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Flood modeling and damage zoning in North Dvina river delta

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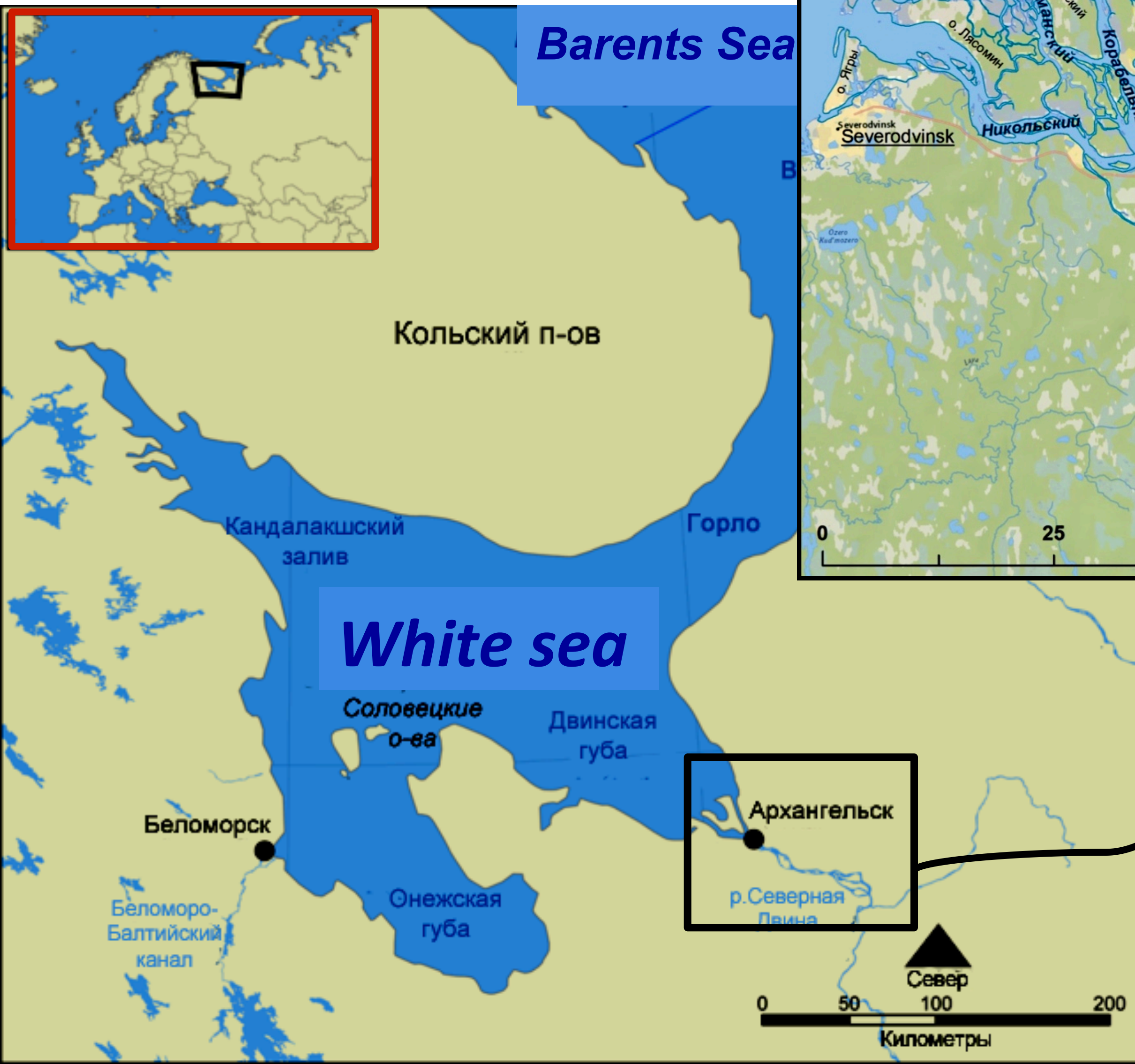
White sea on the Europe map

