TRAFIKVERKET

Bilaga C:5

Slussar i Trollhätte kanal

PM Grumlingsmodellering

Anläggande av sluss i Lilla Edets kommun, Västra Götalands län

2024-09-20

Trafikverket
Postadress: Vikingsgatan 4, 411 01 Göteborg
E-post: trafikverket@trafikverket.se
Telefon: 0771-921 921, Texttelefon: 010-123 50 00
Konfidentialitetsnivå: 1
Dokumenttitel: PM Grumlingsmodellering
Författare: Anders Jensen, WSP Danmark
Kontaktperson: Lars Johansson, Trafikverket
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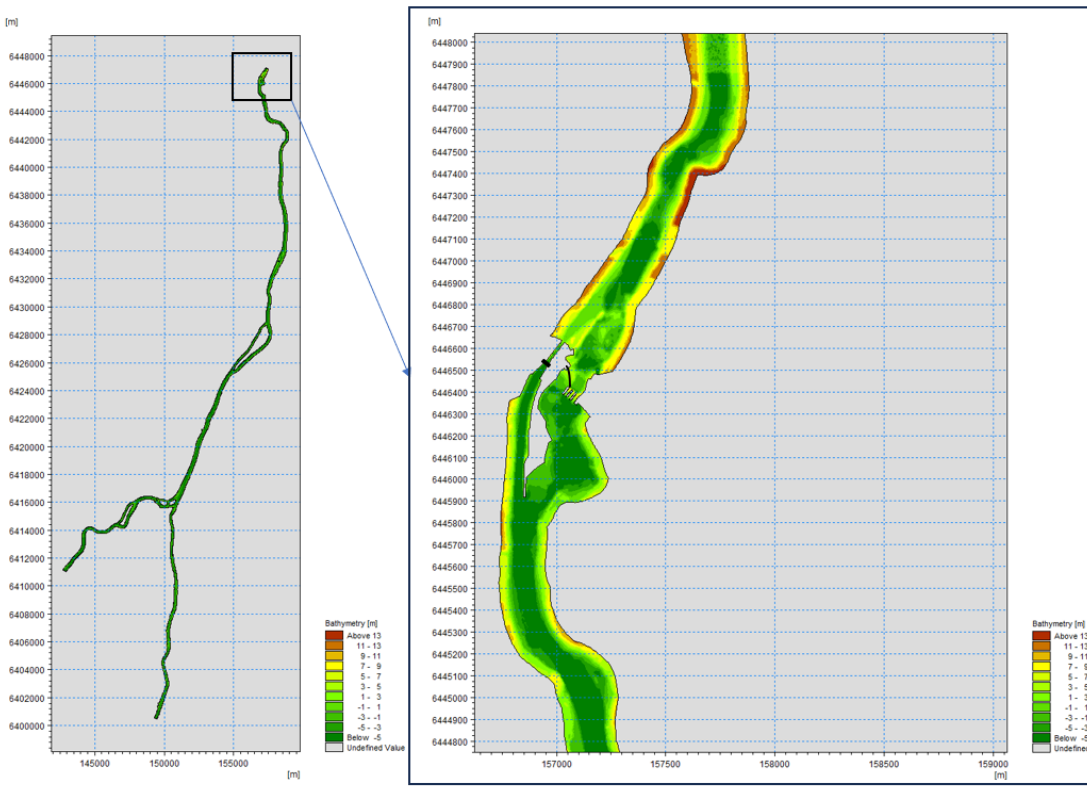
WSP A/S DANMARK

LILLA EDET NEW LOCK

MODELLING OF SEDIMENT DISPERSION FROM CONSTRUCTION ACTIVITIES



LILLA EDET NEW LOCK

MODELLING OF SEDIMENT DISPERSION FROM CONSTRUCTION ACTIVITIES

WSP A/S DANMARK

CONFIDENTIAL

PROJECT NO.: 22004557

WSP
LINNÉS ALLÉ 2
2630 TAASTRUP
DENMARK
T +45 44 85 86 87
M +45 40211164 WSP.COM

QUALITY MANAGEMENT

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Signature	AJE			
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Authorised by	Lea Schmidt			
Signature	LESC			
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SIGNATURES

PREPARED BY
Anders Jensen
Principal Advisor Coastal Dynamics & Numerical Modelling

REVIEWED BY
Martin Fredberg
Associate Water Resources Engineer

TABLES

FIGURES

1 BACKGROUND AND PURPOSE

1.1 BACKGROUND

WSP Sverige AB Sverige has requested WSP A/S Danmark to model sediment dispersion caused by dredging and other construction activities related to construction of a new lock for ships in Göta Älv at Lilla Edet located 34 km downstream from Vänern.

Water intake and a hydroelectric powerplant located downstream of the construction site as well as general environmental concerns, requires specific knowledge of the transport and dispersion of sediment spilled into the river from the construction activities.

The purpose of this study is to provide information in time and space on the expected concentrations of sediment and sedimentation resulting from sediment spilling activities such as dredging of new entrance channels.

2 CONCLUSIONS

- Sediment spilled from the construction site and dredgers do not exceed critical levels at water intakes.
- The plumes from the dredging operation up stream from the hydro power plant does not reach the eastern bank up stream the hydro power plant.
- The sediment concentration in the river drops to below 4 mg/l 1 km down stream from the hydro power plant and drops to around 1 mg/l at Göteborg and where the river flows into the sea.
- Spilled sediment accumulates near the dredging sites where it is sheltered from the stronger current.
- Levels of contaminants does not exceed water quality criteria except very close to the dredging sites.

3 MODEL SETUP AND ASSUMPTIONS

WSP is using the MIKE model tools from DHI. Based on experience we are using a horizontal 2-dimensional model with a flexible net which allows a very high resolution near the working sites and the sources of sediment spill from dredging and other operations.

MIKE 21FM is the leading software package for 2D modelling of hydrodynamics, waves, sediment dynamics, water quality and ecology. It is professional software of high reliability, quality and versatility. MIKE 21 is a modular product and includes simulation engines that are aimed at a very wide range of applications. We will use a horizontal 2-dimensional model which provide depth integrated values of sediment concentrations current velocities etc. in a 2 D grid as we assume that the water column in Göta Älv downstream the construction site is well mixed due to the current induced turbulence. Intrusion of salt water from Kattegat will not reach north of Göteborg and will therefore not be a factor in this part of the model study.

MIKE 21 FM and its three-dimensional variant MIKE 3 FM is based on a flexible mesh approach and has been developed for applications within oceanographic, coastal, estuarine - river environments. In the present case we use the 2D model which means that all values are depth integrated values. This also means that the simulation of the transport of fine-grained sediment from the construction and dredging sites are depth averaged values, causing the spill to be released in the entire water column. In a very well mixed fluvial environment, the 2D approach will be well suited to give a realistic picture of the spreading and transport of the spilled sediment.

