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Precipitation and Air Temperature Impact on Seasonal Variations of Groundwater Levels

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***Abstract* – The aim of this study is to clarify seasonal effects of precipitation and temperature on groundwater level changes in monitoring stations of the Latvia University of Agriculture - Mellupīte, Bērze and Auce. Groundwater regime and level fluctuations depend on climatic conditions such as precipitation intensity, evapotranspiration, surface runoff and drainage, as well as other hydrological factors. The relationship between precipitation, air temperature and groundwater level fluctuations could also lead and give different perspective of possible changes in groundwater quality. Using mathematical statistics and graphic-analytic methods it is concluded that autumn and winter precipitation has the dominant impact on groundwater level fluctuations, whereas spring and summer season fluctuations are more dependent on the air temperature.**

***Keywords* – air temperature, groundwater level, precipitation intensity, seasonal variations**

I. Introduction

Groundwater is one of the most important Latvian natural assets. Shallow groundwater is the top layer of groundwater, which is generally situated in the Quaternary deposits above layers with low permeability, for example, clay layers. Investigations of the relationships between the amount of precipitation, air temperature and variations in the level of groundwater are necessary to facilitate the evaluation of the impact of variations in the level of groundwater on the water quality. It has been proven, utilising various climate models, that, with the increase of the air temperature in the future, the levels of groundwater could increase also during the winter [1]. High levels of groundwater could possibly accelerate the overflow of biogenic substances in the soil massif into groundwater, as well as into the surface water ecosystems. Increased leaching of biogenic elements (predominantly, nitrogen and phosphorus compounds) from the soil is associated with the winter season, when there is no vegetation that consume plant nutrients [2]. The investigation of relationships between the levels of groundwater and meteorological data are also important in order to adjust and improve the model of the balance and regime of groundwater model METUL [3].

As groundwater is the first permanent groundwater aquifer (starting from the earth surface), while groundwater is involved in the single water circulation in nature, groundwater possesses the features of renewable water resources. The groundwater regime and, in particular, that of groundwater and fluctuations of its levels have climatic character in Latvia. Fluctuations of the levels of unconfined groundwater depend on the climatic conditions, such as rainfall intensity and quantity, air temperature, cumulative evaporation or evapotranspiration, surface run-off, as well as on other hydrological, hydrometeorological and relief factors [4], [5] and [6]. Changes in the levels of unconfined groundwater (thus an increase or decrease of the groundwater resources) are seasonal during the year – the level increases during the spring and autumn, and decreases during the winter and, in particular, during the summer [7].

Most of groundwater is formed by the infiltration of precipitation or other surface water (from water bodies and watercourses). Its formation occurs during the time when the amount of precipitation is greater than evapotranspiration. Two stages must be singled out in the process of the formation of groundwater from the precipitation water: the first one is the penetration of the precipitation water into the soil (infiltration), while, during the second stage, after the saturation of the soil with water, its influx (percolation) into the groundwater aquifer starts [7].

The regime of groundwater levels depends mostly on the amount of atmospheric precipitation, air temperature, lithological composition of rocks and degree of the drainage capacity of the area [8].

The purpose of this study is to determine the seasonal impact of precipitation and air temperature on the variations in groundwater levels at the existing monitoring stations that are supervised by the Latvia Agricultural University – Mellupīte, Bērze and Auce.

II. Characteristics of the Study Area

Data of the observations of groundwater levels from the three existing monitoring stations that are supervised by the Latvia University of Agriculture (LLU) have been used in the study – Mellupīte (Zaņa Parish, Saldus County), Bērze (Jaunbērze Parish, Dobele County) and Auce (Lielauce Parish, Auce County) (Fig. 1).

12 groundwater level monitoring wells have been drilled in the above-mentioned areas – 4 wells in Auce, 5 wells in Bērze and 3 wells in Mellupīte; measurements of the groundwater level are made automatically using loggers placed in the wells (Geolog Micro). The loggers automatically read the levels of groundwater (mm) and the water temperature (0) once every hour and calculate the average measurement for 24 hours.

