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Low Flow Risk Assessment for Water Management

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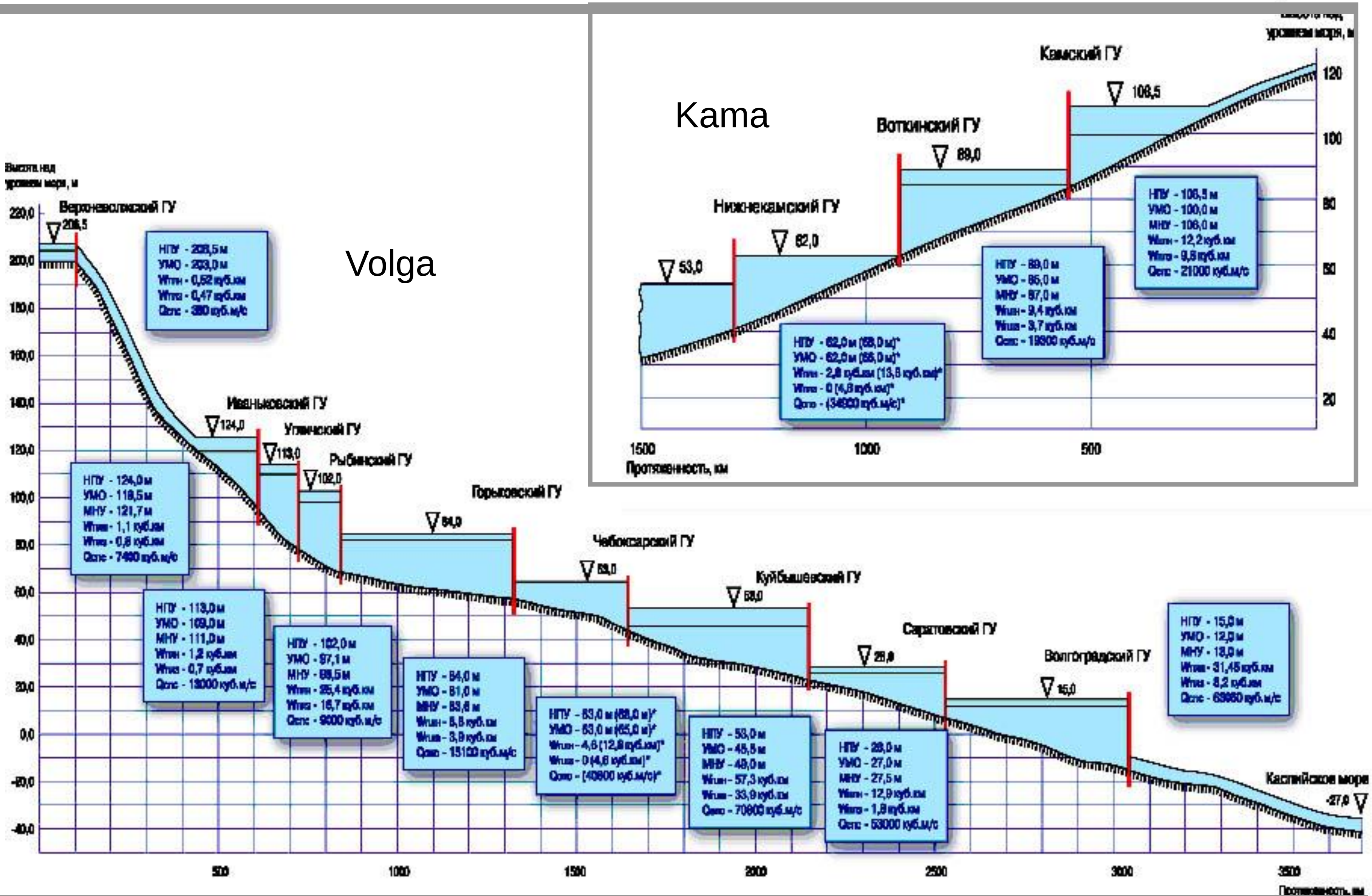
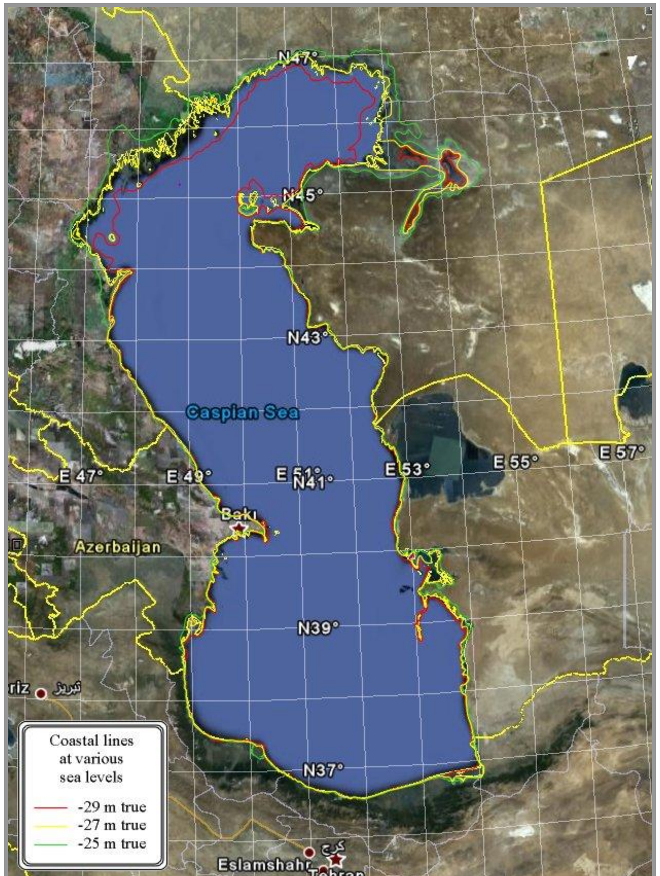
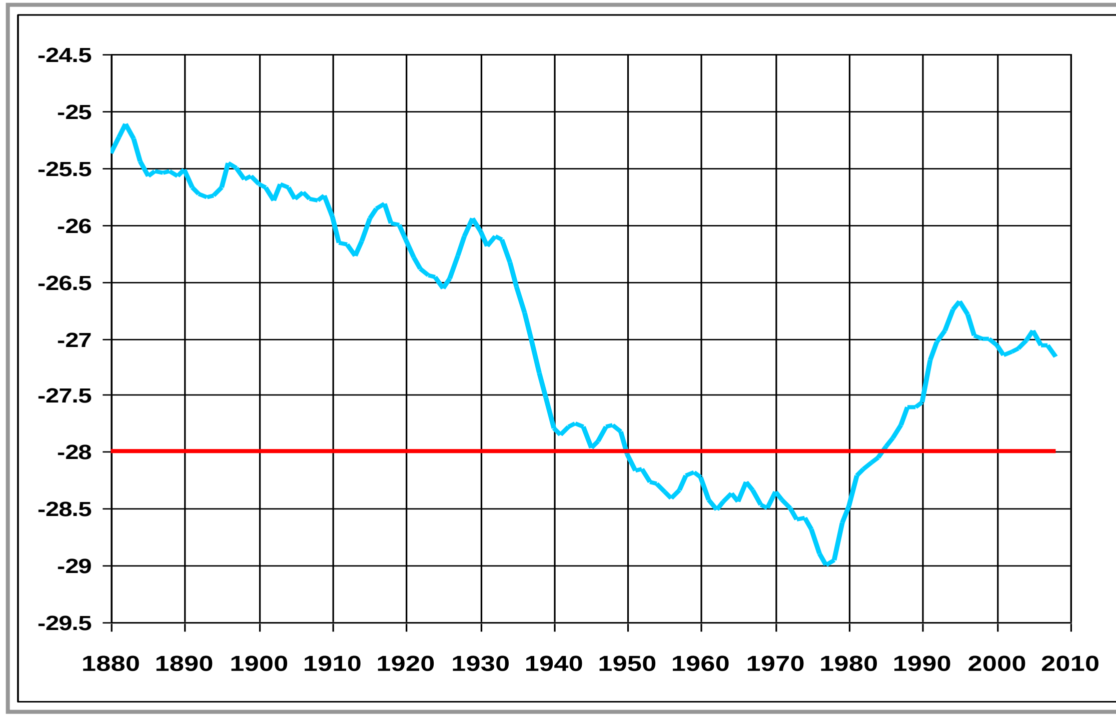
Scheme of the Volga River basin water system