More documentation of MIKE 21 can be found at: [MIKE 21 & MIKE 3 Flow Model FM - Mud Transport Module (mikepoweredbydhi.help)](mikepoweredbydhi.help).

The model includes sedimentation and resuspension of the spilled sediment and there are no constrains regarding minimum or maximum concentrations.

WSP has establish a flexible mesh model covering the distance between the construction site at Lilla Edet to Norra Marieholmsbron in Göteborg and in Nordre Älv where it runs out in Kattegat, see Figure 3-1.

The grid size in the model varies from approximately 1 m around the workplaces and the lock to 10 m further away, see Figure 3-2.

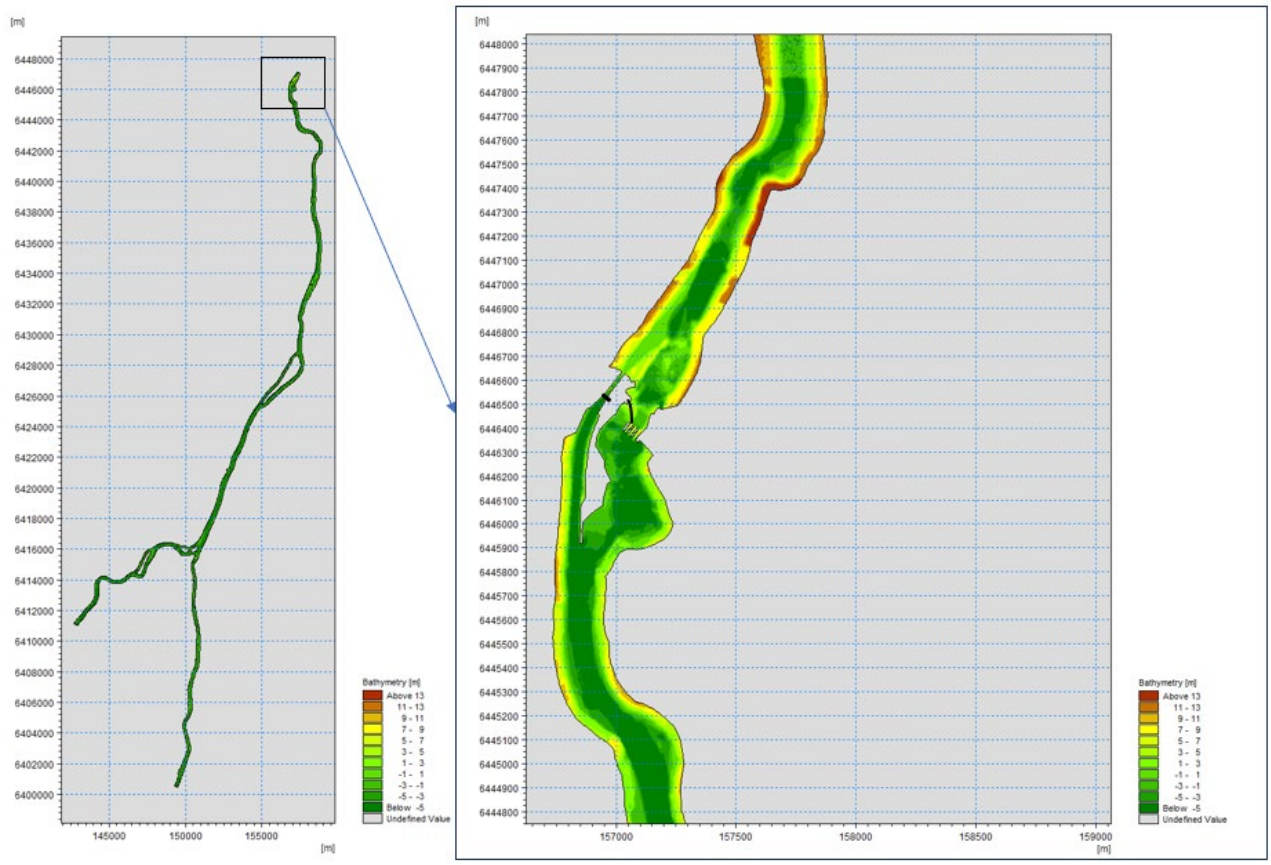

Figure 3-1 Göta Älv bathymetri. based on data provided by WSP Sweden. All coordinates are in Sweref99_12_00

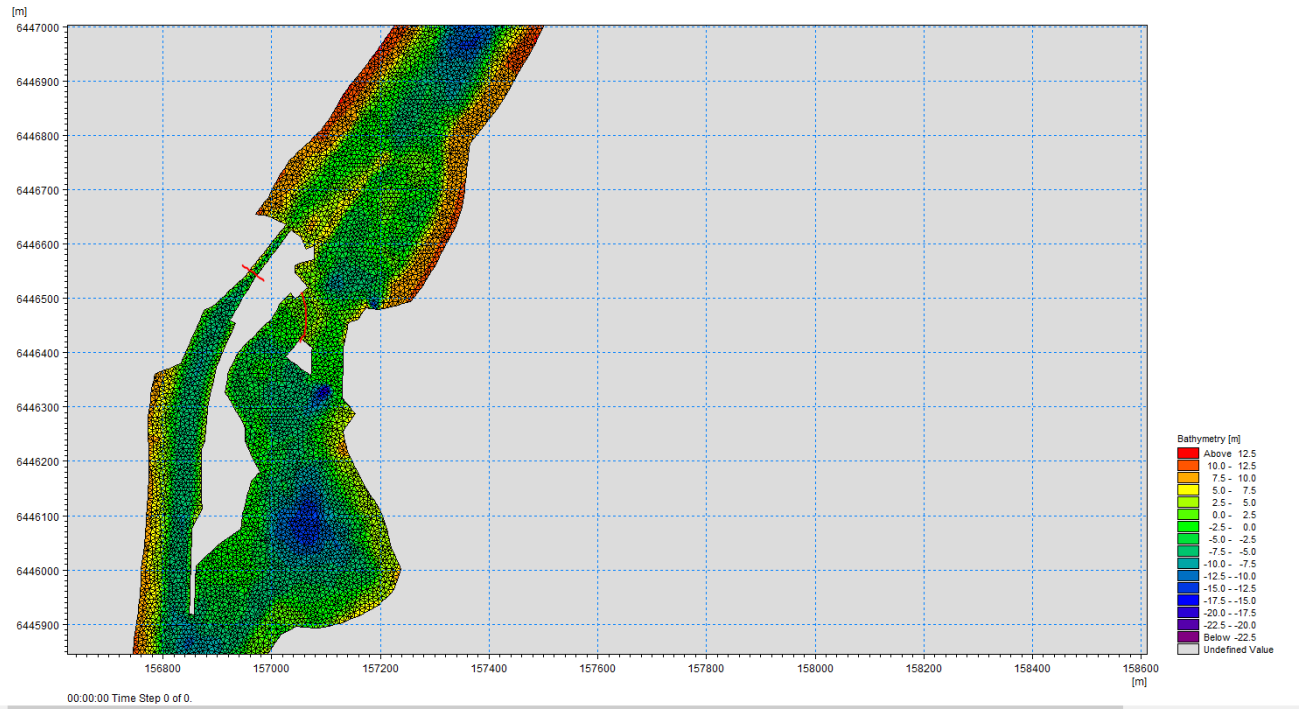

Figure 3-2 Model mesh with closed dam and lock and full flow through the power plant.