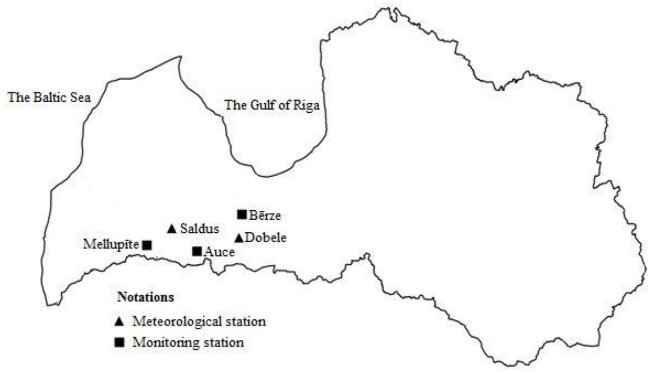

Fig. 1. Meteorological stations and monitoring stations of LLU

The monitoring stations are situated in the areas with different physical-geographic conditions (the main parameters characterizing the area are summarized in Table I), so meteorological data (daily amount of precipitation and air temperature) were obtained using the observations from the Dobele and Saldus meteorological stations.

Respectively, the data from the Dobele meteorological station have been used for the analysis of the levels of unconfined groundwater from the Bērze monitoring station, while the data from the Saldus meteorological station have been used for the analysis of the levels of unconfined groundwater from the Auce and Mellupīte monitoring stations (Fig. 1).

Three monitoring wells from each monitoring station have been selected for analysis: Mellupīte – MG1, MG2 and MG3; Bērze – BG2, BG3 and BG4; Auce – AG1, AG2 and AG3. Each of those wells is characterised in Table II. Nine soil sampling drillholes have been drilled in the territories of the monitoring stations – 5 boreholes in Auce, 1 borehole in Bērze and 3 boreholes in Mellupīte, with the purpose of obtaining soil samples for the grain-size analysis and determination of the hydraulic conductivity. The data obtained from the boreholes are summarised in Table II.

TABLE I

CHARACTERISTICS OF MONITORING STATIONS

	Monitoring station		
	Auce	**Bērze**	**Mellupīte**
Location	Auce County, Lielauce Parish	Dobele County, Jaunberze parish	Saldus county, Zaņa parish
The average annual air temperature *	+7.29 ^{0}	+8.08 ^{0}	+7.02 ^{0}
Month with the lowest average temperature *	February (-3.9 ^{0})	February (-3.3 ^{0})	February (-3.37 ^{0})
Month with the highest average temperature *	July (+16.8 ^{0})	August (+17.8 ^{0})	July (+16.79 ^{0})
The average annual amount of precipitation *	762 mm	566 mm	767 mm
Month with least average amount of precipitation *	February (45 mm)	February (32 mm)	February (44 mm)
Month with most average amount of precipitation *	July (110 mm)	July (76 mm)	July (107 mm)

* The average values of the observation period (2006-2009) used in the study

TABLE II

THE CHARACTERISTICS OF BOREHOLES USED IN THE STUDY

Number of the borehole	Depth of the borehole, m	Soil sampling depth, m	Sand, %	Silt, %	Clay, %	Filtration coefficient in territory of the monitoring station, m/d	The average groundwater depth below land surface, cm
Auce							
AG1	6.00	-	-	-	-	7.46	72.60
AG2	6.00	-	-	-	-		141.30
AG3	11.00	-	-	-	-		77.38
AP1*	1.10	0.00-0.20	92.1	7.1	0.8		-
		0.20-0.65	82.5	15.4	2.1		
		0.65-1.10	95.4	4.2	0.4		
AP2*	1.54	0.00-0.60	89.3	9.8	1		-
		0.60-1.54	-	91	9		
AP3*	4.10	0.00-0.40	78.3	18.8	2.8		-
		0.40-0.60	82.2	16.4	1.4		
		0.60-0.75	73.7	25.2	1.1		
		0.75-2.00	-	90	10		
		2.00-2.40	-	91	9		
		2.40-3.10	-	93	7		
		3.10-3.50	89.3	8.4	2.4		

		3.50-3.70	79.8	18.3	1.8		
		3.70-4.10	-	99	1		
AP4*	2.00	0.00-0.30	79.1	20.3	0.6		-
		0.30-0.50	78.5	20.6	0.9		
		0.50-0.65	83	14.6	2.2		
		0.65-1.10	-	96	4		
		1.10-2.00	-	97	3		
AP5*	3.20	0.00-2.60	-	89	11		-
		2.060-3.20	-	90	10		
Mellupīte							
MG1	7.00	-	-	-	-	2.46	181.18
MG2	4.50	-	-	-	-		181.73
MG3	11.00	-	-	-	-		299.26
MP1*	3.90	0.00-0.45	59.9	28.4	12.2		-
		0.45-0.65	66.9	28.8	4.3		
		0.65-1.10	-	82	18		
		1.10-1.90	71.1	27.1	1.7		
		1.90-3.90	-	82	18		
MP2*	2.60	0.00-1.00	-	94	6		-
		1.00-2.25	-	91	9		
		2.25-2.60	-	93	7		
MP3*	2.00	0.00-0.35	-	90	10		-
		0.35-2.00	-	80	20		
Bērze							
BG2	6.00	-	-	-	-	0.77	152.12
BG3	8.00	-	-	-	-		84.04
BG4	6.00	-	-	-	-		172.68
BP1*	4.15	0.00-0.25	-	72	28		-
		0.25-0.75	-	52	48		
		0.75-1.70	-	57	43		
		1.70-3.40	-	86	14		
		3.40-4.15	-	87	13		