Volga-Kama reservoir system



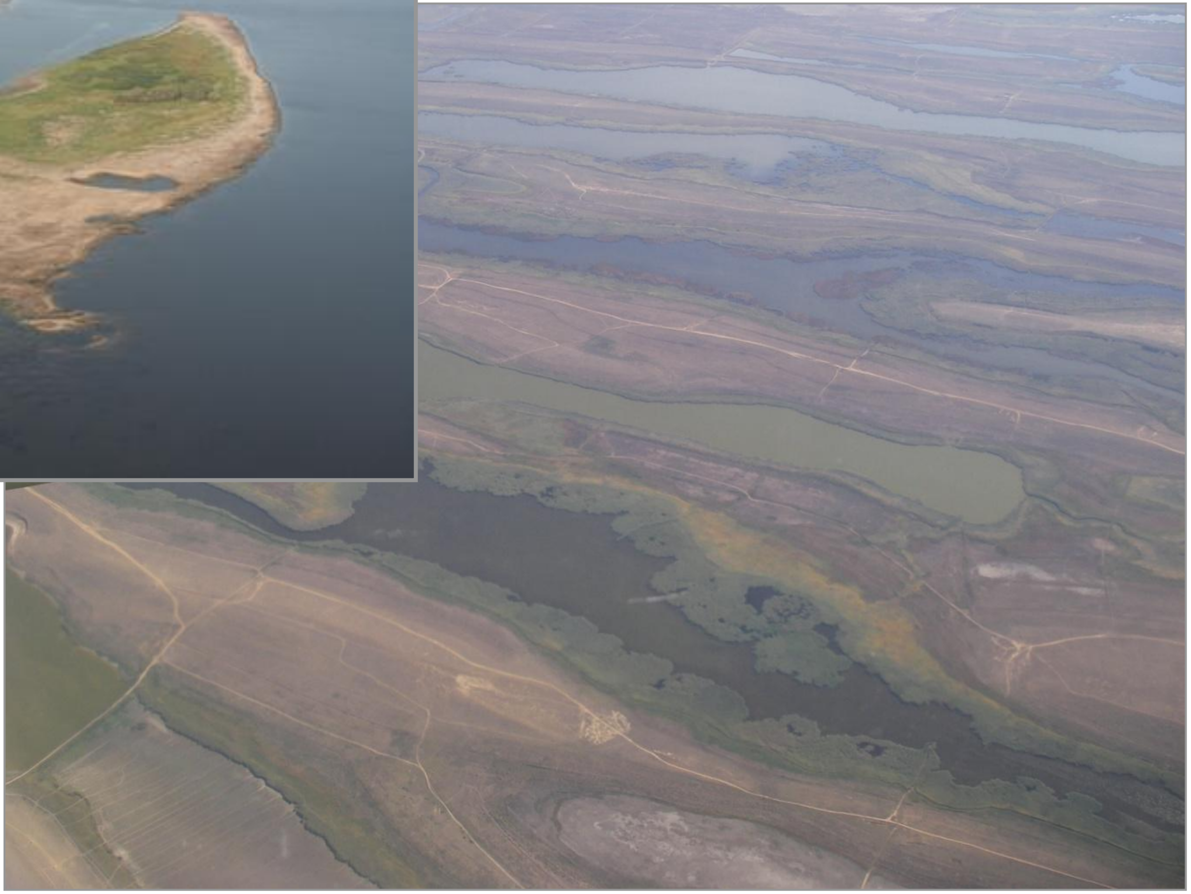
Caspian Sea level



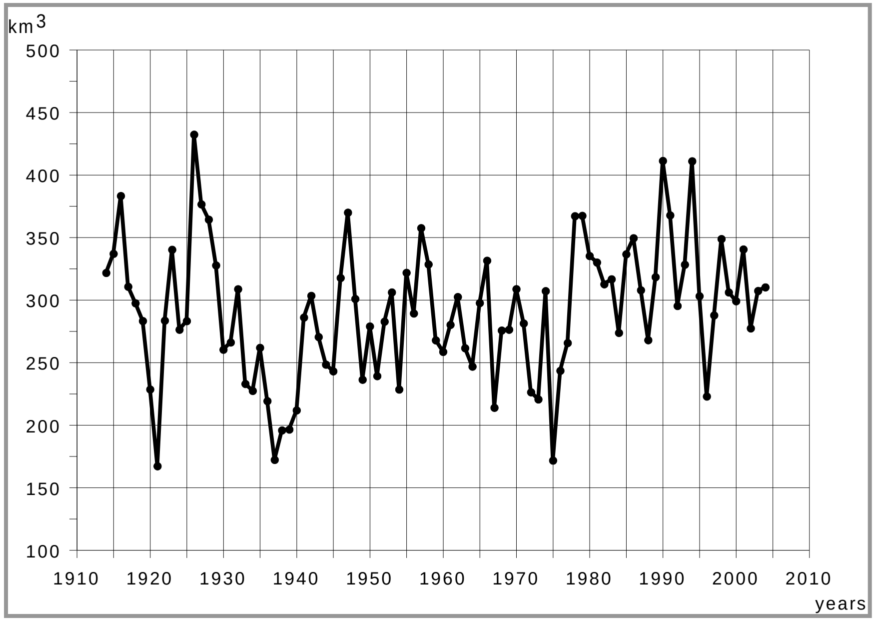


Volga River

Volga delta lakes



Water inflow to the reservoirs of water resources system the Volga River basin



MEASURE OF ARIDIZATION: increasing duration of the group (continuous sequence) of low flow years

Coefficients of autocorrelation R(1) characterize different probabilities of occurrence of low flow periods of long duration

Two-dimensional probability density function

MARKOV EQUATION

$$p(\tau_1+\tau_2,x,y)=\int_{-\infty}^{\infty}\frac{p(\tau_1,x,z)\,p(\tau_2,z,y)}{p(z)}dz\,,\quad \tau_1=t-t_1\,,\tau_2=t-t_2$$

2-dimensional probability as expansion (Sarmanov O.V.)

$$p(\tau,x,y)=p_1(x)p_2(y)\cdot\left[1+\sum_{k=1}^{\infty}R^k P_k(x)P_k(y)\right]$$

$P_k(x)$, $P_k(y)$ - orthonormal polynomials, R - coefficient of correlation

3-parameters gamma-distribution of Kritsky-Menkel

$$p_1(x)=\left[\frac{\Gamma(\gamma_1+b_1)}{\Gamma(\gamma_1)}\right]^{\frac{\gamma_1}{b_1}}\frac{1}{\Gamma(\gamma_1)\left|b_1\right|x_0}\left(\frac{x}{x_0}\right)^{\frac{\gamma_1}{b_1}-1}exp\left\{-\left[\frac{x}{x_0}\frac{\Gamma(\gamma_1+b_1)}{\Gamma(\gamma_1)}\right]^{\frac{1}{b_1}}\right\},\qquad x\geq 0\,,$$

