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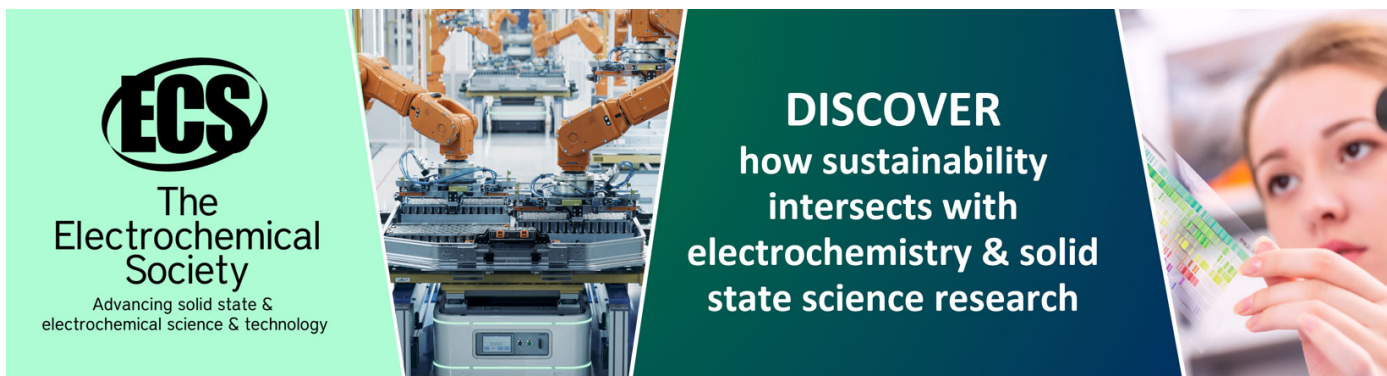
Temperature Monitoring in Geological Wells of the Upper Layers of Quaternary Deposits of the Central Part of the West Siberian Plain

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Temperature Monitoring in Geological Wells of the Upper Layers of Quaternary Deposits of the Central Part of the West Siberian Plain

S E Korkin¹

¹Nizhnevartovsk State University, Nizhnevartovsk

E-mail: egf_nv@mail.ru

Abstract. The present research is based on recording method of soil temperature surveys and underlying quaternary deposits. All surveys were conducted over two key areas as follows: first area is located within the boundaries of Northern taiga landscapes of Western Siberia (Siberian ridges - thermal wells 1, 2, 3 и 8); the second area belongs to middle-taiga landscapes of Western Siberia (Sredneobskaya lowland – thermal wells 4, 5, 5a, 6, 7). All temperature data obtained within the boundaries of key areas was measured by thermal logger DS1921G-F5 for the depths within range of 20 cm, 40 cm, 60 cm, 1 m and by another thermal logger DS1921Z-F5 for the depths within range of 2 m, 3 m, 4 m, 5 m, 6 m, 8 m. The average annual temperature of years 2015-2016 observation period of thermal well 5a (technogenic site) is 8,3 °C for the whole range of depths and considered to be higher by 3,8 °C then average annual temperature recordings of thermal well 5 and, at the same time, considered to be higher by 4,2 °C then recordings of thermal well 6, which belongs to natural bog landscape. The abovementioned data was confirmed by recordings of years 2015-2016 with the difference of 4,8 °C for thermal well 5 and 3,7 °C for thermal well 6. A slightly higher temperature was indicated for the soils underlying anthropogenic objects in correlation to natural, not induced by man-made impact biogenic soils and this fact affects natural processes. The results of the present research indicates that the most warm soils are illuvial-ferruginous. This type of soil warms up quite well at the top portion of the profile (horizons O, E) and stating from the depth of 40 cm the temperature goes down to 0 °C. Black dirt oligotrophic soils are having good warming up abilities. It can keep and increase positive temperature with increasing depth. A slight temperature decrees refers to level of paludal-lacustrine basin of 30–40 cm.. are having good warming up abilities and can keep positive temperature at depth. Alluvial soddy soils of the first key area (floodplain of the Gluboky Sabun River) are considered to be the coldest soils based on the results of the conducted observations. The annual average temperature in this type of soil for the time period of years 2010 to 2017 is about 1,2 °C.

