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Concerning the Stream Turbidity During the Laying of the Underwater Crossing of the Main Pipeline Across the River Lena

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Abstract. The stream turbidity significantly changes during the river bed evolution. It depends on the sediment storage, which is affected by the bottom dredging works, the construction of underwater crossings of main pipelines, bridge crossings, and others.

In the present paper, we consider the change in the stream turbidity during the laying of the underwater crossings of the main pipelines (ML) across the river Lena. A significant increase in the water turbidity and the discharge of suspended sediment has been detected during the construction of linear structures intended for transporting the energy resources. The river bed erosion in the trench area is one of the factors of the decrease in the service life of the underwater crossing of ML when the siphon is trench laid across a water channel. When the bottom is scoured, and the siphon of the underwater pipeline is denuded, significant hydrodynamic loads not specified by the project are added to the operational loads. Torsional, bending, and overturning moments, as well as the phenomena of hydro-abrasive erosive wear, develop [1]. They lead to fatigue failure of individual sections of the underwater pipeline on the base metal and welded joints. It is crucial to conduct further studies to assess the deterioration degree of the ecological state of the river Lena.

1. Introduction

Pipeline laying across the water channel by a trench method involves excavating significant volumes of soil, depends on natural and climatic conditions, and requires additional materials for ballasting the pipe.

Denudation and sagging of the pipeline in the trench are common phenomena during its operation. They lead to stresses in the pipe wall, the level of which increases with the increasing length of the scoured section. Due to sagging, the denuded area fluctuates in the water flow. Thus, the dynamic stresses develop in addition to the static ones [2, 3].

Systematic observations of the solid load of the river Lena are conducted at the Solyanka gauging station, located 6 kilometers downstream of the underwater crossing of the pipeline and ~ 24 km downstream of the city of Olekminsk.

Sediment loads are solid particles formed due to erosion of water basins and channels, transported by the watercourse and forming its bed. River sediments are subdivided into three categories: suspended, traction, and bed loads [4, 5]. Suspended sediment is transported by a water flow in suspension. The traction loads are carried by the water flow in the bottom layer and move by sliding, rolling, or saltation (abruptly). Bed loads form a river bed or floodplain. They constantly interact with the water masses of the stream [4, 5].

All these processes are exacerbated by large volumes of excavation works during the construction of the underwater crossings of ML by the trench method. For example, the project provides 9 meters from the natural landmarks near the water's edge for the depth of the trench across the river Lena and 7 m along the river bottom. The processing of rocky soils is performed after explosive fracturing.

It should be emphasized here that fine soil particles are shed by a water flow outside the construction site during the trenching by dredgers. Laying the excavated soil into reserves and the subsequent backfilling of trenches is performed with reserve soil. The amount of the removed soil of fine fractions reaches 30-40% of the amount of the trench excavation [1].

The mass of the alluvial deposited soil is spread vastly along the river. Specifically, much of the amount of regulated soil (up to 40-50%) is kept within the length (1÷60) of flow depths. As a result, the shortage of ground for backfilling trenches can be 50-70% or more of the required volume. This deficit is compensated by excavating soil from the river bed in the immediate neighborhood of the siphon [1].

Consequently, the volume of earthworks, taking into account the above factors, as well as the drift of the trench during its processing, increases 1.6-2.0 times and is approximately from 122400 to 15300 m^3.

Processing such a large amount of soil in the channel part of the river Lena significantly negatively affects the general ecological state of the water, which is manifested by a change in the stream turbidity.

2. Research materials and methods

The method for determining the stream turbidity of the river Lena is based on the methodology used in the network organizations of the Hydrometeorological Service [4]. It consists of field sampling methods, solid load study, laboratory work for determining water turbidity, determining the particle size distribution of suspended loads and bottom sediments in laboratory conditions.