* The profile bore in territory of the monitoring station

III. Methods

It was already mentioned that fluctuations of the levels of groundwater depend on the rainfall intensity and quantity, air temperature, cumulative evaporation and other factors. The rainfall intensity and air temperature are obtained from direct measurements; hence their impact on fluctuations of the levels of groundwater is mutually comparable [9]. In turn, cumulative evaporation is the value that is calculated indirectly; it can be calculated using various formulas and it depends on several parameters – air temperature, wind velocity, relative humidity etc. [3] and [10].

The methodology applied in the study is based on an empirical study of rainfall intensity and groundwater recharge [11], where the dataset was subdivided into 5-day, 11-day and 13-day periods, depending on the rainfall intensity; the amount of precipitation for the relevant period was summed, and correlation graphs of the amount of precipitation versus changes in the groundwater level during the selected time period were produced. The following conclusion was made as a result of the study: an increase in the groundwater level and its recharge occur, predominantly, when the amount of precipitation exceeds 10 mm per day [11].

In order to evaluate the impact of rainfall intensity and air temperature on fluctuations of the levels of groundwater, 3 hydrological years from the period of observations 2006 – 2009 were analysed, using both graphical-analytical and mathematical-statistical methods. A hydrological year starts on October 1 and ends on September 30 the next year. Four seasons of each hydrological year were investigated – autumn (September, October, November), winter (December, January, February), spring (March, April, May) and summer (June, July, August). In order to determine the impact of rainfall intensity and air temperature on fluctuations of the levels of groundwater, the obtained data on the levels of groundwater were subdivided into periods of 10 days, i.e. the first period incorporated days from 1 to 10 of each month, days 11 – 20 comprised the second period and so on. The following parameters were calculated for the selected periods: the change in the levels of groundwater (cm), the total amount of precipitation (mm) and the average air temperature (0C). The change in the levels of groundwater was determined mathematically, by deducting the initial level for the period from the final level for the period. The obtained value is positive, if the level of groundwater has decreased during the period, or negative, if the level of groundwater has increased. Based on the obtained data, correlation graphs were produced for each month of each hydrological year. Based on the obtained data, an average correlation value for each season for the whole period of observations was determined. The average correlation value demonstrates the dominance of the amount of precipitation or air temperature over fluctuations of the levels of groundwater, i.e. if the obtained correlation value for precipitation is greater than the correlation value for air temperature for the same season, it may be concluded that the impact of the amount of precipitation on fluctuations of the levels of groundwater was greater than that of air temperature for the relevant season.

In order to determine the soil composition and the hydraulic conductivity in the territories of the monitoring stations, an analysis of the grain-size composition was carried out – the sieving method was used for the sandy samples, and the hydrometric analysis – for clayey samples [12]. Based on the obtained results, using a nomograph for the determination of the grain-size composition of topsoil and soil [13], the soil type was determined; loamy sand predominates in Auce, silt loam predominates in Bērze, while sandy loam and silt predominate in Mellupīte; the percentage of sand, silt and clay in the geotechnical boreholes (by layer) was also determined (Table II). To simplify calculations, it was necessary to define constant unified hydraulic conductivity for each soil type using the proportionality principle (hydraulic conductivity for sand vary within 1-100 m/day and those for clay 0.01-0.2 m/day [7]) for the territories of all 3 monitoring stations: the one adopted for sand was 20 m/day, for silt – 1 m/day, and for clay – 0.08 m/day (selected by the authors).

IV. Results

The graphic-analytic evaluation has demonstrated that, depending on the air temperature and amount of precipitation, the level of groundwater in the wells decreases or increases. The results of the graphic-analytic evaluation (by season) are summarised in Table III. In the Zemgale region, where the monitoring stations dealt with in the study are situated, the level of groundwater increases during the autumn because of the decrease in the air temperature, while, during the spring, the level of groundwater initially increases due to the rapid melting of the snow cover because of higher air temperature. The level of groundwater decreases later during the spring because the air temperature continues to increase.