1. Introduction

The research is developed taking into account landscape structure of the central part of Western Siberia generated by Н.Н. Москвиной, В.В. Козиным [1]. The goal of research is to identify climatic changes by means of temperature monitoring of soils of northern and middle taiga subzones of landscapes. The object of research is temperature profile of West Siberian Plain landscapes under impact of climate factors. First key area referred to north taiga subzone. This area has four thermal wells. The first key area is located under conditions of rare island layout of frozen rock for different



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natural conditions. This feature allows to obtain background figures for technogenically non-impacted landscapes in north taiga conditions. The choice of location for installation of thermal wells is based on differentiated criteria such as: relief location, lithological composition, micro climate conditions and moisturization, composition of topsoil and plant formation. The first thermal well is referred to drainage top soils which have illuvial-ferruginous podzols and grown *Pinus sylvestris* L. and lichen of type *Cladonia*. The second thermal well is located at alluvial turf soils of the river valley Sabun. Thermal wells 3 and 8 belongs to oligotrophic black dirt within the boundaries of given key area. The location of the thermal well 3 is referred to upper ridge-hollow marshland named Meggen-Neg-Kui. The thermal well 8 is located 1,2 km away from weather station to South-West direction and was established for recording temperatures of permafrost black dirt at ridge-hollow wetland. The studied area of ridge-hollow wetland has a 2m thickness.

The second key area is equipped by 5 thermal wells at subarea middle taiga and located at right bank of Sredneobskaya lowland. Due to high intensity of technogenic impact caused by petroleum production, the thermal wells were dislocated either in areas with natural conditions and in areas of technogenic impact. The thermal well 4 established in the forest at illuvial-ferruginous podzols with growing *Pinus sylvestris* and *Pinus sibirica* corresponds to nature landscape of the given key area. The thermal well 6 records data of peaty oligotrophic soil. The thermal well 7 belongs to alluvial turf of floodplain Bolshoy Yogan. The thermal wells 5 and 5a belong to technogenic area on peaty oligotrophic soil (oil pipeline Samotlor-Nizhnevartovsk). The temperature of the oil going through the pipeline with diameter 1220 mm is about 17 °C. The pipeline is set at the depth of 1 m from the top of ridge-hollow wetland. The well 5a is located at a close proximity to oil pipeline and check thermal well 5 is located within 20 meters from there.

The outside temperature for the first and the second key areas was obtained from registrations installed at the Gluboky Sabun (Siberian ridges) and Bolshoy Yogan (Sredneobskaya lowland) river valleys.

2. Objects, data and methods

The study area refers to North taiga landscapes. The relief of the first key area corresponds with Siberian ridges, where automorphic soil type – podzol illuvial-ferruginous on fluvioglacial sand prevails. The second key area within the boundaries of Sredneobsk lowlands of the latitudinal current of the Ob River refers to middle taiga landscapes of Western Siberia. Peat oligotrophic soil prevails at this area. The relief of this area is flattened with heights laying within the range from 40 m to 80 m, and from 100 m to 120 m above Baltic Sea level for the areas of water-parting line

The present research is based on method of recording systems used for in-situ measurement of soil temperatures. This method is described in details by Y.A. Popov IO.A. and K.Y.Borisenko[2]. S.A. Kazantsev, A.D.Duchkov [3], P.Y. Konstantinov, A.N. Fedorov, T. Michimura [4]. The studies regarding specila aspects of the temperature profiles of features of the temperature mode in the peat deposit of the oligotrophic swamp of the southern taiga of Western Siberia, are described in researches of E.A.Dykareva, E.A.Golovatskaya, A.D.Dychkova and S.A.Kazantseva [5, 6, 7]. There is also a high level of academic interest raised by the results of air and soil temperature observations made by monitoring net and conducted during joined German-Russian Project «Kulunda» [8]. The worldwide experience formed by exploration of soil temperature profile is highly important for establishment of monitoring system [9]. A thermal logger DS1921G-F5 was used for measuring soil temperatures within depth range of 20 cm, 40 cm, 60 cm, 1 m, with temperature range from -40°C to +85°C and sensitivity of 0,5°C. For the depths more them 1 m was used a thermal logger DS1921Z-F5 with temperature range from -5°C to +26°Cand sensitivity 0,125°C. For air temperature observation a thermal logger DS1921G-F5 was used. A sampling rate for all thermal loggers is 255 min. A 24-hour period was made by 5-6 observations. Based on these observations daily average soil temperatures were calculated following by monthly average calculations. Loggers have protective shells which eliminates any sensitivity defections while installed in the wellbores equipped with 50 mm polyethylene pipe and thermal insulation at the well head. The logging of results was executed by observation during autumn season Further analysis regarding temperature profiles of black dirt soils