Assessment of reliability of the Volga River basin water system

SCENARIOS OF FUTURE FLOW CHANGE

R(1)=0.3

R(1)= 0.4

R(1)= 0.5

Simulation of synthetic time series of annual runoff (10 000 years long)

sample of 100 years-long

transformation of time series by method of double sample

annual runoff

averaged monthly and decade runoff

Simulation of long-term hydrological time-series

METHOD OF EOFs ANALYSIS :

- coefficients of the eigenfunction expansion form uncorrelated (in pairs) random processes with Gaussian distribution
- developing autoregressive model for each such process
- simulation of synthetic time series of the random variables required length with the normal (Gaussian) distributions and correlation and autocorrelation functions in given forms
- Transformation

method of normalization by Moran (1969)

normal 2-D PDF → joint distribution of probabilities (2-D uniform distributions) → PDF with arbitrary law

Simulation of long-term hydrological time-series

The eigenfunctions $X_h(x)$ are determined to satisfy the following expansion:

$$F(t,x) = \sum_h T_h(t) X_h(x) \qquad (1)$$

$F(x,t)$	is a given sequence of random fields for some territory (set of gauging stations)
t	is the discrete time, $t = 1,2, ..., m$
x	is the spatial parameter, $x = 1,2, ..., n$.
$X_h(x)$	are estimated from the data of population of fields, $h = 1,2, ...,$
$T_h(t)$	are varied from one random field to another.

The required set of eigenfunctions can be given as a set of eigenvectors of correlation matrix of random fields.
For each eigenvectors the corresponding function $T_h(t)$ is defined as:

$$T_{h,i} = \frac{\sum_k F_{i,k} X_{h,k}}{\sum_k X_{h,k}^2} \qquad (2)$$

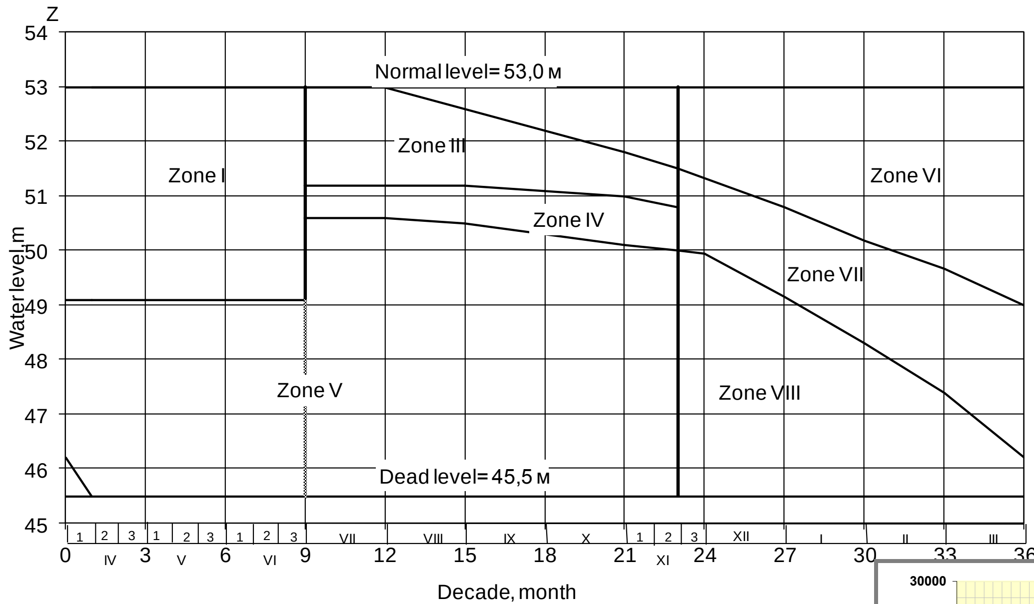
k and i - spatial and time indexes

Parameters of runoff distribution in simulated synthetic time series

R(1)	parameters for the worst 7 years interval from 100 years period				
	*Q*7, m³/s	*Cv*(*Q*7)	*Cs*(*Q*7)	*Q*7, m³/s with *P*,%	
				90%	95%
0,3	6729	0,050	– 0,3	6150	6030
0,4	6655	0,054	– 0,2	6040	5930
0,5	6537	0,065	0,1	5910	5870