Depth measurements are regularly made at the stream gauge at least once a year and with noticeable river bed deformations. To obtain a full cross-section profile of the river bed above the water's edge, the coastal zone is leveled to flood-free marks. Depth measurements are made at equal distances from the water's edge from one bank to another. To determine the area of the stream cross-section with an accuracy of plus or minus 5%, the number of sounding points (verticals) must be at least 20.

It is recommended to measure the river depth from the ice surface. The landmarks above the water's edge are determined by leveling to the water level marks of the highest historical values.

The cross-section profile of the stream gauge is built as a graph with elevations according to the Baltic height system. The distances of the sounding and velocity verticals are measured from the initial point of the stream gauge, which is fixed on the land by signs, as well as in the Technical file of the post. Geographical coordinates are determined with an accuracy of hundredths of a second.

Table 1. Location of the velocity verticals on the river Lena – Solyanka from the initial point (IP) of the Solyanka stream gauge.

Vertical numbers	Distance from IP, m	Vertical numbers	Distance from IP, m
1	100	7	725
2	200	8	850
3	350	9	950
4	450	10	1100
5	550	11	1250
6	675	12	1325

Sounding and velocity verticals (Table 1) during the entire operation of the station are fixed at the same place to observe the riverbed deformation and the change in the current velocity.

To determine the water discharge rate, the current velocity is measured. It is performed at every other sounding point (vertical). That is, current velocity should be measured in at least ten verticals, which are located evenly along the river width. In this case, the current velocities are measured at two points (depth of 0.8 and 0.2) on each velocity vertical.

Suspended load discharge is determined by taking water samples at each point of measured current velocity, followed by filtration on pre-weighed filters.

Filtration is performed directly at the object using the Kuprin GR-16 device, that is, after each sampling on the velocity vertical, twice after water sampling from 0.8 and 0.2 depths.

Fig. 1 demonstrates the change in the water level at this post from May to September 2009. In 2009, the spring flood on the Lena began earlier than usual. April 20 is considered as the beginning of the spring flood, which is 11 days earlier than the norm.

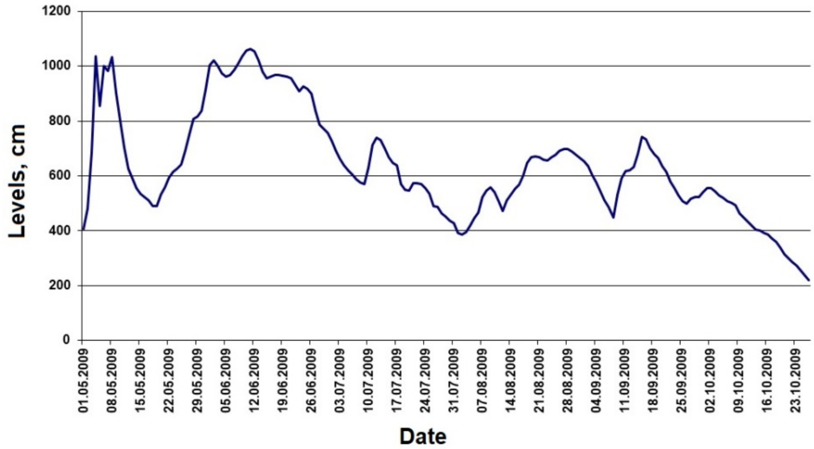


Figure 1. Water levels of the river Lena at the Solyanka stream gauge from May to October 2009.

Due to the inhomogeneous development of spring processes after May 8, the river water content decreased at the Solyanka post. It increased only from the beginning of the third decade of May. In 2009, the annual maximum of the water level was observed at the Solyanka post on June 11. It is 18 days later than the norm after the river had cleared of ice. Thus, in 2009, the highest annual water level was not due to the ice jams. The annual maximum of the water level was close to the typical values, although it is almost two decades later by the date. The spring flood ended at the end of the first decade of July, which is close to average terms.

After the spring flood, six rainfall floods took place in the area of the underwater crossing of ML during the summer-autumn period.

In the summer period of backfilling the trench, the stream was tested for turbidity. The dates of collecting water samples are presented in Table 2. The flat datum at the Solyanka stream gauge corresponds to 119.42 m, according to BS. In total, 12 series of samples were taken as consistent with the field technique.