were done with use of Microsoft Office Excel 2007. The use of the abovementioned equipment showed up the following technical issues: for the local soils it is enough to use loggers with temperature range from -5°C to $+26^{\circ}\text{C}$ with sensitivity 0.125°C . This shall provide a more accurate calculations for the days, weeks, seasons and year. It is necessary to use thermistor chain with outlet channel needed for communicational devices. In the present research data on temperature of soils and area is being analyzed for the years 2010 – 2017.

3. Results and discussion

A set of natural decreases within the boundaries of central part of West Siberian Plain (high level of water floods in years 2002, 2007, 2015) and anomaly hot and lack of water summer seasons in years 2003, 2012, 2016 just underline the role of climatic changes. As per opinion of F.N. Ryansky [10], natural cycles with periods of action by 12, 36,106 years also refer to the processes having huge impact on normal work of geosystems. Process-Flow Characteristic is the geophysical complex of a number of natural periodic changes, which include sharp fluctuations of dryness - humidity with economically tangible development of droughts and floods, active erosion, long severe and snowy winters (for example, the winter period of 2014-2015, 2016 -2017yy.) [11]. Fluctuations in meteorological parameters provoke outbursts of development of class leading factors associated with a complex of natural processes. Temperature is a key factor in biogenic relief formation, which affects the growth, vegetation productivity and decomposition. Below is an analysis of mid-annual and average monthly temperatures obtained at key sites. The results of monitoring the soil temperature reflect the general regularities of arrival and consumption of solar radiation. The formation of minimum soil temperatures in the annual cycle, beside the temperature of the underlying surface, is also affected by phase transitions during the freezing of moisture in peat, the height of the snow cover and the amount of heat accumulated by the peat deposit during the warm period. The depth of penetration of 0°C temperature into the soil is an important characteristic of the thermal regime in the cold period, which determines the depth of the layer with negative temperatures [7]. Typical variety of soils and vegetation formations is associated with the geological-geomorphological structure of the territory. Surfaces drained by rivers and streams are illuvial-ferruginous podzols, formed by dusty sandy loam under pine-cedar cranberry-green forest and precisely the boundaries of the Sredneobsk lowland. In conditions of increased hydromorphism and stagnant regime, peat oligotrophic soil is formed. Alluvial turf soils are formed in the floodplain during short-term flooding with flood waters [12]. Anthropogenic forms of relief are formed with human participation, further development occurs under the influence of natural mechanisms, which leads to the formation of a category of concomitant forms of relief [13]. The economic activities of the research area are mainly represented by oil production facilities [14].

The average annual temperatures for podzols in thermowells 1 (1 key section), 4 (2 key section) from 2010 to 2017 are presented in Table 1. The results from two sites show that for a thermowell 1 the minimum value of 2.3°C is recorded during the observation period of 2010 - 2011, for thermowells 4 the minimum indicator is 2.3°C , recorded during the observation period of 2010-2011. The maximum indicator of average annual temperatures in the thermowell 1, is equal to 3.9°C , was recorded during the observation period 2015-2016, for the thermowell 4 the maximum value is 3.7°C , it was also fixed during the observation period of 2015 - 2016, which is consistent with the data presented in the "Report on the characteristics of climate on the territory of the Russian Federation in 2016", which is the annual official publication of Roshydromet (the eleventh issue in the series of annual reports) [15].

The report is a source of regularly updated high-quality data on the status and trends of climate changes in Russia. It is based on the results of regular climate monitoring based on the data of the state observational network and climate research conducted by the Roshydromet Research Institute. The first three quarters of the year 2016 mean temperature for Russia exceeded the historical maximum. Extremely warm year 2016 in the marine Arctic led to a significant increase of the trend over the last 30 years from 0.68°C to 0.79°C in 10 years.

This year was record warm in the troposphere and record cold in the lower stratosphere at low latitudes and in the Northern Hemisphere as a whole.

Table 1. Average annual temperature for podzols in thermowells 1 (1 key section), 4 (2 key section) from 2010 to 2017.