Likely scenario for flow in Göta Älv during the construction period will be used as hydrodynamic boundary condition and the spill rates is estimated based on information of dredging method, transport and disposal of the dredged material, description of the material to be dredged as well as description of any other activities which may generate spill of sediment during the construction period.

The spill rate (3kg/s) is estimated based on comprehensive measurements of spill rates conducted 300 m down stream of backhoe dredgers dredging in glacial till and loading onto barges at water depths ranging from 3 m to 6 m and in current velocities up to 1.5 m/s. The data set includes 3 years of almost constant measurements during the construction of the fixed link between Denmark and Sweden. The data is reported in (Öresundskonsortiet, 2000) and was validated and approved by Miljödomstolen (Vattendomstolen) at the end of the project.

The grain size of the spilled sediment is also estimated based on measurements of in situ fall velocities 300 m down stream the dredgers during the Øresund project. At this distance all sediment larger than 63 µm has settled out and only particles smaller than 63 µm (silt and clay) will stay in suspension and be carried down stream. The silt and clay fraction which also includes organic particles, are also the sediment types which carries the contaminants due to the surface-active nature of the minerals and the organic particles. For this project medium silt with a fall velocity of 0.5 mm/s (fresh water 10°C) is used. Due to the relatively strong currents in the main river flow, the resulting transport and dispersion of the particulate matter is relatively unsensible to the fall velocity of particles smaller than 63 µm.

The total dredged volume is 700 m^3 per day distributed with 350 m^3 down stream of the existing ship lock and 350 m^3 located upstream of the existing ship lock.

The levels of contaminants in the sediment to be dredged is shown in Table 3-1 together with criteria for water quality.

Table 3-1 Mean concentrations of contaminants found in the sediment to be dredged

Stof	Unit	Concentration	Criteria
Antracen	mg/kg Ts	0.1127	0.024
Fluoranten	mg/kg Ts	0.4300	2
Benso(a)pyren	mg/kg Ts	0.1760	-
Total 16 EPA-PAH ex. LOQ	mg/kg Ts	2.343	-
Total 16 EPA-PAH incl. LOQ	mg/kg Ts	2.0092	-

Tributyltenn (TBT)	mg/kg Ts	0.009989	1.6
TOC analyserat	% Ts	1.186842	-
Glödförlust	% Ts	3.66875	-

Model scenarios with flow through the hydro power plant are shown in Table 3-2

Table 3-2 Model scenarios with flow through the hydro power plant

Flow in the river	Dredging spill down stream lock	Dredging spill up stream lock	Dredging time / day	Lock operation
1200m^3/s (maximum)	3 kg/s	3 kg/s	9 hrs	15 hrs
300 m^3/s (mean)	3 kg/s	3 kg/s	9 hrs	15 hrs
171 m^3/s (low)	3 kg/s	3 kg/s	9 hrs	15 hrs
140 m^3/s (low)	3 kg/s	3 kg/s	9 hrs	15 hrs

4 RESULTS

Concentration of sediment spilled from two dredging operations, one up stream and another downstream of the lock during high, medium and low flow in Göta Älv are presented in sections 4.1, 0 and 0 whereas the sediment concentration of spilled sediment during medium flow for the entire river down stream of Lilla Edet is presented in section.

The modelled sediment concentrations do not include the natural background sediment concentration in the river, nor does it include sediment spilled from other construction or dredging operations in the river.

The results shows that the sediment from the dredging operations at Lilla Edet does not reach the eastern bank of the river up stream of the hydro power plant. The results also shows that higher flow rate in the river, dilutes the sediment plumes coming from the dredging operations.

4.1 SEDIMENT CONCENTRATIONS. FLOW 1200 M^3/S

Sediment concentration and exceedance frequency of 10 mg/l and 25 mg/l during dredging. Flow in the river is 1200 m^3/s and all the flow goes through the power plant are shown on Figure 4-1, Figure 4-2 and Figure 4-3.