R(1)	Duration of excursions below threshold, years							
	1	2	3	4	5	6	7	8
	The number of excursions							
0.3	560	124	26	3	1	0	0	0
0.4	495	119	33	8	4	0	0	0
0.5	411	114	42	15	4	2	1	0

Water management in the Volga River basin

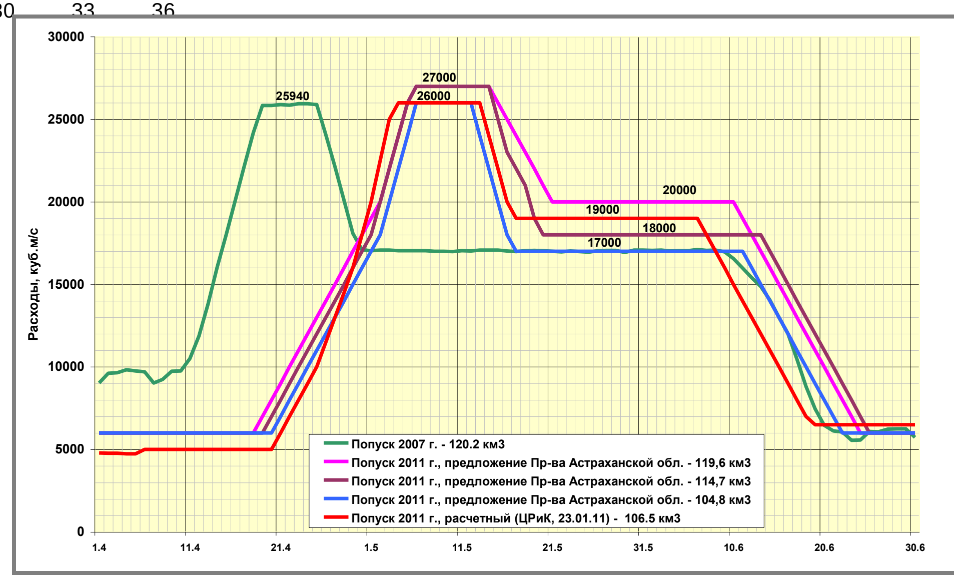


Control rules of Kuibyshev reservoir

Water management requirements

1. Hydropower
2. Fishing
3. Agriculture
4. Transport
5. Municipal Water Supply

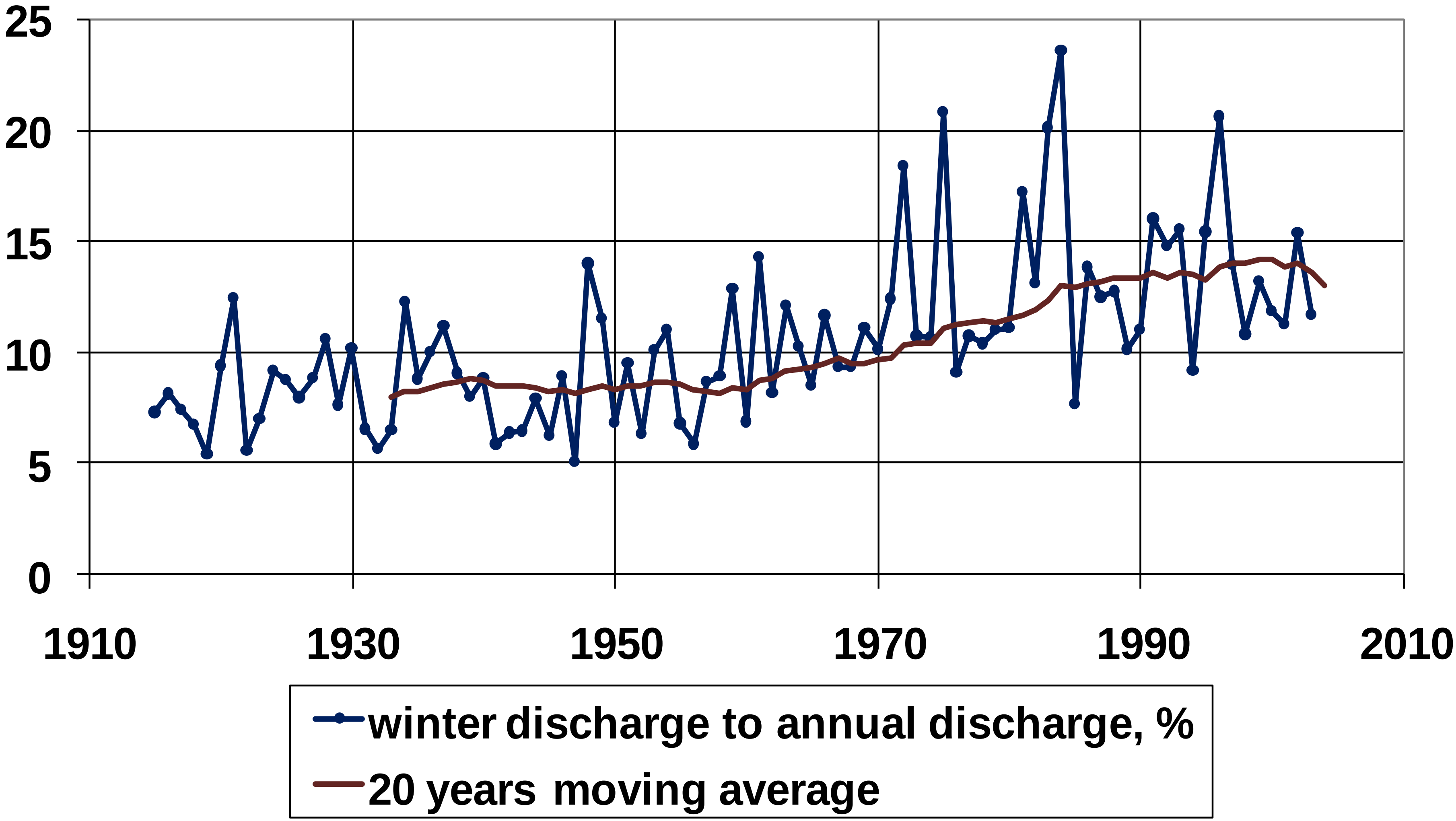
Spring passes through Volgogradskyi Hydrounite



Coordinates of probability curves of volumes of water releases downstream of Volgogradskiy hydrounite in April-June

Probability of water release	Water release, km^3			
	Variant 1	Variant 2	Variant 3	Variant 4
Maximum value, 1%	192.0	182.0	182.8	178.5
10%	154.4	161.5	150.2	158.0
25%	140.4	135.6	132.6	144.2
40%	119.6	119.9	121.4	120.4
Average annual value	114.6	117.1	112.9	114.6
65%	103.9	106.0	101.6	100.7
75%	91.6	94.6	93.3	91.5
90%	71.1	71.2	71.9	70.9
Minimum value, 99%	53.4	58.4	61.3	51.3

Changes of the Volga winter runoff



The questions are:

How to set a requirements for management during low flow period?

How to take into account in low flow forecasts a climate change impacts?

THANK YOU VERY MUCH
FOR YOUR ATTENTION!

DANKE FÜR AUFMERKSAMKEIT!