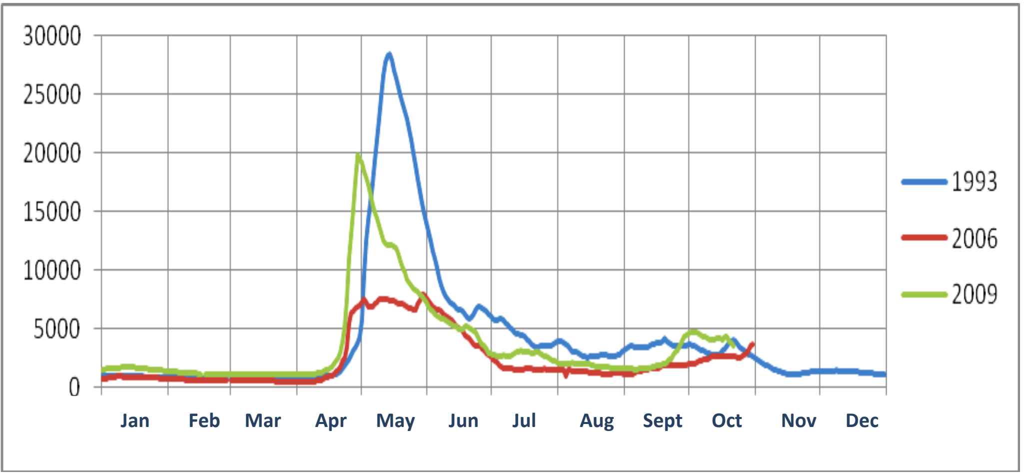


Area of the delta is about ***900*** *km*^{2}

Hydrological characteristics

RIVER FLOW

Discharge hydrograph Q, m^3/s



River basin area F = 360 000 km^2
Length L = 1302 km
Average discharge Q_{av} = 3330 m^3/c
Average maximum discharge Q_{max} = 21500 m^3/c

MARINE FACTORS

Average tides height **1,3 m**

Average wind surges height **1,9 m**

Distance of wind surges and tide wave penetration **135 km**

The effects of the sea regime are:

- additional rising of flooding levels in spring and in autumn
- inverse flows,
- salt water intrusion

ICE COVER REGIME

Ice jams create additional friction and sharp water level rising

Arkhangelsk – the largest seaport in European north of Russia

Severodvinsk – the biggest Russian shipbuilding center

- **wood plants, pulp and paper plant, wood-chemical plants**
- Population: **more than 0,5 million people**

Methodology: Hydrodynamics models of river flow
2-dimensional

The Saint Venant system of equations (motion and energy conservation equations) :

$$\begin{cases} \frac{1}{g}\cdot\frac{\partial u}{\partial t}+\frac{u}{g}\cdot\frac{\partial u}{\partial x}+\frac{v}{g}\cdot\frac{\partial u}{\partial y}+\frac{u^2}{C^2 h}=-\frac{\partial z}{\partial x} \\ \frac{1}{g}\cdot\frac{\partial v}{\partial t}+\frac{u}{g}\cdot\frac{\partial v}{\partial x}+\frac{v}{g}\cdot\frac{\partial v}{\partial y}+\frac{|uv|}{C^2 h}=-\frac{\partial z}{\partial y} \\ \frac{\partial(u\cdot h)}{\partial x}+\frac{\partial(v\cdot h)}{\partial y}=0 \end{cases}$$

$$C=\frac{h^{1/6}}{n}$$

Software package for hydrological modeling produced by Danish Hydrological Institute (**DHI**)

MIKE 21 is used

input data:

•Relief – DEM (Digital Elevation Model) from topographical and navigation maps, field measurements, remote sensing etc.

