples*

 DOI 10.4409/Am-032-11-0032

Water Quality

Electrical conductivity (EC) and total dissolved solid (TDS) values of 22 groundwater samples, which were collected from the wells and springs, are plotted on the graphs at Figure 10. According to Figure 10, TDS and EC values are close to each other at the groundwater samples taken from the wells but SK2, SK23 and SK25 groundwater samples have high EC values.

SK25 sample had been collected from the shallow well which is fed by the infiltrated salty surface water of Southern Marshland in Sultansazligi Wetland (according to the field observations it is determined that salty drainage water flow through Sultansazligi Wetland so salty drainage water increases the salt concentration of the surface water of this wetland (Yildiz, 2007)) so SK25 sample has high EC value.

Additionally SK2, SK23 groundwater samples taken from the deep wells have been polluted by the drainage water of Calbalma Drainage Water Pumping Station (Yildiz, 2007)), so TDS and EC values are high at the groundwater samples SK2 and SK23. Ilıpınar spring (K1 groundwater sample) which is placed at the Ecemiş Fault zone has high EC and TDS value, geothermal water coming from this fault increases EC and TDS values of Ilıpınar Spring. Additionally groundwater samples K6, K7, K8 and K18 taken from the springs (which are flowing out from the limestone layers) have high EC and TDS values.