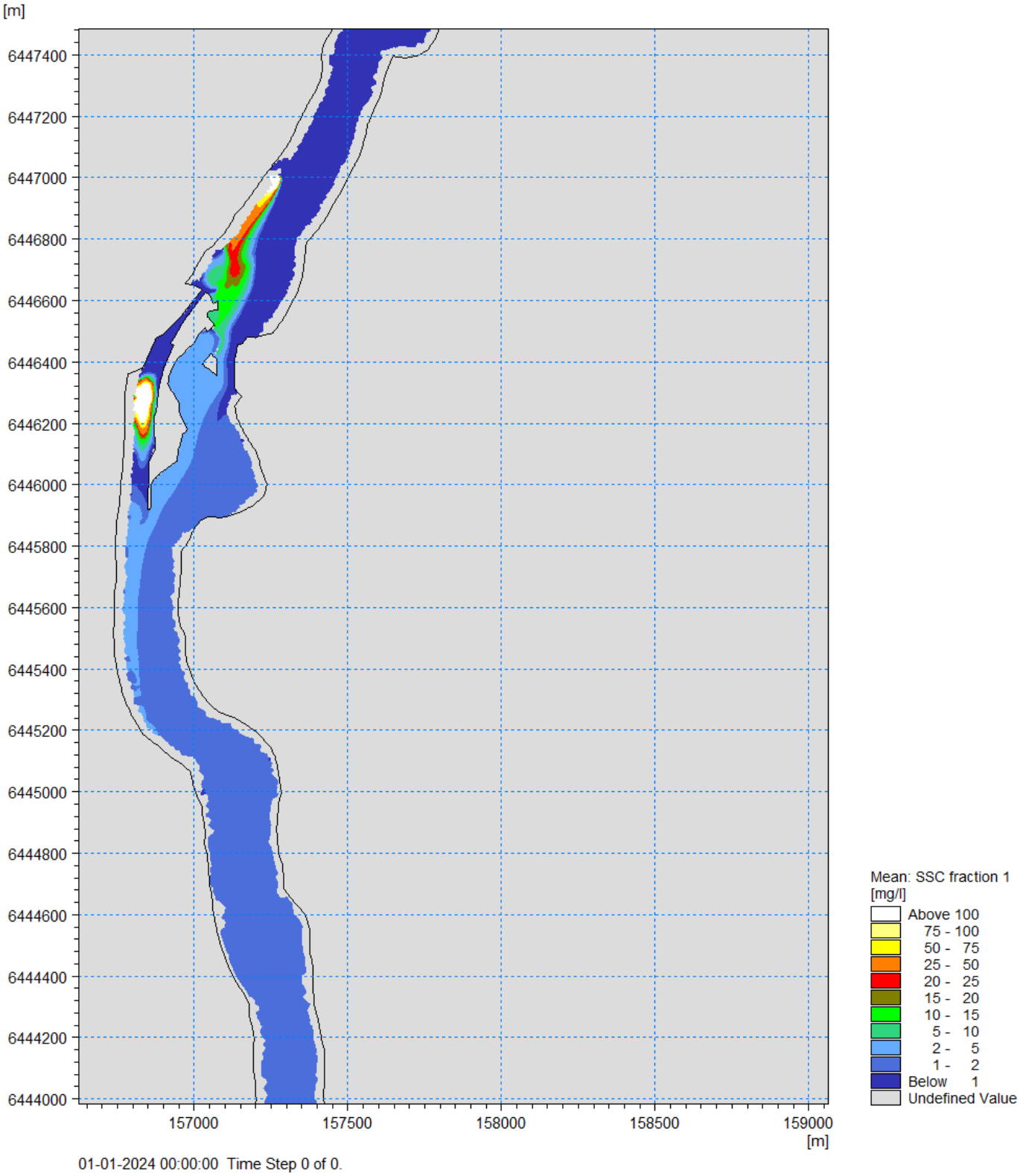

Figure 4-1 Mean sediment concentration during dredging operations up stream and down stream of the lock. Flow is 1200 m³/s. All flow through the hydro power plant.

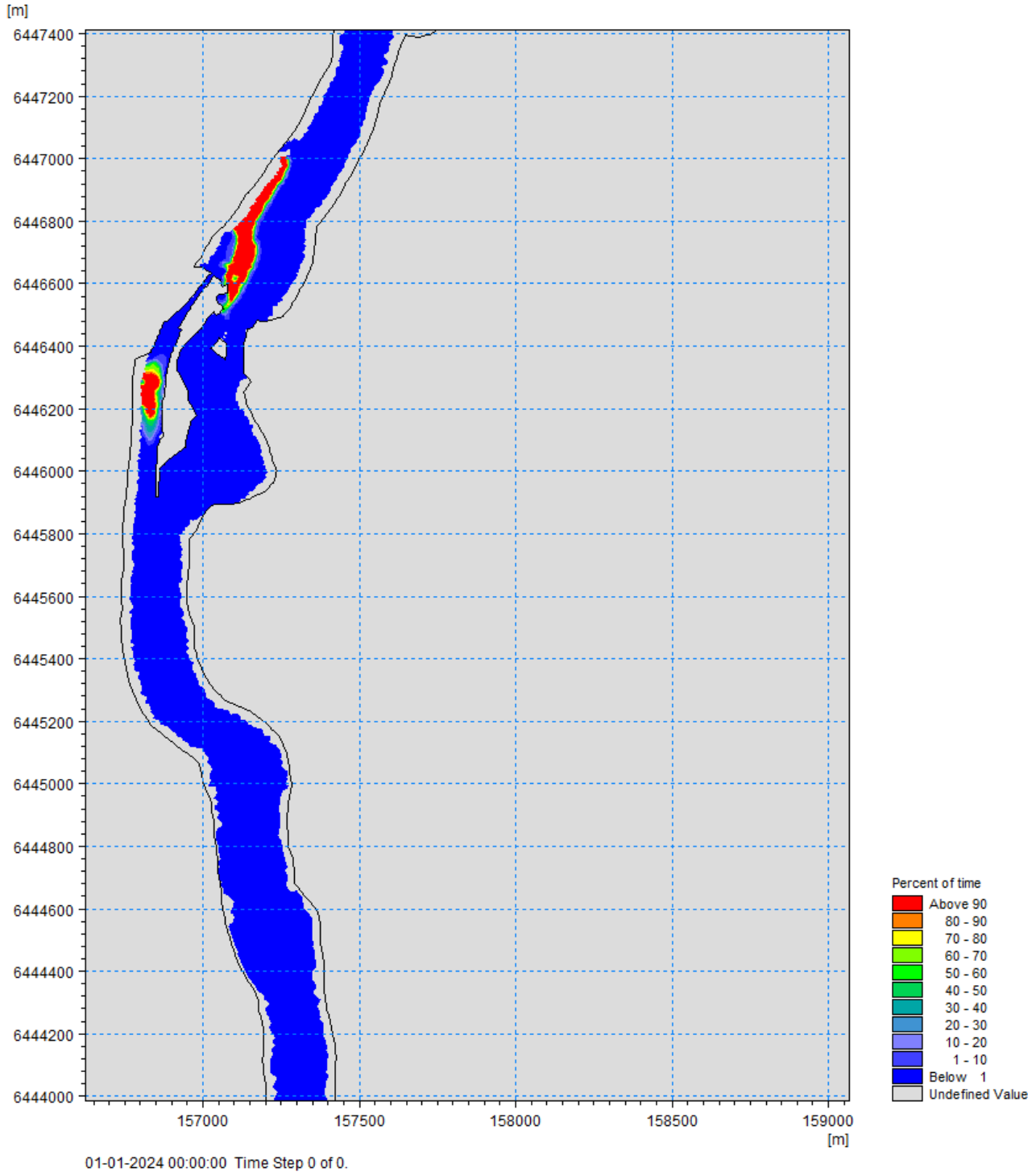

Figure 4-2 Percent of time during dredging where the sediment concentration exceeds 10 mg/l. Flow is 1200 m^3/s. All flow through the hydro power plant.