•Input water discharge

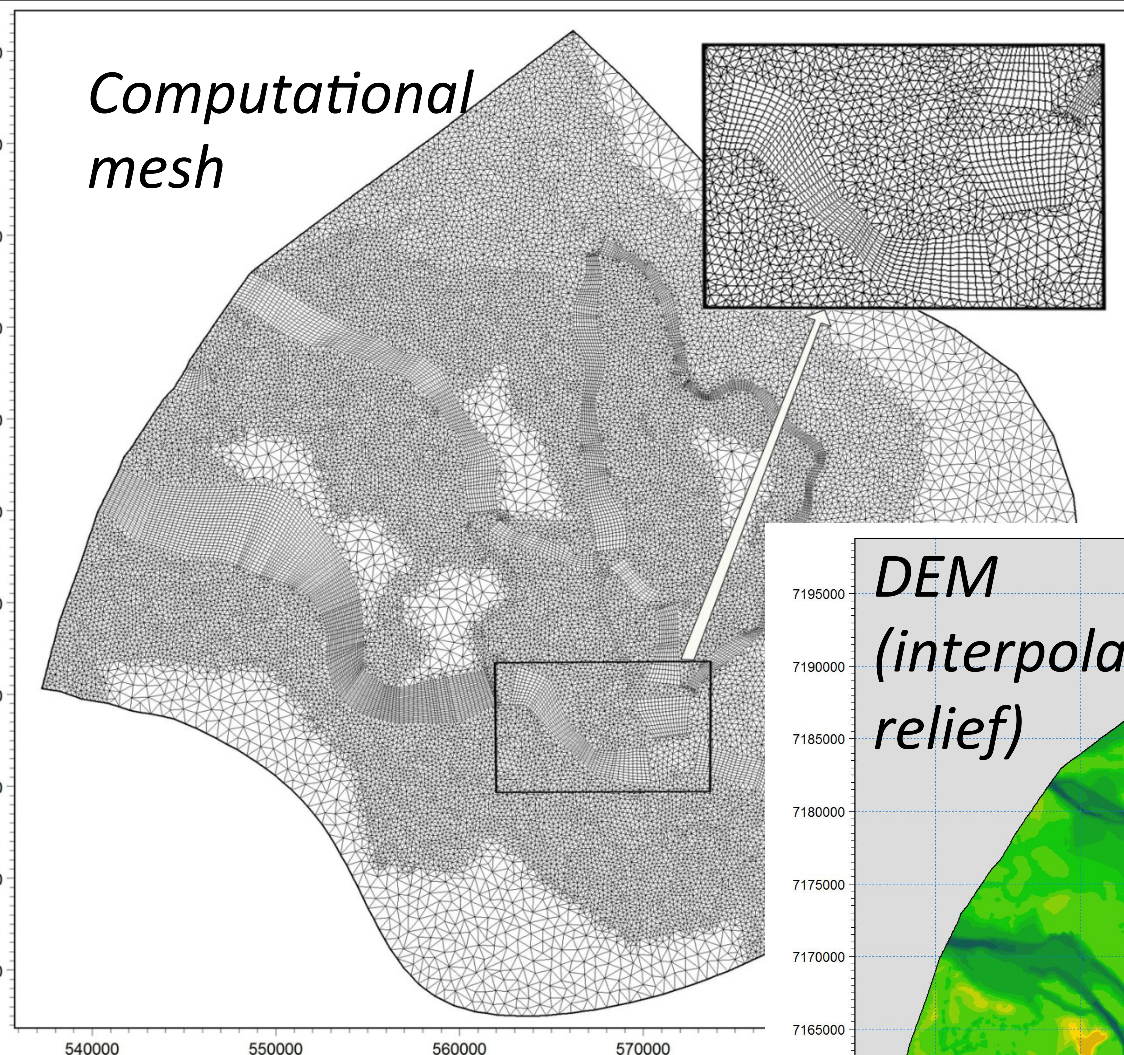
•Water level in the boundaries