Measuring №	Survey depth	Year							
		2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017	2010-2017 average
1	0.2 m		3.22	2.23	2.98	3.97	4.41	3.54	3.39
	0.4 m	2.35	3.48	2.55	3.22		4.36	3.90	3.31
	0.6 m	2.63	3.27		3.06	3.86	4.33	3.68	3.47
	1.0 m	2.47	3.18	2.51	2.99	3.75	4.11	3.66	3.24
	2.0 m	2.40	3.00		2.99	3.59	4.02	3.74	3.29
	3.0 m	2.51	2.66	2.63	2.69	3.18	3.65	3.55	2.98
	4.0 m	2.17	2.51	2.44	2.61	3.00	3.53	3.50	2.82
	5.0 m	1.84	2.28		2.47	2.85	3.34	3.34	2.69
	6.0 m	2.06	2.44	2.63			3.53	3.54	2.84
	average	2.30	2.90	2.50	2.90	3.50	3.90	3.60	3.10
4	0.2 m	2.85	4.14	3.15			4.22		3.59
	0.4 m	2.88	4.20	1.45			4.29	3.09	3.18
	0.6 m	2.73		3.14			3.98	3.20	3.26
	1.0 m	1.96	3.09	2.49	2.24	3.34	3.38	2.74	2.75
	2.0 m	1.79	2.76		2.80	3.66	3.10	3.39	2.92
	3.0 m	1.67	2.44		2.51	3.05	3.62	2.98	2.71
	4.0 m							3.58	
	6.0 m	2.02					3.63	3.67	3.58
	8.0 m						3.74	3.77	3.11
	average	2.30	3.30	2.60	2.50	3.30	3.70	3.30	3.20

Upland moors widely present in the West Siberian boreal areas, are represented by oligotrophic boggy soils. The minimum average annual temperatures in the borehole No. 3 was 3.4° C, recorded during observations in 2013-2014 in the boreal sub-taiga area; and 1.3° C in the borehole No. 8 recorded in 2011-2012, and 3.3° C in the borehole No. 6 recorded in 2013-2014 in mid-taiga subarea. The main temperatures recorded in oligotrophic boggy soils recorded in 2010-2017 are shown in Table 2. The maximum average annual temperature in the borehole No. 3 was 4.4° C, recorded during observations in 2014-2015, 3.1° C in the borehole No. 8 recorded in 2015-2016, and 4.8° C in the borehole No. 6 recorded in 2015-2016. The observations over the boreholes 3, 8, 5, 6 in 2010-2017 lead us to the following conclusions: The borehole No. 3 thermal behavior has an insignificant increase at 0.3° C; the borehole No. 8 thermal behavior has a visible increase at 1.8° C with higher values in 2015-2016; the borehole No. 5 thermal behavior has not shown any negative or positive temperature changes during observations. The borehole No. 6 shows higher values in 2015 – 2016. The geothermal data analysis made for the alluvial sod soils in the borehole 2 (primary area 1), borehole 7 (primary area 2) in 2010-2017 (Table 3) leads us to conclusion that the annual average thermal behavior in the Glubokiy Sabun river floodplain in the primary area 1 shows a visible increase at 2.5° C; the annual average thermal behavior in the Bolshoi Egan river floodplain in the primary area 2 shows an insignificant increase at 0.7° C.

The average annual temperature during observations in 2015-2016 in the borehole 5a (industrial area) was at 8.3° C at all depths, which is 3.8° C higher than the average annual temperature in the borehole 5; and 4.2° C higher than the borehole 6, located in natural moorlands (Table 4). This fact

was confirmed by observations in 2016 - 2017 with a difference of 4.8 °C for 5 boreholes and 3.7 °C for 6 boreholes. Borehole 6 is 10 km to the south-west from borehole 5 and corresponds to a natural site with a long period of observation. The average annual temperature in the fifth borehole is 0.6 °C less than in the sixth for 2015 – 2016, and 0.3 °C less for 2016 - 2017.

Table 2. Average annual temperatures in oligotrophic boggy soils recorded in the boreholes 3, 8 (primary area 1) and 5, 6 (primary area 2) in 2010-2017.