TABLE III

Results of the Graphic-Analytic Evaluation

	Air temperature	**Groundwater level change in temperature affects (“+” or “-”)**	**Precipitation per day**	**Groundwater level change in rainfall affects (“+” or “-”)**	**Delay of the groundwater level changes, days**
Autumn					
Auce	0^0 - $+5^0$	+ (0.3-0.4 m)	above 5 mm	+ (0.05-0.15 m)	delay not observed
Bērze	0^0 - $+5^0$	+ (0.7-0.8 m)	above 5 mm	+ (0.1-0.2 m)	2-4 days after rain
Mellupīte	0^0 - $+5^0$	+ (0.6-0.8 m)	above 5 mm	+ (0.1-0.2 m)	1-2 days after rain
Winter					
Auce	-10^0 - 0^0	- (0.2-0.3 m)	above 5 mm	effect not observed	delay not observed
Bērze	-10^0 - 0^0	- (0.8-1.0 m)	above 5 mm	effect not observed	2-4 days after rain
Mellupīte	-10^0 - 0^0	- (0.5-0.6 m)	above 5 mm	effect not observed	1-2 days after rain
Winter (thaw)					
Auce	above 0^0	+ (0.05-0.1 m)	above 5 mm	+ (0.05-0.1 m)	delay not observed
Bērze	above 0^0	+ (0.15-0.2 m)	above 5 mm	+ (0.15-0.2 m)	2-4 days after the thaw accession
Mellupīte	above 0^0	+ (0.1-0.15 m)	above 5 mm	+ (0.1-0.15 m)	1-2 days after the thaw accession
Spring (flood)					
Auce	0^0 - $+5^0$	+ (0.15-0.25 m)	above 5 mm	effect not observed	delay not observed
Bērze	0^0 - $+5^0$	+ (0.8-0.9 m)	above 5 mm	effect not observed	delay not observed
Mellupīte	0^0 - $+5^0$	+ (0.25-0.3 m)	above 5 mm	+ (0.05-0.1 m)	delay not observed
Spring					
Auce	$+5^0$ - $+10^0$	- (0.35-0.5 m)	above 5 mm	+ (0.05 m)	delay not observed
Bērze	$+5^0$ - $+10^0$	- (1.0-1.15 m)	above 5 mm	effect not observed	delay not observed

Mellupīte	$+5^0$ - $+10^0$	- (0.8-0.9 m)	above 5 mm	effect not observed	delay not observed
Summer					
Auce	$+10^0$ - $+20^0$	stable summer water table	above 5 mm	+ (0.05-0.2 m)	delay not observed
Bērze	$+10^0$ - $+20^0$	stable summer water table	above 5 mm	+ (0.1-0.3 m)	2-4 days after rain
Mellupīte	$+10^0$ - $+20^0$	stable summer water table	above 5 mm	+ (0.1-0.3 m)	1-2 days after rain

"+" Groundwater level increasing in the well
"-" Groundwater level declining in the well

Groundwater levels depend on the air temperature during the winter season – when the air temperature is negative, the level of groundwater decreases, when the air temperature is positive for a short period of time (a thaw occurs), but the topsoil is still frozen, the level of groundwater increases. Some specialists consider that the frozen topsoil does not filter water, but observations in situ do not support such a point of view. The frozen topsoil layer does not hinder the gravitational water flow. The permeability of the frozen layer is greater, if it has been drier during the freezing [14].

The impact of precipitation is the most evident during the summer and autumn seasons. When the amount of precipitation exceeds 5 mm per day, an increase in the level of groundwater is observed. After the end of rainfall, the level of groundwater stabilises gradually to the initial level. With the amount of precipitation up to 5 mm/day, the water retention in topsoils (topsoil humidification, evaporation) and overgrow (transpiration) can reach 57-100% [15].