Three series of samples were collected during the spring flood recession. Four series were taken during the decline of the first rain flood wave, two - during the rising phase of the fourth flood wave, one series of samples - during the rise of the penultimate flood wave, the remaining two series - during the decline of the fourth and fifth flood waves.

Table 2. Schedule of water sampling for turbidity and hydrological data of the river cross section in 2009.

Day, month	Water level, BS, m	Cross section width, m
June 24	128,69	1360
July 2	126,34	1340
July 9	125,11	1320
July 17	125,81	1330
July 21	125,14	1320
July 29	123,95	1305
July 31	123,69	1300
August 19	126,09	1332
August 28	126,39	1340
September 2	125,78	1325
September 15	126,86	1345
September 19	126,07	1332

According to the field technique, each series of samples consists of 14 or 24 water samples taken at seven or twelve velocity verticals at two points on each vertical. The location of the velocity vertical is constant and determined by GPS. Turbidity values are presented in Table 3.

Table 3. Turbidity distribution along the verticals (g/m^3).

No. Vert.	24.06	2.07	9.07	17.07	21.07	29.07	31.07	19.08	28.08	2.09	15.09	19.09
1	27,8	27,6	17,6	37,0	16,3	20,1	24,2	40,5	16,0	14,8	73,6	13,2
2	-	-	-	-	-	17,3	15,3	51,4	16,2	14,8	78,1	7,8
3	25,0	20,2	21,3	14,1	20,0	16,5	11,8	73,5	12,0	13,2	83,3	4,0
4	-	-	-	-	-	19,0	18,0	118,2	11,0	12,1	43,6	4,4
5	26,6	36,8	17,6	10,1	20	22,3	18,6	11,8	12,8	12,4	36,3	3,9
6	-	-	-	-	-	21,1	18,0	12,2	13,6	12,4	39,4	6,3
7	24,6	19,2	17,8	12,3	18,8	20,8	10,9	12,9	12,8	13,6	23,2	3,6
8	-	-	-	-	-	18,6	11,4	14,2	13,1	11,4	35,9	3,2
9	27,4	20,0	23,3	13,2	18,9	18,5	19,1	10,4	14,6	8,6	22,0	3,9
10						18,1	7,2	14,2	9,9	7,0	57,3	2,6
11	28,6	17,9	23,8	16,2	18,6	21,0	11,8	24,2	11,3	3,5	48,4	2,0
12	31,8	15,4	15,9	14,5	15,6	17,8	12,5	51,6	14,4	3,7	28,1	3,4

The excessive turbidity of the water recorded on June 24 along the coastal verticals No. 11 and No. 12, located at 1250 and 1325 meters from the initial point (IP) of the gauging station on the left bank, can be accepted as the coastal turbidity caused by the backfilling of the oil pipeline trench on the coastal slopes of the river bottom (Fig. 2, a).