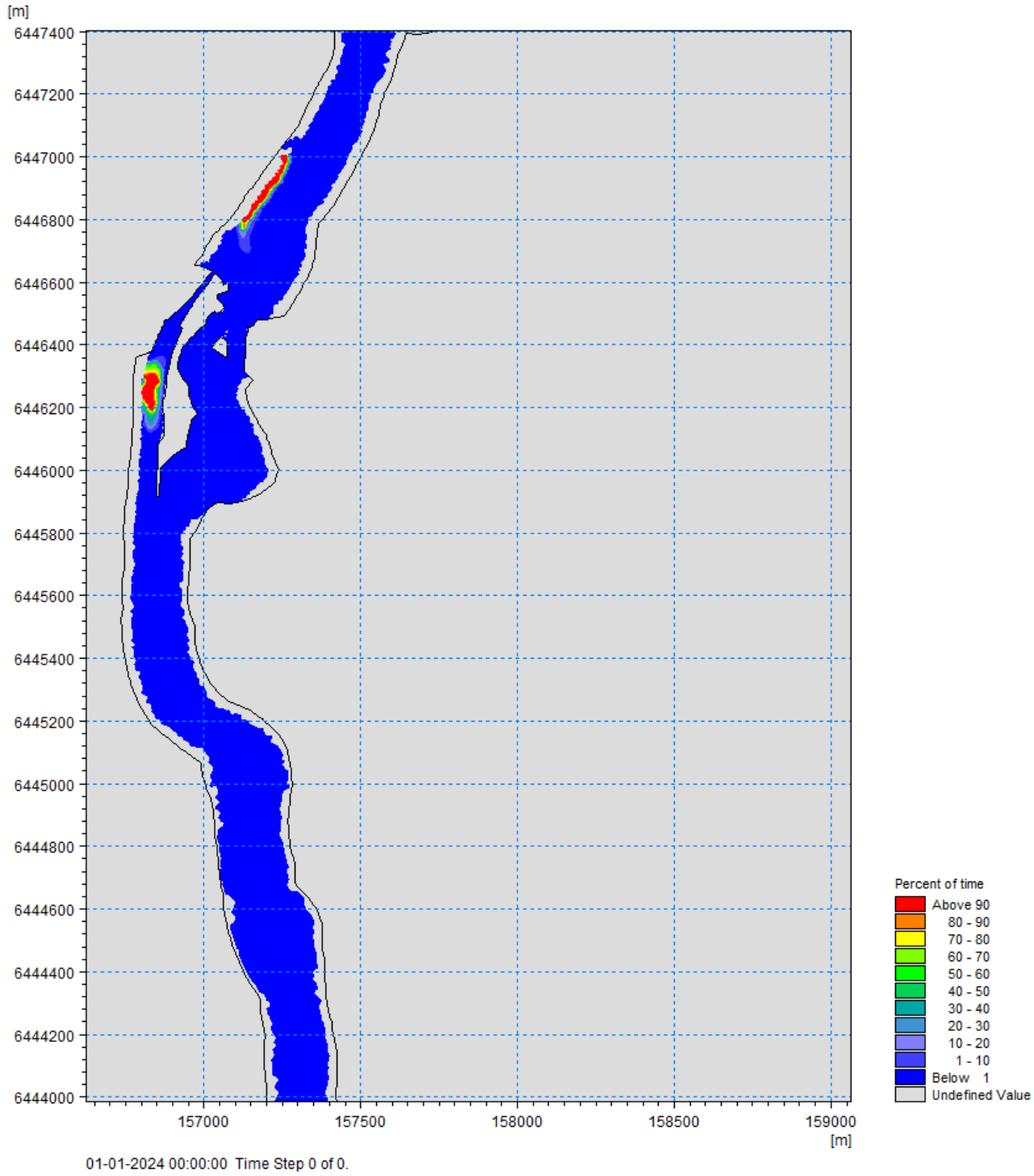

Figure 4-3 Percent of time during dredging where the sediment concentration exceeds 25 mg/l. Flow is 1200 m^3/s. All flow through the hydro power plant.

4.2 SEDIMENT CONCENTRATIONS. FLOW 300 M³/S

Sediment concentration and exceedance frequency of 10 mg/l and 25 mg/l during dredging. Flow in the river is 300 m³/s and all the flow goes through the power plant are shown on Figure 4-4, Figure 4-5, Figure 4-6.

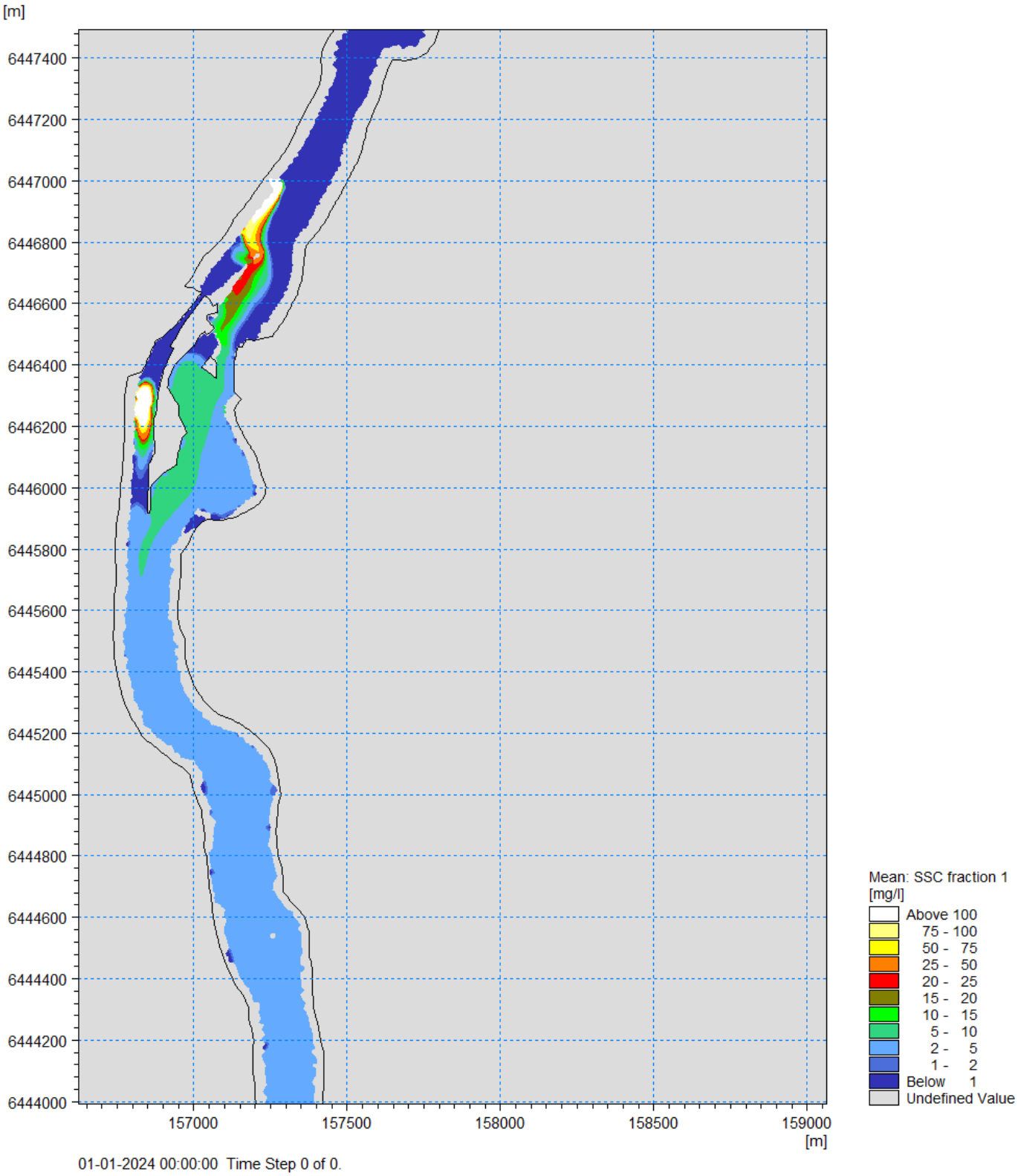

Figure 4-4 Mean sediment concentration during dredging operations up stream and down stream of the lock. Flow is 300 m³/s. All flow through the hydro power plant.