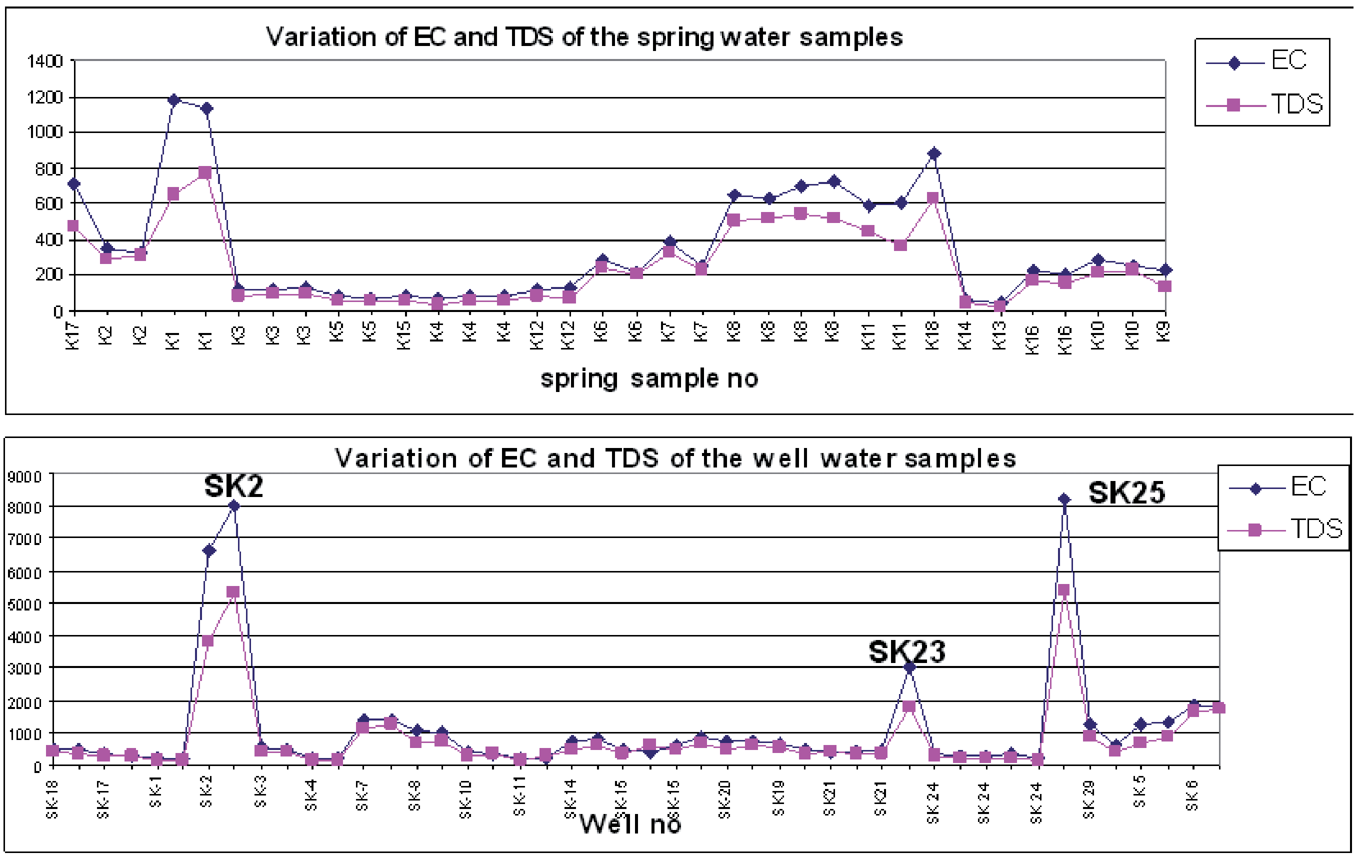

Fig. 10: *Electrical conductivity (EC)-total dissolved solid (TDS) values of groundwater. Samples (EC:µS/cm, TDS: mg/lt)*

Na ion increases the hardness of the water and if the irrigation water has high concentration of Na then this irrigation water can be harmful for the crops. So water which has high concentration of Na is not suitable for the irrigation. Na% and Sodium Absorption Ratio (SAR) values are computed according to the groundwater chemistry results for Develi Closed Basin in order to determine the groundwater quality for the irrigation. Irrigation water quality of the groundwater samples taken from the wells are shown in Table 4 and Table 5 shows irrigation water quality of the spring water samples. Groundwater samples SK2, SK23, SK25, K1 and K17 can not be seen in Table 4 and Table 5, because their hydrogeochemical characteristics (high EC, TDS and Na concentrations; *see Table 2 and Table 3*) do not fit to the irrigation water quality properties. Additionally boron concentration must not exceed 2 mg/lt, because crops are sensitive to boron concentration at Develi Closed Basin (Yildiz 2007), but SK 2 and K1 have high boron concentrations.

Na%, pH, TH and SAR variations of the groundwater samples taken from the springs and wells at Develi Closed Basin, can be seen at Figure 11. French water hardness is used for the water analysis. When Figure 11 is examined, it is determined that Ilipınar Spring water (K1), groundwater samples SK2 and SK6 taken from the deep wells have high Na% and total hardness (TH) values. Ecemiş Fault affects the hydrogeochemical properties of Ilipınar Spring. Calbalma Drainage Water Pumping Station pollutes deep well where SK2 groundwater samples had been taken. Additionally there is surface water pollution at the deep well where SK6 had been taken (Yildiz, 2007) so this water sample has high Na% and high total hardness value.

Table 6 shows the classification of the groundwater samples taken from the wells according to the total hardness and Table 7 shows the classification of the spring water samples according to the total hardness. When Table 6 and Table 7 are examined, it can be said that generally groundwater samples taken from the wells are not suitable to drink but generally spring water samples can be drinkable. But spring water samples K1, K8, K11 and K18 are hard water so they are not suitable for drinking water. Total hardness of SK2 is 57,8 and 108 ^{O}F, total hardness of SK6 is 92,85 and 95 ^{o}F and total hardness of SK7 is 60,15 and 63.1 ^{o}F. These water samples are very hard water so Table 7 does not include these water samples.