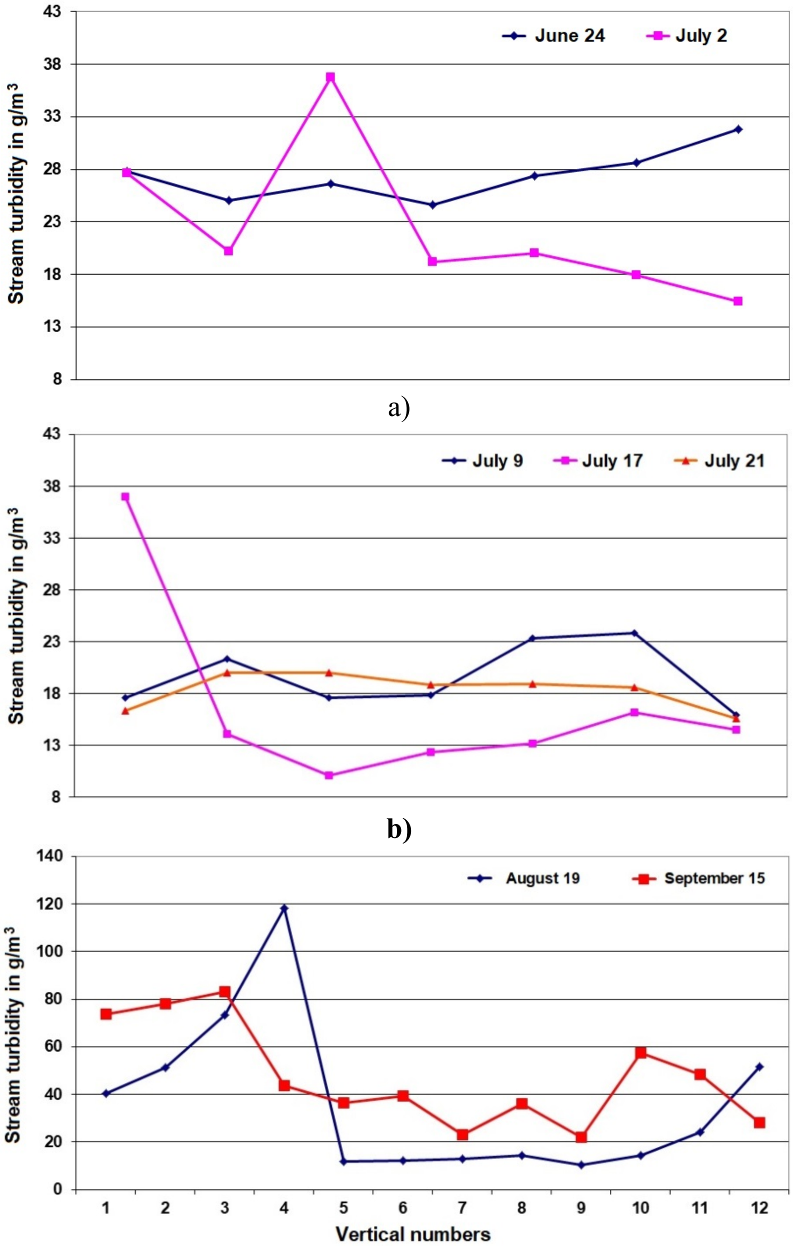
On July 2 and 9, the water turbidity approximately doubled (Fig. 2, b) compared to the water turbidity on July 17 at a distance of 550 meters from the IP of the gauging station, as well as compared to the turbidity 725 meters away. It should be referred to as the consequences of works on the underwater crossing of ML.

Excessive water turbidity was recorded on August 19 and September 15 as well (Fig. 2, c). In the field books, it was noted that the works had been performed at the underwater crossing of ML on those dates.

The highest water turbidity was noted 450 meters from the IP of the gauging station on August 19 (Fig. 2, c) (Tables 2, 3). The weight of the solid particles was 118.2 grams per cubic meter of water.

For the 550-1100 meters river strip, the stream turbidity exceeded the value of the previous sampling by 4 to 10 times (Tables 2, 3).

In the next series of sampling (Fig. 2, c), collected during the works at the underwater crossing of ML on September 15, the stream turbidity exceeded the values obtained on September 2 along the entire width of the river (Tables 2, 3). In the following sampling, the turbidity decreased over the entire width of the river by about ten times (Tables 2, 3).



c)

Figure 2. Changes in the stream turbidity over the Lena-Solyanka width.

Water samples for turbidity were not collected for all periods of excavation works at the underwater crossing of ML. Therefore, we present the materials of the works on the Solyanka gauging station, obtained by FSBI YaUGMS (Yakutsk Weather Control and Environmental Service).

According to the results of observations of suspended sediment discharge by specialists of FSBI YaUGMS on the Solyanka gauging station for the period from 2001 to 2011, during the period of construction of the underwater crossing of ML, the amount of the suspended load discharge increased from 6.3 to 11.2 times and reached a maximum of 990 kg/sec compared to the recorded minimum level in 2006 and 2007, especially in August and September from 2008 to 2011 (Fig. 3).