Calibration parameter is bottom **roughness *n***

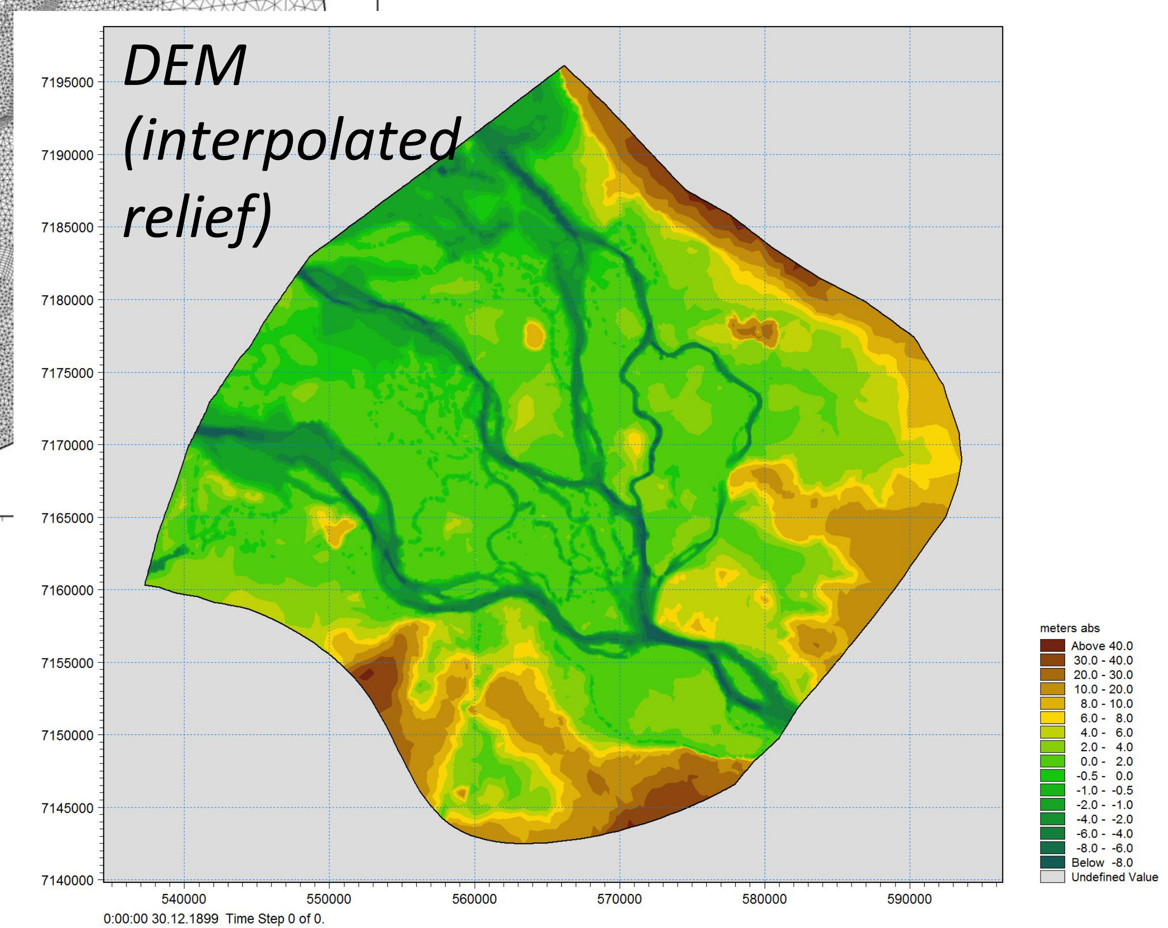
results:

Planned distribution **of water levels, depths, velocities**

water discharges in the river branches

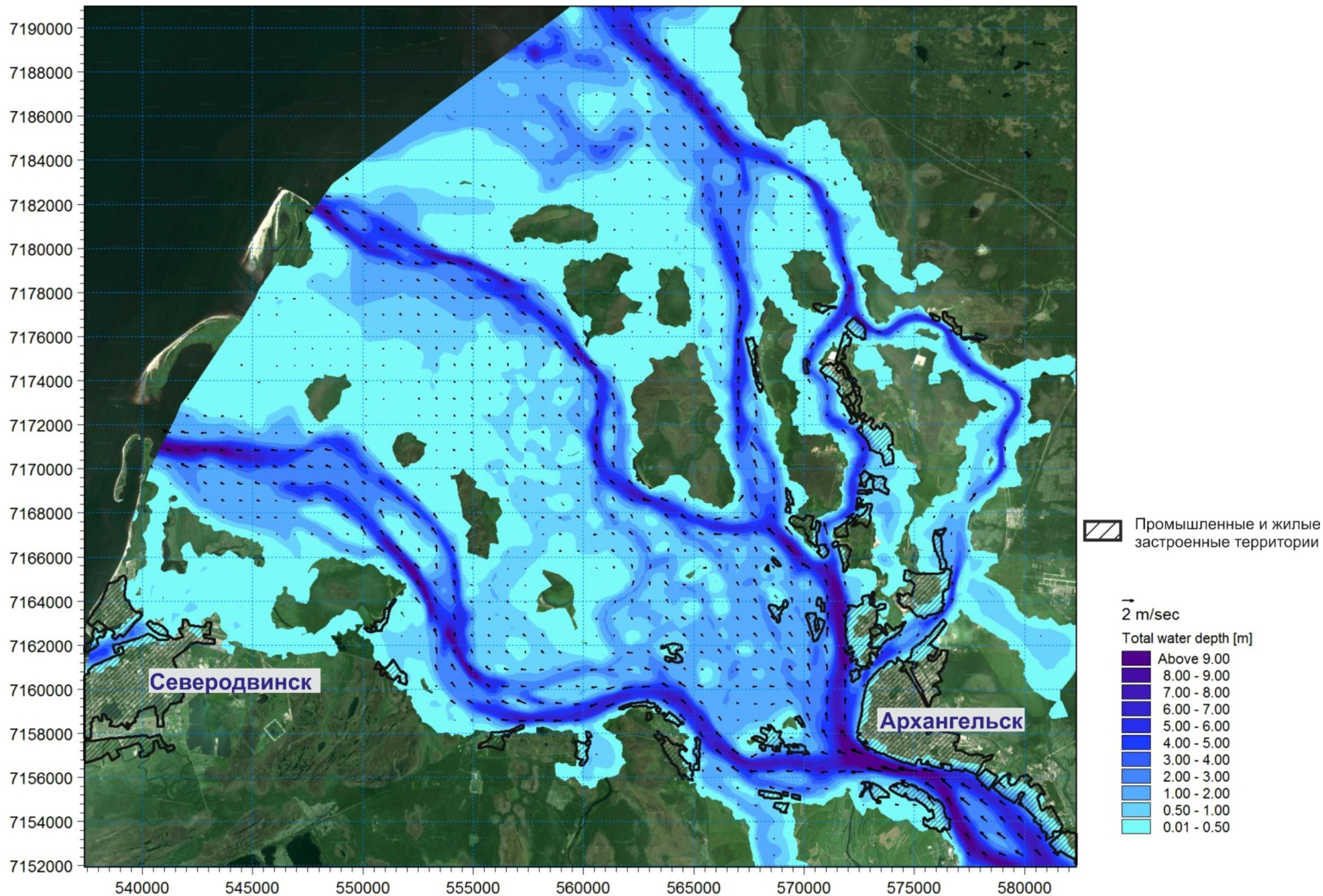


Computational mesh
540000
550000
560000
570000



DEM (interpolated relief)
7195000
7190000
7185000
7180000
7175000
7170000
7165000
7160000
7155000
7150000
7145000
7140000
540000
550000
560000
570000
580000
590000
0:00:00 30.12.1899 Time Step 0 of 0.
meters abs
Above 40.0
30.0 - 40.0
20.0 - 30.0
10.0 - 20.0
8.0 - 10.0
6.0 - 8.0
4.0 - 6.0
2.0 - 4.0
0.0 - 2.0
-0.5 - 0.0
-1.0 - -0.5
-2.0 - -1.0
-4.0 - -2.0
-6.0 - -4.0
-8.0 - -6.0
Below -8.0
Undefined Value

