Gully thermoerosion on the Yamal peninsula.

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The high (15-40 m) sand and loam marine terraces at the western part of the Jamal peninsula are deeply eroded by gullies. Gully network density is 1.24 km/sq.km. There are four main processes which trigger off natural gully erosion: 1) river channel migration and erosion of high banks; 2) massive ground ice melting, cryoplanation; 3) cryogenic lakes discharge; 4) thaw slumps and active layer detachment failure (skinflow). In zones of production and transportation facilities the anthropogenic influence increases gully erosion potential due to: 1) technogenic deterioration of vegetation cover; 2) snow water storage increasing at upper parts of gully basins due to snow retardation near constructions; 3) runoff coefficient increasing on impermeable surfaces of the roads and buildings; 4) formation of local anthropogenic sources of the warm water. Combination of high natural gully erosion potential and additional anthropogenic influence causes extremely intensive gully heads growth: up to 20-30 m/year on loam deposits and 150-200 m/year on sands. The mathematical model of the gully erosion was developed. It is based on superposition of deformation equation

$$dz/dt+(1/W)*dQs/dx=0;$$

and sediment balance equation combined with empirical formula for incision rate determination:

$$(1/W)*dQs/dx+k1*dz/dx+k2*w*S=0$$

Here x,t-longitudinal and time coordinates, z - bed level, W - river channel width, Qs= Q*S - suspended sediments discharge, Q - water discharge, S - suspended sediment concentration, w - fall velocity. For thermoerosion process, when gully incision rate is more than rate of permafrost melting, erosion coefficient k1=0.000035*T C for sands and 0.0000035*T C for loams and clays. For erosion process, if rate of permafrost melting is more than gully incision rate, k1=0.0012*q for clays, 0.0063*q for loams and 1.3*q for sands. Here T C - water temperature, q - specific water discharge. Silting coefficient k2=E/(A-SP), where E - erosion, A - accumulation and SP - sediment supply volume. This model was used for gully network growth prediction in Bovanenkoskoye gas productive field for different conditions of anthropogenic influence, including "green- house" climate warming effect.