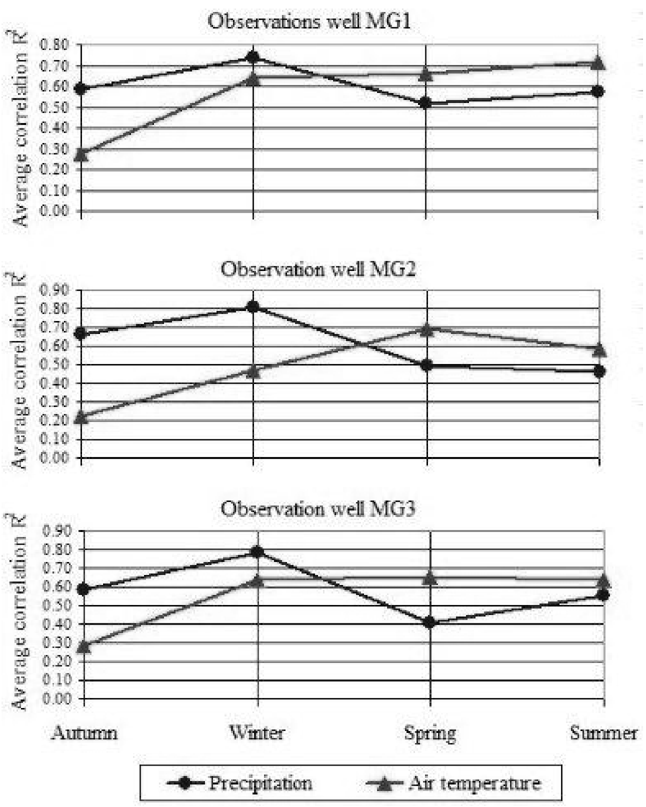

Fig. 2. The average correlation value over the seasons in wells of monitoring station Mellupīte

Evaluating relationships of the totality of samples using the mathematical statistical analysis, the correlation value R2 is determined, which demonstrates how great is the impact of precipitation and air temperature on the levels of groundwater in the wells of the monitoring stations. The results of the analysis are summarized in Table IV. As regards the wells of the Mellupīte and Bērze monitoring stations, the impact of precipitation on the levels of groundwater is predominant during the autumn and winter seasons, while, during the spring and summer seasons, the impact of air temperature on the fluctuations of the levels of groundwater is the most important (Fig. 2 and 3). The situation in the Auce monitoring station is different due to the influx of spring water in the wells, which upset normal fluctuations of the levels of groundwater influenced by the amount of precipitation and air temperature (Fig. 4).

TABLE IV
RESULTS OF THE MATHEMATICAL STATISTICS ANALYSIS

	Correlation of rainfall to the groundwater level	Correlation of air temperature to groundwater level
Mellupīte; borehole MG1		
Autumn	0.5876	0.2735
Winter	0.7373	0.6403
Spring	0.5162	0.6603
Summer	0.5696	0.7159
Mellupīte; borehole MG2		
Autumn	0.6589	0.2200
Winter	0.8083	0.4658
Spring	0.4887	0.6935
Summer	0.4652	0.5836
Mellupīte; borehole MG3		
Autumn	0.5858	0.2827
Winter	0.7827	0.6411
Spring	0.4099	0.6555
Summer	0.5553	0.6392
Auce; borehole AG1		
Autumn	0.4140	0.4464
Winter	0.6519	0.6262
Spring	0.5024	0.7556
Summer	0.5103	0.5696
Auce; borehole AG2		
Autumn	0.3252	0.1733
Winter	0.6169	0.4579

Spring	0.6761	0.4725
Summer	0.5077	0.4840
Auce; borehole AG3		
Autumn	0.4334	0.5558
Winter	0.5348	0.3852
Spring	0.6786	0.4593
Summer	0.4570	0.2786
Bērze; borehole BG2		
Autumn	0.7084	0.4533
Winter	0.6043	0.5059
Spring	0.3812	0.5697
Summer	0.3993	0.8323
Bērze; borehole BG3		
Autumn	0.7084	0.4533
Winter	0.6043	0.5059
Spring	0.3014	0.3090
Summer	0.4610	0.6616
Bērze; borehole BG4		
Autumn	0.7906	0.5077
Winter	0.5560	0.6274
Spring	0.6026	0.9971
Summer	0.5314	0.4799