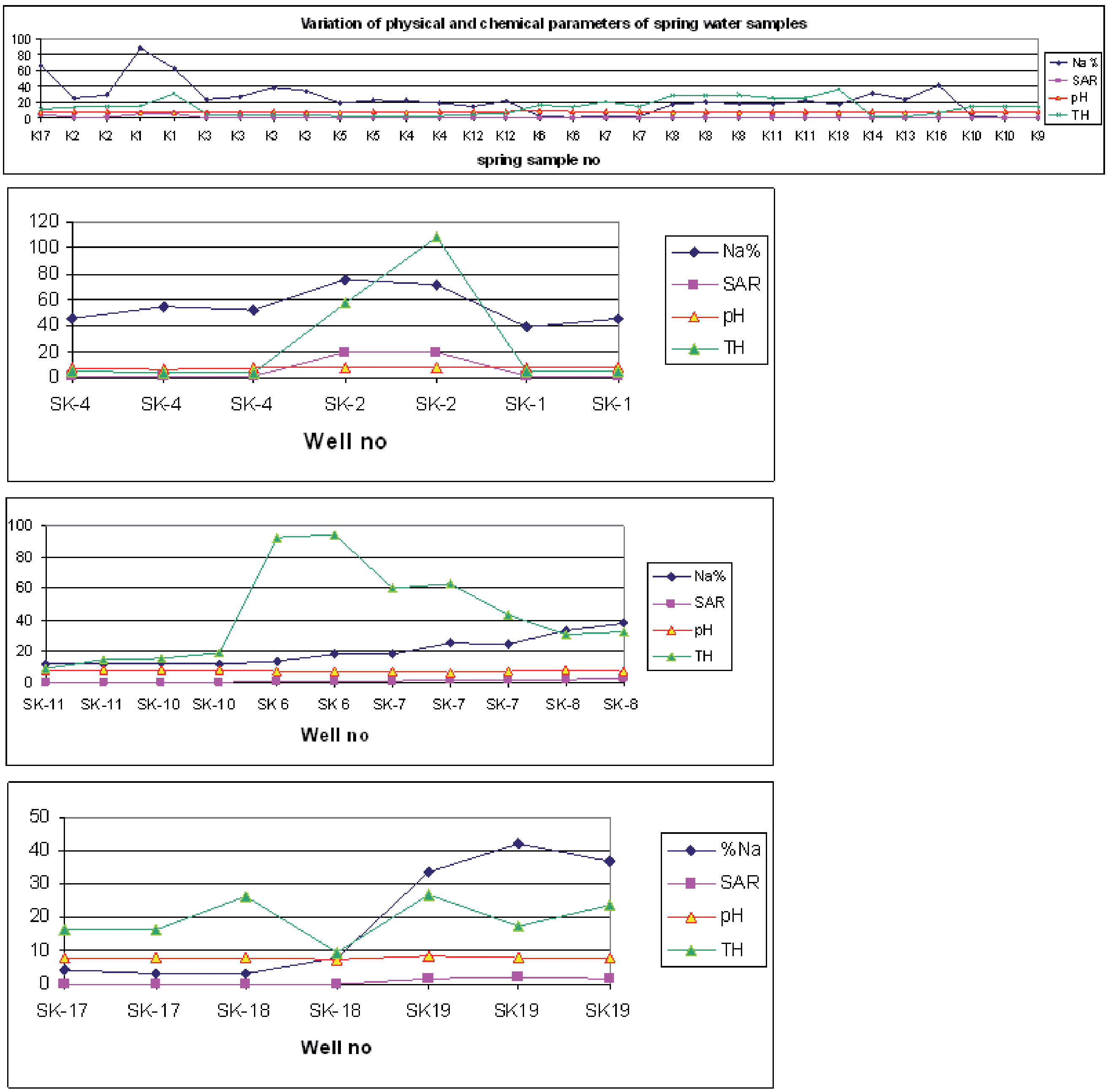

Fig. 11: *%Na, SAR, pH and Total Hardness of the groundwater samples)*

DOI 10.4409/Am-032-11-0032

Tab. 4: *Irrigation water quality of the water samples taken from the deep wells. Classification standart: Water pollution control regulation, 1991)*

