- A.Sidorchuk.
- Geographical Faculty, Moscow State University, 199899 Moscow, Russia.

Palaeohydrology in the Southern Russian Plain: methods and results.

Introduction

The water yield from the southern Russian Plain varied broadly during the Late Glacial and Holocene. These changes were independent of the melt water runoff from the ice-sheet, as the latter was situated much more to the north. The transformation of the periglacial landscapes into a typical steppe and forest steppe was accompanied by the periods of low soil permeability due to permafrost development over the territory, the periods of climate aridisation and by periods of permafrost melting and soil permeability increase.

The morphology of river valleys in the Don River basin reflects the changes of the water flow in the past. For example, the paleochannels with the bankfull channel width 1400 m, maximum depth 9 m, and meander length 5000 m were defined on the floodplain of the Khoper River near Povorino (the recent Khoper River near Povorino have the channel width 60 m, maximum depth 4 m, meander length 840 m.). The radiocarbon and pollen analysis showed that the channel was formed during the Late Glacial 10-12 thousand years ago in the conditions of periglacial dry steppe.

Moreover, there are large aeolian dunes on the older parts of floodplain which indicate the existence of periods with mean flow decrease on the same river.
The existence of such different palaeogeographical features within the relatively small territory gives a unique opportunity to reconstruct in detail the climatic and hydrological history of the southern part of the Russian Plain during the Late Glacial and the Holocene.

The methodology of palaehydrological analysis.

The palaeohydrological analysis is usually based on: 1. geomorphological analysis; 2. granulometrical analysis; 3. paleobotanical analysis; 4. geochronological analysis; 5. hydraulic and hydrologic calculation. The combination of methods, listed below, were developed and used for reconstructions of palaeodischarges and palaeolandscapes at the Khoper River valley at the Southern Russian Plain.

The geomorphologic analysis includes:

1. Palaeogeomorphological mapping of the floodplains and low terraces of the Khoper River valley. The position and relative age of all the paleochannel remnants were reconstructed, and relative stages of river valley evolution were determined.
2. The main morphometrical parameters of the largest palaeochannel were estimated (palaeochannel slope;palaeochannel cross-section area versus altitude; floodplain altitude; palaeomeander length, amplitude, deflection angle; palaeochannel width). It was possible also to reconstruct the whole topography and digital elevation model of the paleochannel and its floodplain.

The granulometrical analysis was used to determine mean, median and quintile diameters of the alluvium particles for the paleochannel and its floodplain.

The results of geomorphologic and granulometrical analysis were used for hydraulic calculations of the stage - discharge relation for paleochannel. The calculations were performed for a single cross-section, where slope S, cross-section area A and mean depth d for a given stage were available. For this case Chezy-Manning formula is used for discharge calculation. For a digital elevation model for a paleovalley section, two-dimensional Saint-Venant equations were used with finite elements hydraulic model for their solution. In both cases the coefficient of the channel resistance was calculated from mean diameter D of the paleochannel bottom alluvium.

The stage - discharge relation can then be used for calculations of absolute maximum, mean maximum and mean annual discharges, when altitudes and probabilities of one or several palaeostages are available, and the curves of probability for annual maximum and daily discharges are known.

The meanders of Khoper paleochannel are highly developed with omega-like shape. The lifetime of these meanders was calculated with help of the model of meander formation, it is about 1000 years. That means, that the probability of the absolute maximum of discharge is about once for 1000 years.

There were no avulsions on the floodplain during paleochannel lifetime. It means, that the velocity on the floodplain surface was never more, than critical velocity of intensive erosion initiation. This velocity can be estimated from floodplain alluvium grainsize. The depth of the water, related to critical velocity was calculated. With the floodplain altitude it gives maximum stage of water during paleochannel lifetime, and it gives maximum discharge from stage - discharge relation.

With the given maximum discharge and its probability all other maximum discharges and their probabilities can be calculated, if the probability distribution curve for maximum discharges is known. This curve for a recent Khoper River can not be used, because the paleolandscape and the conditions of flow generation in Khoper basin were different from the recent in the Past.

For this purpose the paleobotanical methods of climatic and landscape reconstructions, initiated by V.P. Grichuk, were used These methods are based on the composition of the fossil flora at a certain site, derived from palynological and plant macrofossil data. Geographical analysis of modern plant ranges for all the species found at the fossil flora allows to find the closest modern floristic analogue to the past vegetation at the site. The modern plant communities, main landscape features and climatic parameters for this region-analogue are close to those at the site in the Past. For the paleochannels of the Khoper River regions - analogue are situated in Bol'shezemelskaya Tundra and Yamal peninsula and dry steppe of the northern Kazakhstan.

When the recent region - analogue of the Past landscape and flow generation conditions are thus determined, the hydrological parameters of the recent rivers of this region can be used for calculations of paleohydrological and paleoclimatic characteristics - mean maximum discharge, mean annual discharge, flood period flow volume, annual and seasonal precipitation depth.

Mean maximum discharge can be determined from calculated for paleochannel absolute maximum discharge and its probability and parameters of distribution curve for maximum discharges of the rivers - analogue. A two-parametric gamma-distribution is usually used for these calculation.

Mean annual discharge can be determined from the above calculated maximum discharges and their probabilities for paleochannel and parameters of distribution curve for daily discharges of the rivers - analogue. A Gudrich curve is usually used for these calculations.

Flood period flow volume can be determined from the above calculated maximum discharges and their probabilities for paleochannel and parameters of flood wave shape of the rivers - analogue. A Gudrich curve is also used for these calculations.

Annual precipitation depth can be determined from the above calculated mean annual discharge for paleochannel and runoff coefficient of the rivers - analogue. The same can be done for the flood period.

Results

Calculations show, that 11-12 thousand years ago mean maximum discharge of paleo-Khoper was about 7500 m^3/s, mean annual discharge was 570 m^3/s, runoff depth was 940 mm and rainfall depth was 1050 mm (tabl.).

	Recent	Late Glacial	LG/R ratio
Basin area	19100	19100	1.
Absolute maximum discharge m^3/s	2140	13190	6.2
Mean maximum discharge m^3/s	991	7400	7.5
Mean annual discharge m^3/s	67.8	570	8.4
Runoff coefficient	0.2	0.9	4.5
Annual precipitation mm	460	1000	2.2
Channel width (bankfull) m	60	1400	23.3
Channel mean depth (bankfull) m	2.1	5.1	2.4
Meander wavelength m	840	5000	6.0
Channel slope m/km	0.063	0.154	2.4
Bed load mean diameter mm	0.5	0.5 (0.18)	1.0 (0.4)
Channel roughness (Manning coefficient)	0.0287	0.0287	1.0

The main cause of the paleochannel formation with the discharge 8 times more than recent one, when rainfall increase was only two-fold, is periglacial conditions with huge permafrost and very sparse vegetation.