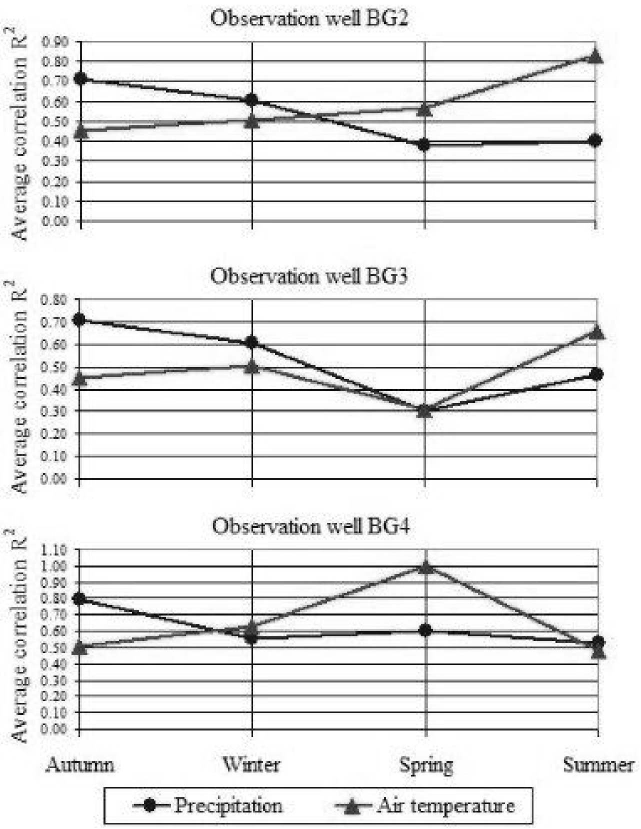

Fig. 3. The average correlation value over the seasons in wells of monitoring station Bērze

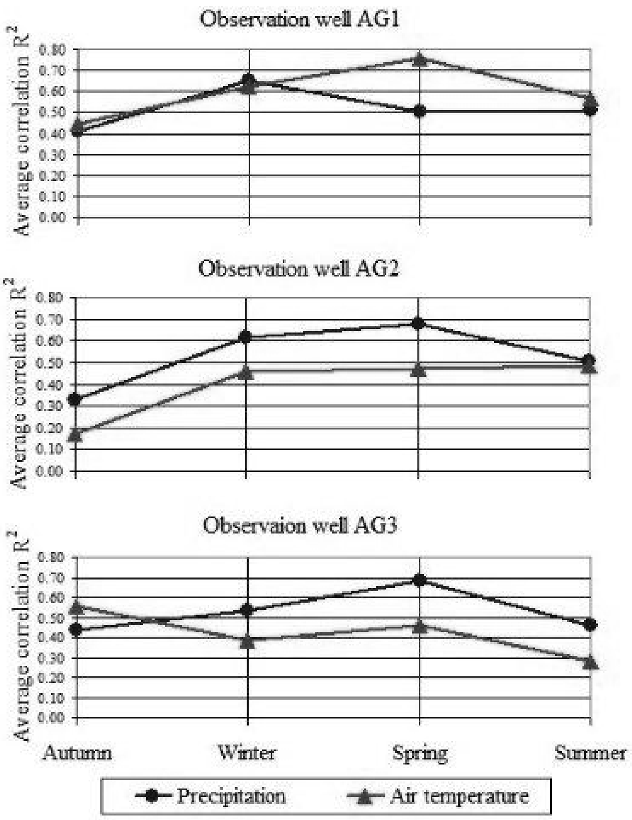

Fig. 4. The average correlation value over the seasons in wells of monitoring station Auce

V. DISCUSSION

Evaluating the results from all three monitoring stations obtained using the methods of the graphic-analytic and mathematical statistical analysis, it has been confirmed that the level of groundwater increases during the spring and autumn, and decreases during the winter and, in particular, during the summer [7]. Fluctuations of the level of groundwater during each season are, predominantly, determined by one or the other of the parameters under discussion.

The level of groundwater during the autumn and winter seasons varies under the impact of the amount of precipitation – the level of groundwater increases, if the air temperatures are above zero and the amount of precipitation exceeds 5 mm per day. A relationship is observed during that period of time that, when the air temperature gradually decreases to 0^0, the level of groundwater increases steadily, due to the fact that, under the influence of low air temperature, rainwater is unable to evaporate completely and penetrates into the groundwater. It is called “the autumn-winter increase”, which is influenced by the amount of atmospheric precipitation and its intensity during the autumn and winter seasons, and it ends when a period with negative air temperatures occurs [16]. The amount of precipitation, which is smaller than 5 mm per day during the autumn season, does not significantly influence fluctuations of the level of groundwater. When the air temperature decreases below 0^0, the level of groundwater decreases as well, but, during the winter season, when a thaw and positive air temperatures occur, the level of groundwater tends to increase by 0.2-0.3 m in Auce, by 0.8-1.0 m in Bērze and by 0.5-0.6 m in Mellupīte. As a result of the temperature decrease below 0^0, capillary ascent of groundwater takes place from deeper and warmer layers towards higher layers that are closer to the earth's surface, which explains the decrease of the level of groundwater during the winter [17]. With water moving up, the topsoil pores are filled with water, which then also freezes. This is called “the pre-spring lowering”, the duration of which depends on the duration of the period of constant negative air temperatures in connection with the cessation of infiltration in the aeration zone during the freezing period [16].