Measur ement ID	Measureme nt depth	Year							
		2010- 2011	2011- 2012	2012- 2013	2013- 2014	2014- 2015	2015- 2016	2016- 2017	2010- 2017 averag e
3	0.2 m	3.91	4.51	3.43	3.31	4.64			3.96
	0.4 m	3.59	4.19	3.91	3.78	5.29			4.15
	0.6 m	3.55	4.15	3.21		4.25			3.79
	1.0 m	3.14	3.74	3.64	3.26	4.17			3.59
	2.0 m			3.63		3.59			3.61
	average	3.50	4.10	3.60	3.40	4.4			3.8
8	0.2 m		2.45	1.78		2.85	3.14	2.63	2.57
	0.4 m		1.06	1.50	1.16	2.64	2.77	2.30	1.90
	0.6 m		0.65	1.36	1.47	2.99	3.29	2.99	2.12
	1.0 m		1.07		1.59	2.86	3.14	3.03	2.34
	2.0 m						3.44	3.63	3.54
	average		1.30	1.50	1.60	2.80	3.1	2.8	2.5
5	0.2 m						4.62	4.17	4.39
	0.4 m						3.62	3.68	3.65
	0.6 m						4.22	4.32	4.27
	1.0 m						4.22	4.36	4.29
	2.0 m						4.48	4.61	4.54
	average						4.2	4.2	4.2
6	0.2 m	2.61		6.71	1.22		5.65	4.98	4.23
	0.4 m			5.2	3.95	5.17	5.6	5.14	5.01
	0.6 m			4.26	3.48	4.68	4.73	4.28	4.29
	1.0 m			4.21	3.77	4.65	4.88	4.6	4.42
	2.0 m			3.86	3.77	3.92	4.1	4.14	3.96
	3.0 m			3.78	3.69	3.76	4.02	4.17	3.88
	average			4.7	3.3	4.4	4.8	4.5	4.3

Table 3. Average annual temperatures in oligotrophic alluvial sod soils recorded in the boreholes 2 (primary area 1) and 7 (primary area 2) in 2010-2017.

Measur ement ID	Measureme nt depth	Year							
		2010- 2011	2011- 2012	2012- 2013	2013- 2014	2014- 2015	2015- 2016	2016- 2017	2010- 2016 avera ge
2	0.2 m	-0.34	0.69	-0.07	1.09	2.21	2.36	1.45	1.06
	0.4 m	-0.50	1.16	0.54	1.59	2.69	2.79		1.38
	0.6 m	-0.45	0.44	0.07	1.43	2.36	2.46	1.99	1.18
	1.0 m	-0.07	0.47	0.46	1.13	1.98	2.22	1.69	1.12
	2.0 m		0.24		0.90	1.54	1.93	1.63	1.25
	average	-0.30	0.60	0.20	1.20	2.20	2.30	1.70	1.20

7	0.2 m	5.73	4.47	4.61	5.19	5.65	5.18	5.14
	0.4 m		4.76	4.87	5.42		5.43	5.12
	0.6 m		4.13	3.96	4.55	4.90	4.55	4.42
	1.0 m		4.25	4.09	4.54	4.75	4.65	4.46
	2.0 m		4.63		4.61	4.73	4.08	4.51
	average		4.30	3.70	4.20	4.20	4.40	4.60

Table 4. Soil temperature indicators for boreholes 5 and 5a for the periods of 2015 - 2016 and 2016 – 2017.

t°C					
		borehole 5		borehole 5a	
		2015-2016	2016-2017	2015-2016	2016-2017
average	annual	4.20	4.20	8.00	8.30
temperature					

Analyzing obtained results, we come to conclusion that the average annual air temperature for the first key site increases during the observation period 2011 - 2012 and 2015 - 2016 (Table 5), and for the second key site within the same period of observation, and for the area of boreholes 6 and 7 the period 2014 - 2015 is added (Tables 6, 7), which is reflected in the sums of positive and negative temperatures.

Table 5. Comparative data for the primary air temperature indicators in the area of borehole 1.