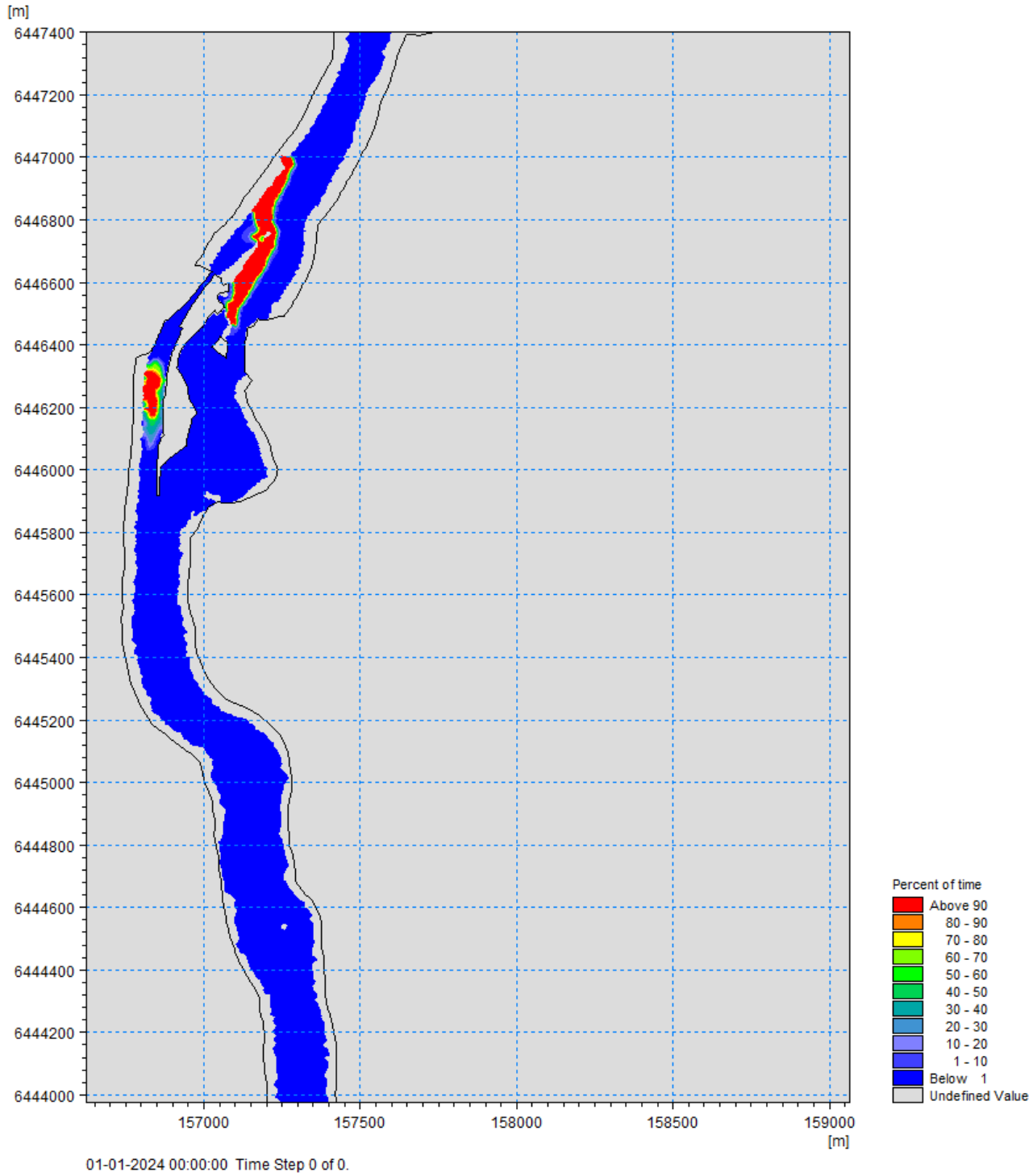

Figure 4-5 Percent of time during dredging where the sediment concentration exceeds 10 mg/l. Flow is 300 m^3/s. All flow through the hydro power plant.