Within the framework of the Wyoming study, three groundwater recharge episodes were singled out, depending on the depth of a groundwater aquifer/level. Our study corresponds to the part of the above-mentioned study, which characterises high levels of groundwater, and it can be stated that it confirms the conclusions of scientists of the University of Wyoming, i.e. the regime of the top layer of groundwater is closely related to the amount of precipitation. Most of short-term rainfall generates separate processes of recharge of the levels of groundwater, and, depending on the existing depth of the level of groundwater, the level increase episodes for such rainfall are distinguishable from one another [18].

The fluctuations of the level of groundwater during the spring and summer seasons depend on the air temperature. During the spring, with an increase in the air temperature, the level of groundwater increases as well, by 0.15-0.3 m due to the melting of the snow cover and ice. With the air temperature increasing, the melting starts from the bottom of the frozen topsoil layer, thus increasing the level of groundwater [17]. It is also called “the spring increase”, starting from the start of the period of positive air temperature; its duration and size depend on the thickness of snow accumulated during the winter period and intensity of its melting [16]. When the air temperature increases above $+10^0$, the level of groundwater gradually decreases by 0.35-0.50 m in Auce, by 1.00-1.15 m in Bērze and by 0.80-0.90 m in Mellupīte, and the summer levels become stable – 2.00 m below the earth surface in Mellupīte, 2.20 m below the earth surface in Bērze and 1.50 m below the earth surface in Auce. During the time period when the level of groundwater steadily decreases, there is no infiltration of rainwater into groundwater, because of the fast evaporation of precipitation under the influence of relatively high air temperatures. The above-mentioned decrease of the level of groundwater is called “the summer-autumn decrease”, which is associated with intensive evaporation from the top of groundwater during the vegetation period [16].

It was observed analyzing the data that the impact of the amount of precipitation on the fluctuations of the level of groundwater at the monitoring objects occurs with a time delay, i.e., at the Mellupīte monitoring station, the level of groundwater increases 1 - 2 days (Fig. 5) after the amount of precipitation exceeds 5 mm/day, at the Bērze monitoring station – 2 - 4 days later (Fig. 6), while, at the Auce monitoring station, the level of groundwater increases exactly on the day when the observed amount of precipitation has exceeded 5-10 mm (Fig. 7) (the most characteristic well for each monitoring station is shown in the figures).

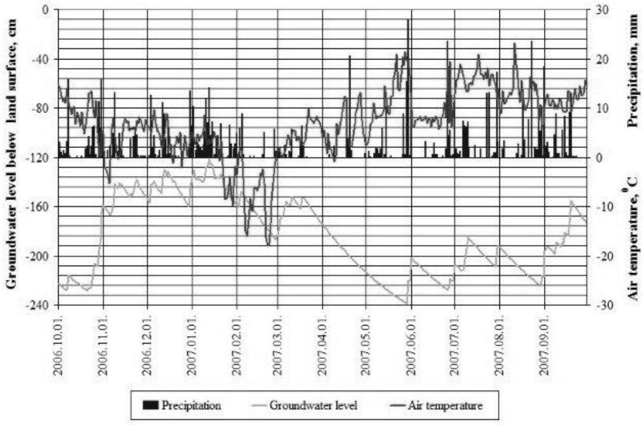

Fig. 5. Observed precipitation, air temperature and groundwater level in the borehole MG1 (2006 - 2007 hydrological year)

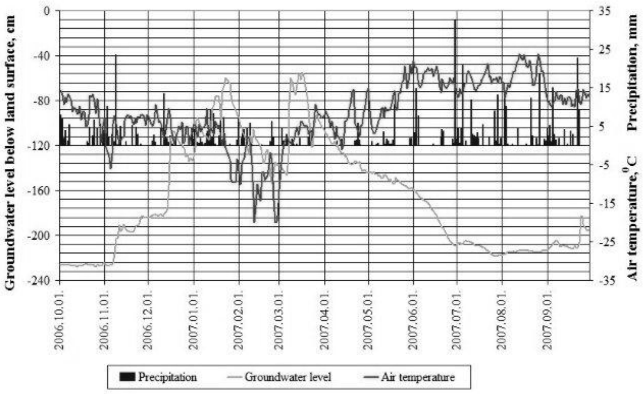

Fig. 6. Observed precipitation, air temperature and groundwater level in the borehole BG3 (2006 – 2007 hydrological year)