SAR	EC (µS/ cm)	Water class	Deep well water sample code	Salinity probability in soil
< 10	250	Very good	SK1, SK4, SK30,SK31	Low
< 10	251-750	Good	SK3, SK5,SK10, SK11, SK14, SK15,SK17, SK18,SK19, SK20 SK21, SK24, SK28	Medium
< 10	751-2000	Utilizable	SK6, SK7,SK8	High
Na %	**Water Class**	**Deep well water sample code**		
<20	Very good	SK6, SK 10, SK 11, SK17, SK18		
21-40	Good	SK1, SK3, SK7, SK8, SK14, SK15, SK20, SK21, SK28, SK29		

Tab. 5: *Irrigation water quality of the spring water samples (Classification standart: Water pollution control regulation, 1991)*

SAR	EC (µS/ cm)	Water class	Spring water sample code	Salinity probability in soil
< 10	250	Very good	K3, K4, K5, K9, K12, K13, K14, K15	Low
< 10	251-750	Good	K2, K6,K7, K8, K10, K11, K17, K18	Medium
< 10	751-2000	Utilizable	K1	High
Na %	**Water class**	**Spring water sample code**		
<20	Very good	K6, K7, K8, K10, K18		
21-40	Good	K2, K3, K4, K5, K11, K12, K13, K14		

Tab. 6: *Classification of the water samples taken from the deep well according to hardness. (Classification reference: Unsal N, Celik M. (2008)*

Hardness(F°)	Water Class	Well no
0-10	Drinking water	SK1, SK4, SK30, SK31
11-22	Fresh water	SK3, SK5, SK10, SK11, SK24
23-32	Hard water	SK8, SK14, SK15, SK17, SK19, SK20, SK21, K28
33-54	Very hard water	SK18, SK29

Tab. 7: *Classification of the spring water samples according to hardness (Classification reference: Unsal N, Celik M. (2008))*

Hardness(F°)	Water Class	Spring no
0-10	Drinking water	K3, K4, K5, K12, K13, K14, K16, K17
11-22	Fresh water	K2, K6, K7, K9, K10
23-32	Hard water	K1, K8, K11
33-54	Very hard water	K18

Discussion

Develi Closed Basin is a pull-apart tectonic basin filled by the Quaternary sediment (alluvium) deposits. Volcanic rocks crop out at the northern side of the basin, volcanic Erciyes Mount is located at the north of Develi Closed Basin. Ecemiş Fault Zone, Erciyes Volcanism and rivers carrying sediment to the basin affect the geomorphology of Develi Closed Basin. The Aladaglar Masif, located at the south of the basin, is a mountain range formed by carbonate rock formations. Erciyes Volcanism, Ecemis Fault Belt and limestone layers of Aladaglar affect the groundwater character at the Develi Closed Basin.

Water samples which had been collected from Develi Closed Basin have high concentrations of carbonate and bi-carbonate. Chloride concentrations of the groundwater samples taken from wells are higher than the chloride concentrations of the spring water samples. Groundwater samples taken from wells are saturated to dolomite, calcite and aragonite but not saturated to anhidrite and gypsum.

Ilıpinar Spring is located on Ecemiş Fault so its EC, TDS and boron concentrations are very high, this spring water is not suitable for the irrigation and can not be used as the drinking water. Groundwater of the deep wells near Calbalma Drainage Water Pumping Station (where SK2 and SK23 groundwater samples had been taken) have high EC, TDS, Na and boron concentrations because of the drainage water pollution, so water of these wells are not suitable for the irrigation. Groundwater sample SK 25 taken from the shallow well near Sultansazligi Wetland (Southern Marshland) has high EC value because Southern Marshland feed this shallow well (Yildiz, 2007). Nitrate and ammonium pollution are determined at Soysallı and Dundarli Springs according to the former water chemistry analysis of these springs (*see Table 2 and Table 3*). Additionally deep wells at Yesilhisar District (water samples SK6, SK7) have high concentrations of EC because of surface water pollution.