Modeled flood depths and velocities (river discharge Q=29500 m^3/s)



Application: potential damage assessment (Belikov V.V., 2005)

Specific flow energy (per unit width)

$$P = 0,5\rho H V^2$$

H – flow depth

V – flow velocity

ρ – fluid density

The grade of potential damage

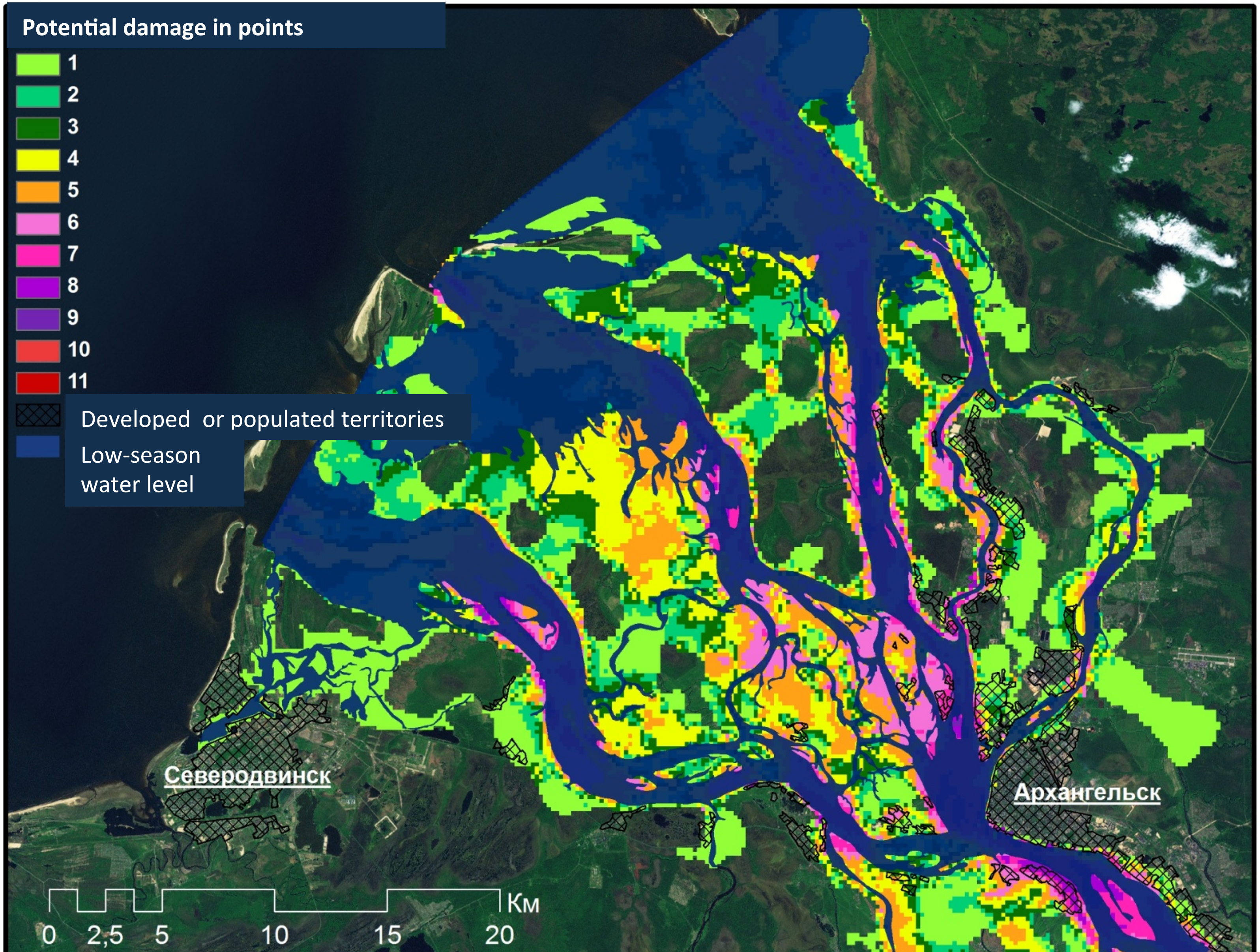
$$B = 2Lg(P)$$

$B = 1$ - no significant destructions

… … …

$B = 11$ - complete failure of concrete constructions

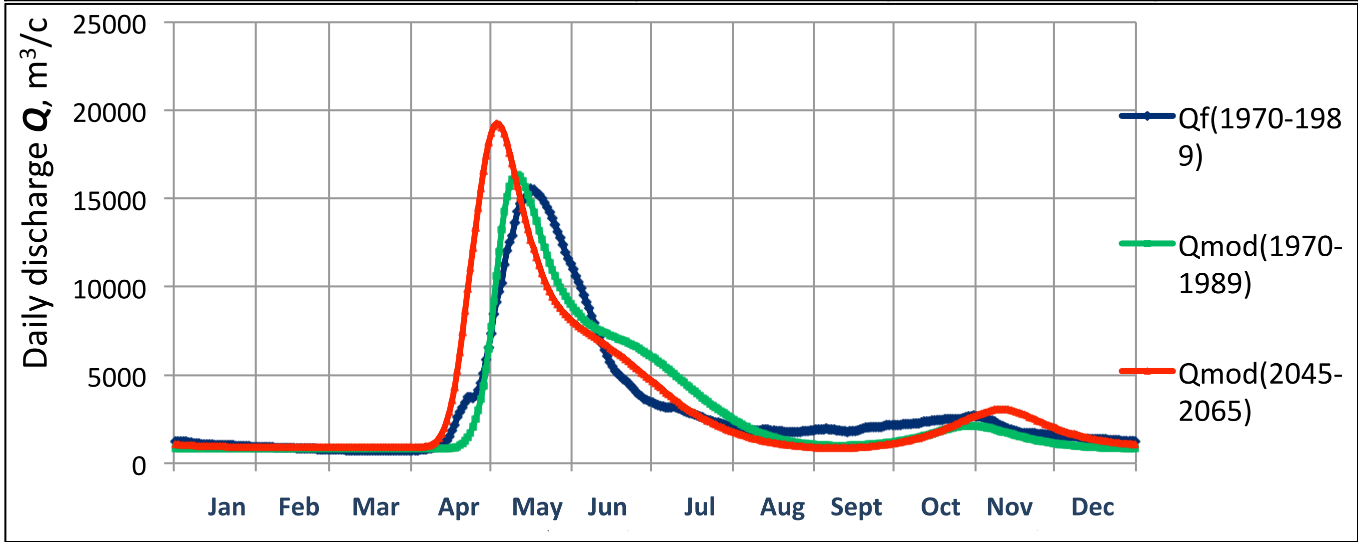
Grades of potential damage from flooding from 1 (min) to 11 (max) while river discharge is 29500 m^3/s (5 % exceedance probability)



Basin runoff formation modeling (Ecomag model, Motovilov Yu.,1999)

Results of estimation of future North Dvina runoff changes, based on data from global circulation models (Krylenko I.N., Antokhona E.N., 2012

Data	Average annual runoff volume, **km³**	Average runoff volume for months from April to July, **km³**	Averaged maximum discharge, **m³/s**
Observed runoff (1970-1989)	98.5	65.6	20 090
Runoff modeled on the base of meteorological station dataset (1970-1989)	100.1	69.0	18 820
Runoff modeled on the base of global circulation dataset (1970-1989)	94.5	69.4	17 311
Runoff modeled on the base of global circulation models dataset *(2046-2065)*	***99.2***	***84.0***	***23 046***



Thank you for your attention!!!