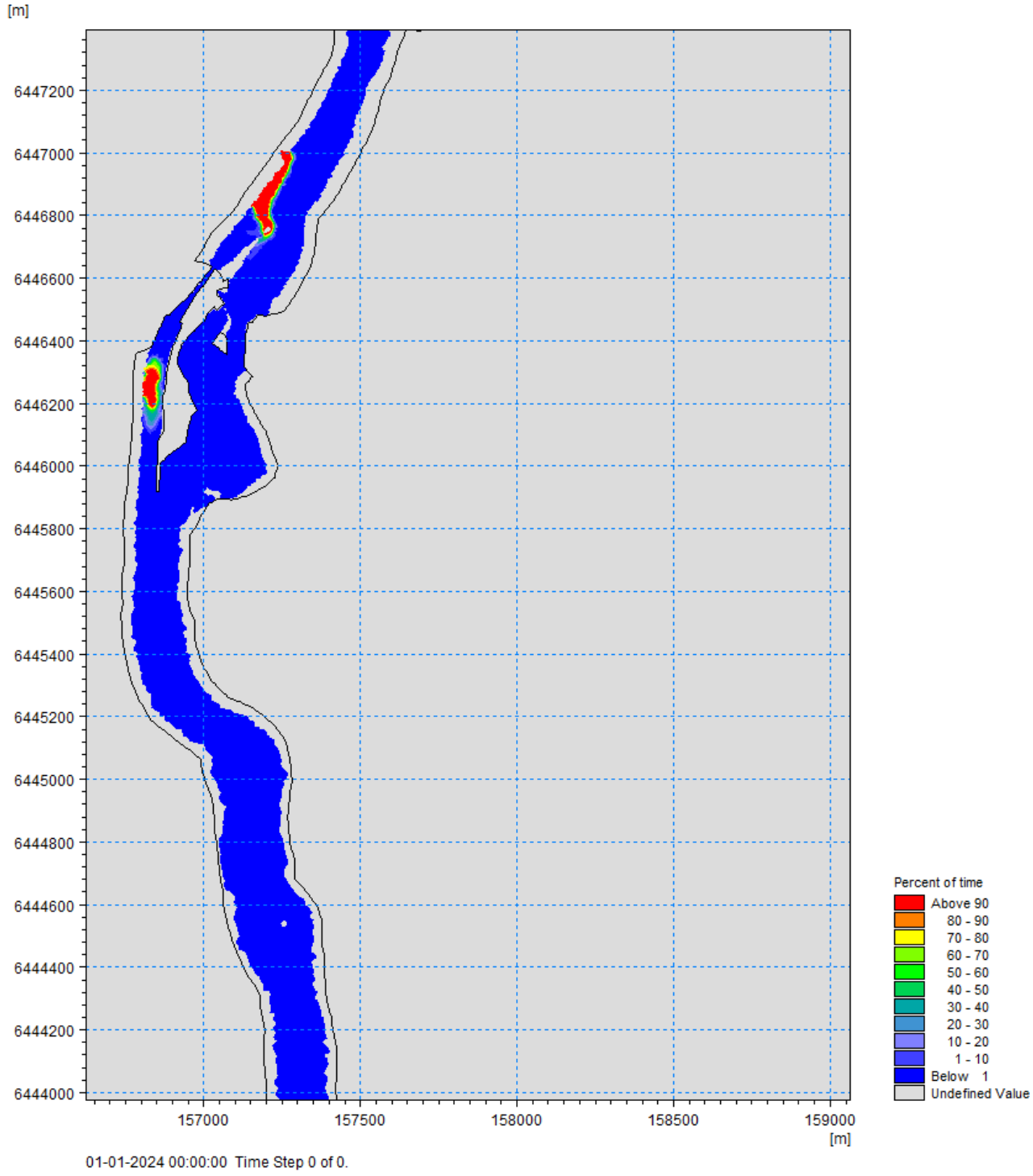

Figure 4-6 Percent of time during dredging where the sediment concentration exceeds 25 mg/l. Flow is 300 m^3/s. All flow through the hydro power plant.

4.3 SEDIMENT CONCENTRATIONS. FLOW 170 M³/S

Sediment concentration and exceedance frequency of 10 mg/l and 25 mg/l during dredging. Flow in the river is 170 m3/s and all the flow goes through the power plant are shown on Figure 4-7, Figure 4-8 and Figure 4-9

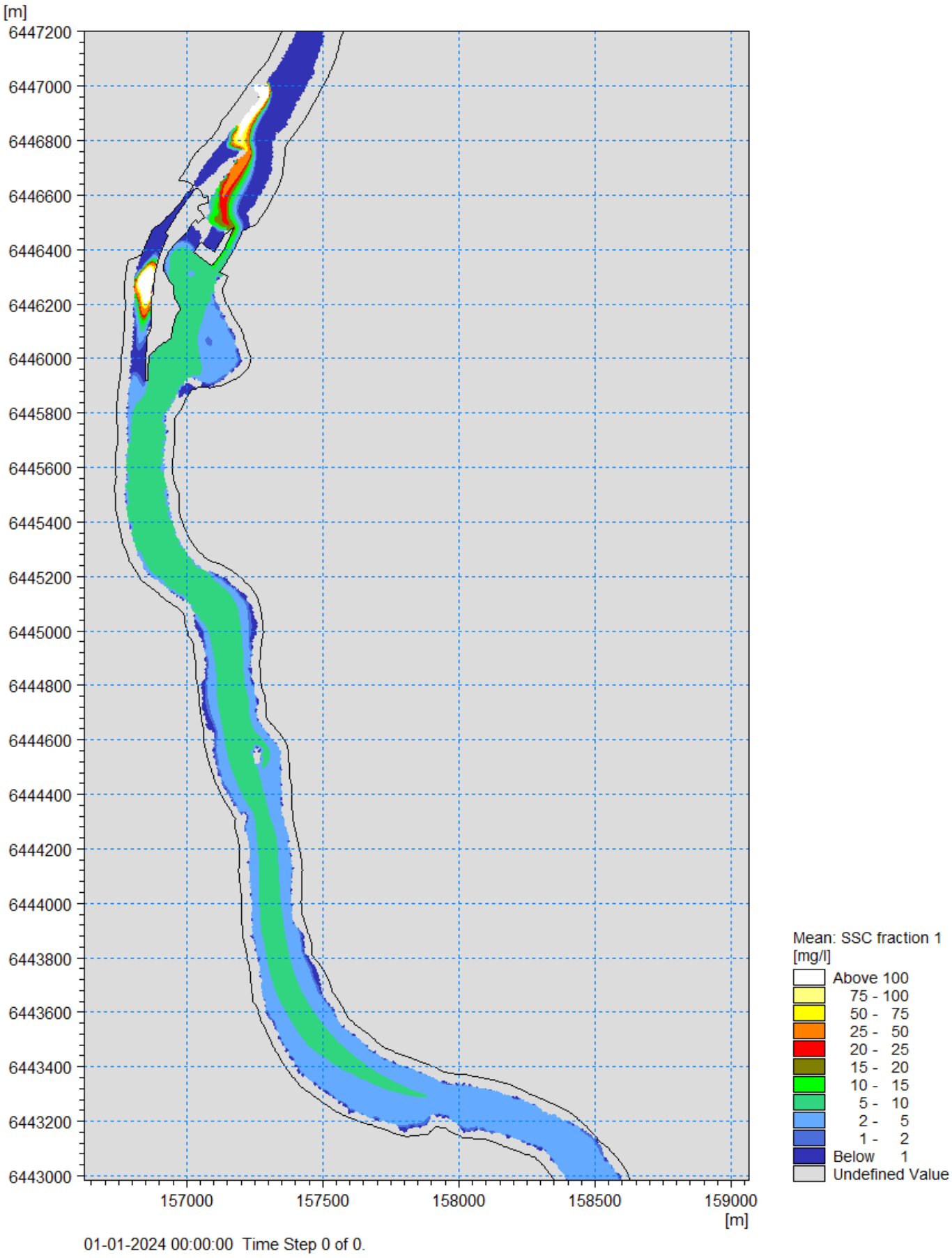

Figure 4-7 Mean sediment concentration during dredging operations up stream and down stream of the lock. Flow is 170 m³/s. All flow through the hydro power plant.