Months	2010-2011	2011-2012	2013-2014	2014-2015	2015-2016	2016-2017
September	3.91	8.29	4.63	2.55	5.49	10.18
October	0.36	0.42	-3.56	-7.46	-4.17	-5.35
November	-13.35	-16.72	-8.13	-18.42	-16.23	-21.56
December	-29.29	-16.46	-13.82	-14.14	-16.23	-22.43
January	-25.04	-22.76	-26.30	-22.95	-25.74	-25.46
February	-22.23	-18.12	-26.96	-15.45	-12.13	-17.69
March	-8.75	-11.28	-8.67	-10.43	-8.49	-4.58
April	0.62	-1.75	-1.46	-0.28	1.84	-2.26
May	6.49	5.59	2.81	7.51	4.38	2.43
June	17.38	19.74	12.92	17.42	19.79	17.23
July	11.69	18.99	16.46	16.04	20.83	16.31
August	10.37	13.88	12.02	11.81	15.51	14.57
annual	-3.99	-1.68	-3.34	-2.82	-1.26	-3.22
average						
sum of	1425.7	1764.4	1540.8	1706.2	2131.9	1898.4
positive						
temperatures						
sum of	-3077.6	-2764.8	-2713.9	2744.7	-2594.0	-3074.5
negative						
temperatures						

Table 6. Comparative data for the primary air temperature indicators for borehole 4.

Month	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017
October	-	-1.11	-2.90	-4.74	-2.51	-2.60
November	-13.13	-15.94	-4.42	-14.11	-13.53	-19.26
December	-15.54	-23.18	-11.25	-12.63	-14.85	-19.26
January	-20.72	-24.00	-20.37	-16.29	-22.16	-22.40

February	-17.43	-17.32	-17.61	-11.48	-9.54	-22.03
March	-8.28	-14.08	-4.22	-8.61	-7.84	-2.94
April	1.61	-0.32	-0.79	1.02	3.33	0.81
May	8.30	4.02	6.47	11.28	7.29	4.96
June	21.80	13.17	14.65	18.47	18.57	17.79
July	20.52	20.85	16.43	16.36	20.10	17.50
August	14.46	15.89	14.92	12.66	17.90	16.03
September	10.00	7.22	5.37	6.98	14.21	7.97
annual average	0.15	-2.90	-0.31	-0.09	0.91	-1.73
sum of positive temperatures	2362.7	1959.69	1814.1	2102.8	2310.2	1948.3
sum of negative temperatures	-2272.4	-2989.7	-1841.8	-2023.6	-2190.7	-2655.8

Table 7. Comparative data for the primary air temperature indicators in the area of boreholes 6 and 7.

Month	2010-2011	2011-2012	2013-2014	2014-2015	2015-2016	2016-2017
October			-1.96	-4.14	-2.98	-1.81
November	-16.71	-13.28	-3.78	-13.59	-13.16	-18.60
December	-24.07	-15.70	-10.88	-12.82	-14.47	-21.71
January	-22.13	-20.93	-22.28	-19.17	-21.94	-21.27
February	-19.03	-17.52	-24.55	-10.96	-8.57	-15.74
March	-6.04	-7.84	-4.01	-6.67	-6.22	-1.82
April	4.00	2.23	1.78	3.06	4.80	2.43
May	8.69	8.83	7.39	11.49	8.84	7.12
June	18.16	20.97	14.92	19.23	19.20	18.94
July	13.68	19.54	16.37	16.92	20.04	17.42
August	12.26	13.27	14.52	12.89	17.42	15.55
September	10.80	9.54	5.76	7.27	12.34	7.50
annual average	-1.47	0.23	-0.56	0.29	1.28	-1.0
sum of positive temperatures	2230.0	2318.6	1907.6	2176.5	2541.2	2100.5
sum of negative temperatures	-2501.0	-2298.0	2041.4	2081.6	2064.3	2495.3

4. Conclusions

As a result of soils temperature monitoring it is possible to identify that the following patterns of temperature changes in natural landscapes mostly depend on meteorological indicators. While soils for industrial facilities show higher temperatures than natural landscapes without anthropogenic impact, which is a factor of heating effects development during engineering development of the territory. The presented results are included in the database of background temperature indicators of the upper part of annual heat cycle layer, on the basis of which it is possible to make forecasts of changes and use the data in project-supporting activities. The results of the study show that the warmest soils are iron pan ashen-gray soils, they are well-warmed at the profile top (horizons O, E); the temperature is reduced to zero from a depth of 40 cm. Peat oligotrophic soils can easily warm up, retain and increase positive temperatures with depth; a slight decrease in temperature corresponds to a level of inside-the-bog water of 30-40 cm. Alluvial soils can easily warm up and maintain positive temperatures at their depth. Cold soils, according to the study results, are alluvial sod soils of the first key area (the

floodplain of the Gluboky Sabun River. In these soils the average annual temperature is 1.2 °C from 2010 to 2017.

5. References

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