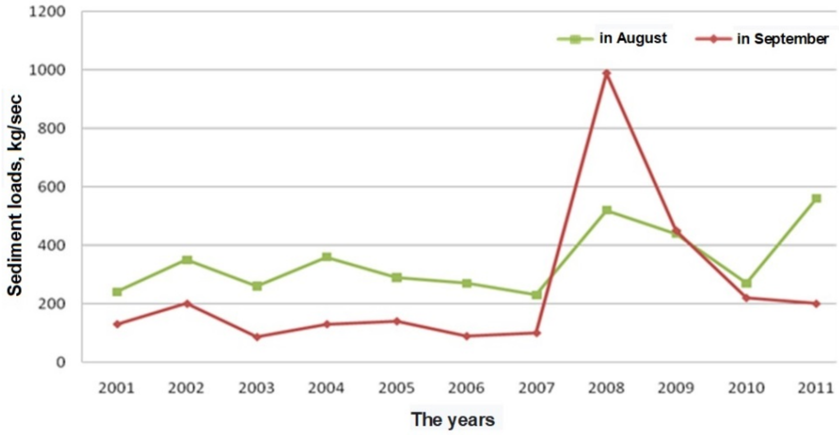


Figure 3. Changes in suspended load discharge at the Solyanka gauging station on the river Lena in August and September, 2001-2011.

According to the survey data on changes in the stream turbidity and the suspended load discharge during the construction of the underwater crossing of ML, the anthropogenic pollution of the river Lena had reached a high level during the construction period from 2008 to 2011.

Burial and post-trenching works, as well as backfilling of denuded and sagging sections of pipelines, are performed annually at each underwater crossing. All these preventive measures result in pollution of the river watercourse [6]. These and other anthropogenic factors lead to the deterioration of drinking water in many river basins of the Russian Federation and the whole ecological situation.

3. Discussion

Intensive anthropogenic pollution of the river Lena was observed during the construction of two lines of the Hatassy-Pavlovsk underwater crossing of the main gas pipeline (MGL) across the river Lena. The first line was built in 2003. From 2007 to 2012, earthworks on burial and post-trenching of the first line were performed at the Hatassy-Pavlovsk section year-round by OOO Sprut (Irkutsk). Construction and trenching of the second (reserve) line of the underwater crossing were at the same period. Owing to the continuous earthworks, a huge amount of soil was removed from the river bottom, the bulk of which was left in the riverbed. These volumes significantly deform the morphology of the river bottom, change the natural formation of channel micro-, meso- and macroforms of the river Lena in the Tabaga-Yakutsk section [7]. After excavation in 2010, three vessels were left at the site of the underwater crossing of the river channel: two vessels were in the middle of the river with artificial fencing in the form of a sandy hillock, and the third one at the coast [7].

Due to the created obstacles near Hatassy-Pavlovsk underwater crossing of MGL across the river Lena, a powerful ice jam had formed in May 2010. Settlements located in the floodplain of the river Lena from the village Hatassy and above were flooded.

The ice jam was provoked by a large volume of soil pulled out during excavation work at the underwater pipeline (two lines), post-trenching of the second line, which was laid in April 2009, in winter, as well as two abandoned floating cranes at the left and right banks of the river, protected by the emerged sandy islands of artificial origin [8].

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4. Conclusions

1. According to the well-known methods of studying solid load, field techniques, and sample collecting, determining water turbidity and the granulometric composition of suspended sediments and bed loads, the stream turbidity was determined during the construction works of the underwater crossing of ML across the river Lena from June to September 2009.

2. A significant increase in the stream turbidity is observed during construction works at the underwater crossing of ML across the river Lena. The turbidity spreads over a distance of more than six kilometers downstream.

3. This hydrological process may cause pollution of the water basin and deterioration of the ecological state of the river Lena during construction and operation of the underwater crossings of main pipelines, which require further research.

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