Acknowledgment: The authors express their sincere thanks to the chemistry laboratory of 12th Regional Directorate of Turkish State Hydraulic Works for the water chemistry analysis, geophysical engineer Ms. Hatice Kutlug, geology engineer Mr.Sedat Celenk (MSc.) and Scientific Research Council of Gazi University for the financial support.

References

Bayari S., Yildiz F.E. (2011). Effects of the North Atlantic Oscillation and Groundwater Use on the Contraction of Sultansazligi Wetland. Hydrogeology Journal, ISSN 1431-2174, DOI 10.1007/s10040-011-0809-z, Springer Publication.

Dalay N. (2000). Water leakage effect to the groundwater, Agcasar Dam, Kayseri Turkey. Hacettepe University. Unpublished MSc Thesisi (in Turkish), Ankara, p.p 51-61.

Donmez M., Turkecan A., Akçay A.E. (2003). Report of volcanic rocks at Kayseri-Nigde and Nevsehir (in Turkish), General Directorate of Mineral Research and Exploration, Ankara, p.p. 81-84.

DSI. (1970). Hydrogeological investigation report of Develi Yesilhisar Plain, (in Turkish), Groundwater Department of Turkish State of Hydraulic Works, Ankara, p.p. 20-24.

DSI. (1995). Revised hydrogeological investigation report of Develi-Yesilhisar Plain (in Turkish), Groundwater Section of 12th Regional Directorate of Turkish State of Hydraulic Works, Kayseri, p.p. 1-19.

ENCON. (1999). Biological and ecological research report of internationally important wetlands (in Turkish) 2nd report, Ministry of Environment and Forestry, Ankara, p.p. 7-23.

Erol O. (1999). A geomorphological study of the Sultansazlığı Lake, Central Anatolia. Quaternary Science Reviews, 18: p.p.647-657.

Goncuoğlu CM., Toprak G.M.V., Kuscu I., Erler A., Olgun E. (1991). Geological report of the western side of Central Anatolia, Report 1 (in Turkish) Middle East Technical University, Ankara, p.p. 1-30.

Gurer I. (2004). Kayseri Sultansazligi Nature Protection Area Natural Resource Management Project, Water Resources Management and Use, Final Report, Republic of Turkey, Ministry of Environment and Forestry, Publication of General Directorate of National Park and Wildlife, Ankara, Turkey.

Gurer I., Yildiz F.E., Unsal N. (2005). Classical water budget computation of Kayseri -Develi Closed Basin (in Turkish), Proceeding of 2nd National Water Engineering Symposium, Izmir, p.p. 95-105.

Gurer I., Yildiz F.E. (2007). Uncertainities in the water budget computatıons of Develi Closed Basın in Turkey, International Conference on Environment: Survival and Sustainability, Nicosia, Cyprus, p.p.596.

Kara H. (1997). Report of the geologial map of Turkey G19 (in Turkish) General Directorate of Mineral Research and Exploration, Ankara, p.p.10-30.

Kaya N., Yurdagul M. (2001). Determination of water leakage at Agasar Dam (Kayseri-Yahyali) by using groundwater observations (in Turkish), Proceeding of 3rd National Hydrology Congress Izmir, p.p. 503-510.

Unsal N., Celik M. (2008). Hydrogeochemistry along the flow path of a confined aquifer, Duzce Plain North Western Turkey, Bull.Eng.Geol.Environment, 67: p.p.267-275.

Ministry of Environment (1991). Water Pollution Control Regulation

Yildiz F.E. (2007). Determination of groundwater-surface water interaction at Sultansazlığı Wetland (Kayseri) (in Turkish) Unpublished PhD thesis, Institute of Science and Technology, Gazi University, Ankara p.p. 109-122.

 DOI 10.4409/Am-032-11-0032