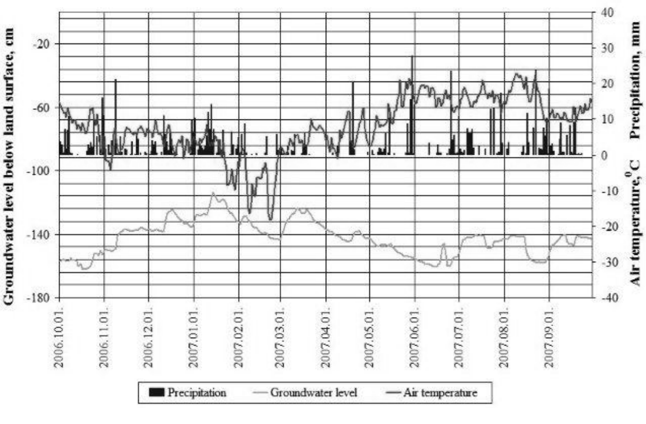

Fig. 7. Observed precipitation, air temperature and groundwater level in the borehole AG1 (2006 - 2007 hydrological year)

If the amount of precipitation is smaller, no increase of the levels of groundwater is observed in the wells of the monitoring stations. That is explained by different grain-size composition of soils at those monitoring stations and the average depth of the levels of groundwater.

The shallowest groundwater table is at Auce. The average level of groundwater there was 0.72-1.41 m below the earth surface during the period of observations, depending on the well. Loamy sand predominates in the area, with the hydraulic conductivity k=7.69 m/day, which ensures that the precipitation that has failed to evaporate infiltrates in the soil and influences the level of groundwater on the same day when the amount of precipitation exceeds 5 mm, increasing it. The average levels of groundwater at the Mellupīte monitoring station are the deepest for the areas under discussion (1.81 – 2.99 m below the earth surface, depending on the well). Sandy loam and silt soils with the hydraulic conductivity k=2.46 m/day are predominant there, which ensures that the precipitation that has failed to evaporate infiltrates in the soil and increases the level of groundwater with an average delay of 1 to 2 days. In turn, studying the Bērze monitoring station, we can see that the prevailing silt loam soils have a very low hydraulic conductivity k=0.77 m/day, while the average level of groundwater is 0.84 – 1.73 m below the earth surface, which is the reason why the level of groundwater increases 2 to 4 days after the amount of precipitation exceeds 5 mm/day (Table II).

VI. Conclusions

As a result of the study, the predominant impact of meteorological conditions (air temperature and amount of precipitation) on the fluctuations of the level of groundwater by the season has been proven, using the graphic-analytical method and the method of mathematical statistical analysis. It is possible to utilise the methodology utilised during the study for the analysis of levels of groundwater depending on the amount of precipitation and air temperature.

At the Mellupīte and Bērze monitoring stations, during the autumn (Sepember, October, November) and winter (December, January, February) seasons, the impact of the amount of precipitation on the fluctuations of the level of groundwater is predominant. That is observed during the periods, when the air temperature varies from 0^0 to $+10^0$, and the amount of precipitation exceeds 5-10 mm per day.

In turn, during the spring (March, April, May) and summer (June, July, August) seasons, the level fluctuations depend on the average air temperatures, if they vary from 0^0 to $+10^0$.

When the air temperature is from 0^0 to $+10^0$, the levels of groundwater increase, but, when the air temperature decreases (0^0 to -10^0), the level of groundwater decreases as well. If the air temperature is above $+10^0$ or below -10^0, the levels of groundwater stabilise at the level below the earth surface, which is characteristic for summer or winter, correspondingly.

The correlation of the air temperature amount of precipitation with the levels of groundwater for the wells of the Auce monitoring stations is not as good as that observed in the wells of the Bērze and Mellupīte monitoring stations. That is explained by the influx of spring water in the wells of the Auce monitoring station, which distorts normal fluctuations of the level of groundwater under the influence of the amount of precipitation and air temperature.

The delay of the impact of precipitation is most evident in the areas with a low soil hydraulic conductivity, i.e. the lower the hydraulic conductivity, the later fluctuations of the level of groundwater are observed after rainfall, with the same levels.

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