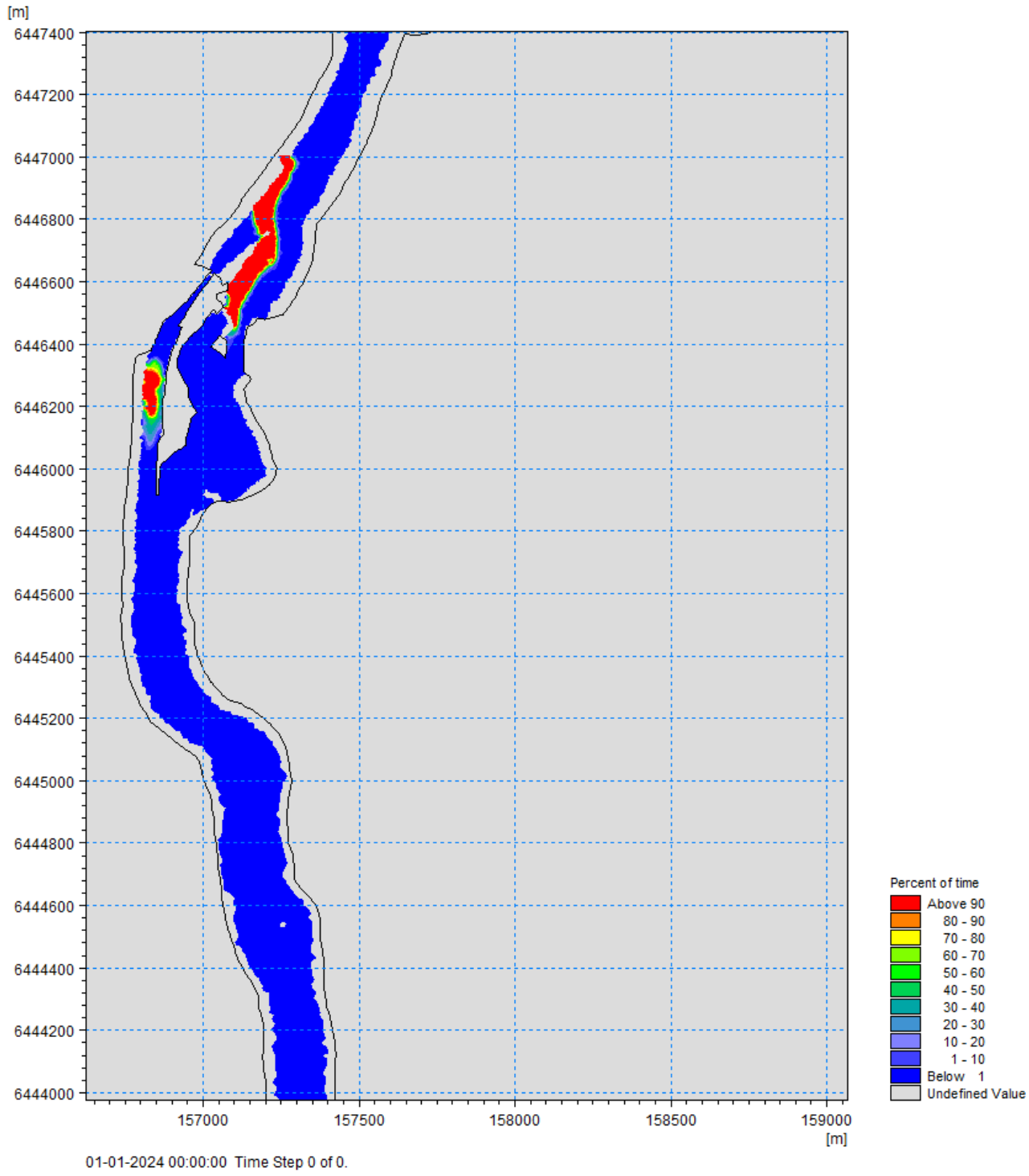

Figure 4-8 Percent of time during dredging where the sediment concentration exceeds 10 mg/l. Flow is 170 m³/s. All flow through the hydro power plant.

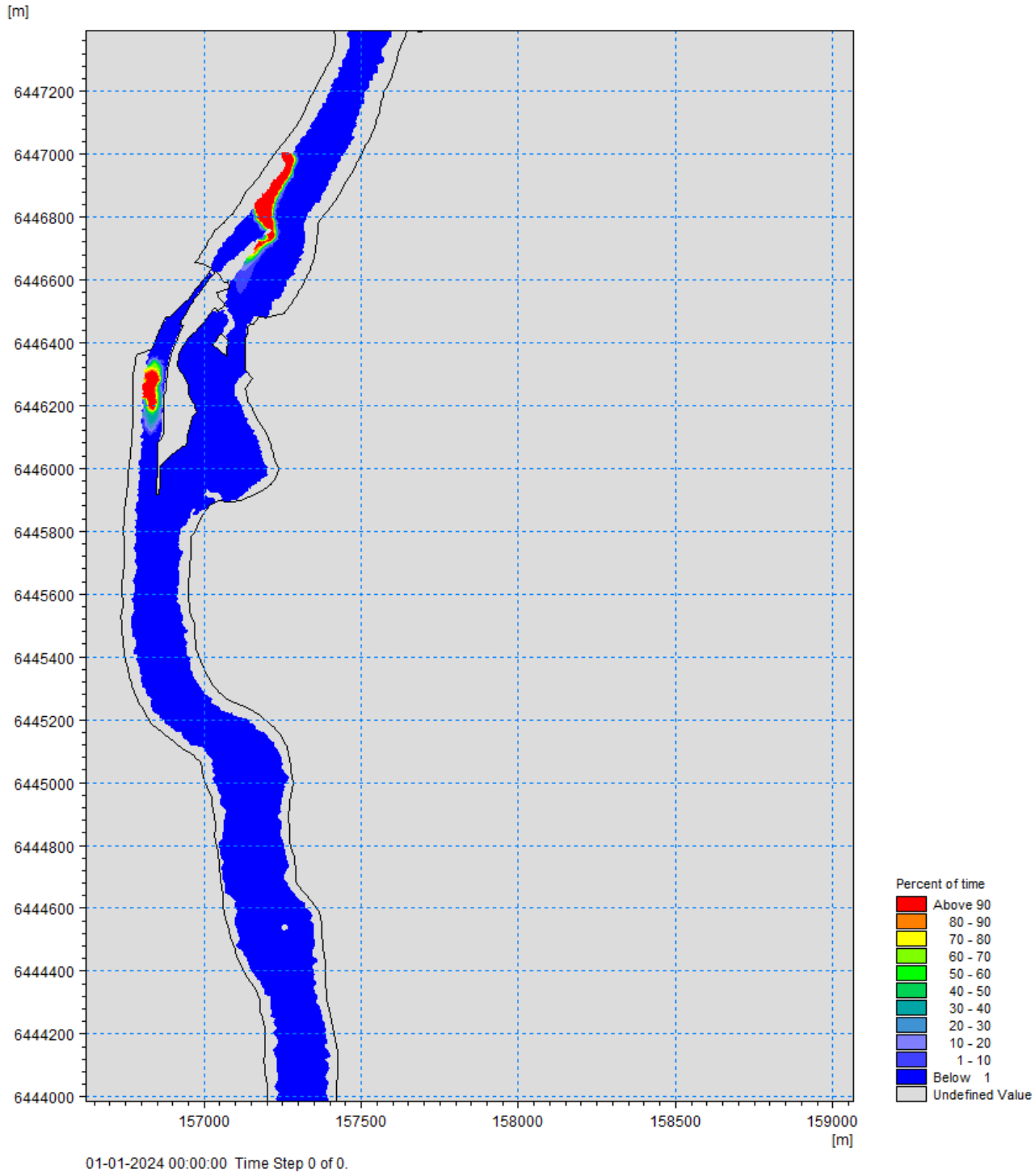

Figure 4-9 Percent of time during dredging where the sediment concentration exceeds 25 mg/l. Flow is 170 m^3/s. All flow through the hydro power plant.

4.4 SEDIMENT CONCENTRATIONS. FLOW 140 M³/S

Sediment concentration and exceedance frequency of 10 mg/l and 25 mg/l during dredging. Flow in the river is 140m³/s and all the flow goes through the power plant are shown on Figure 4-10, Figure 4-11 and Figure 4-12.

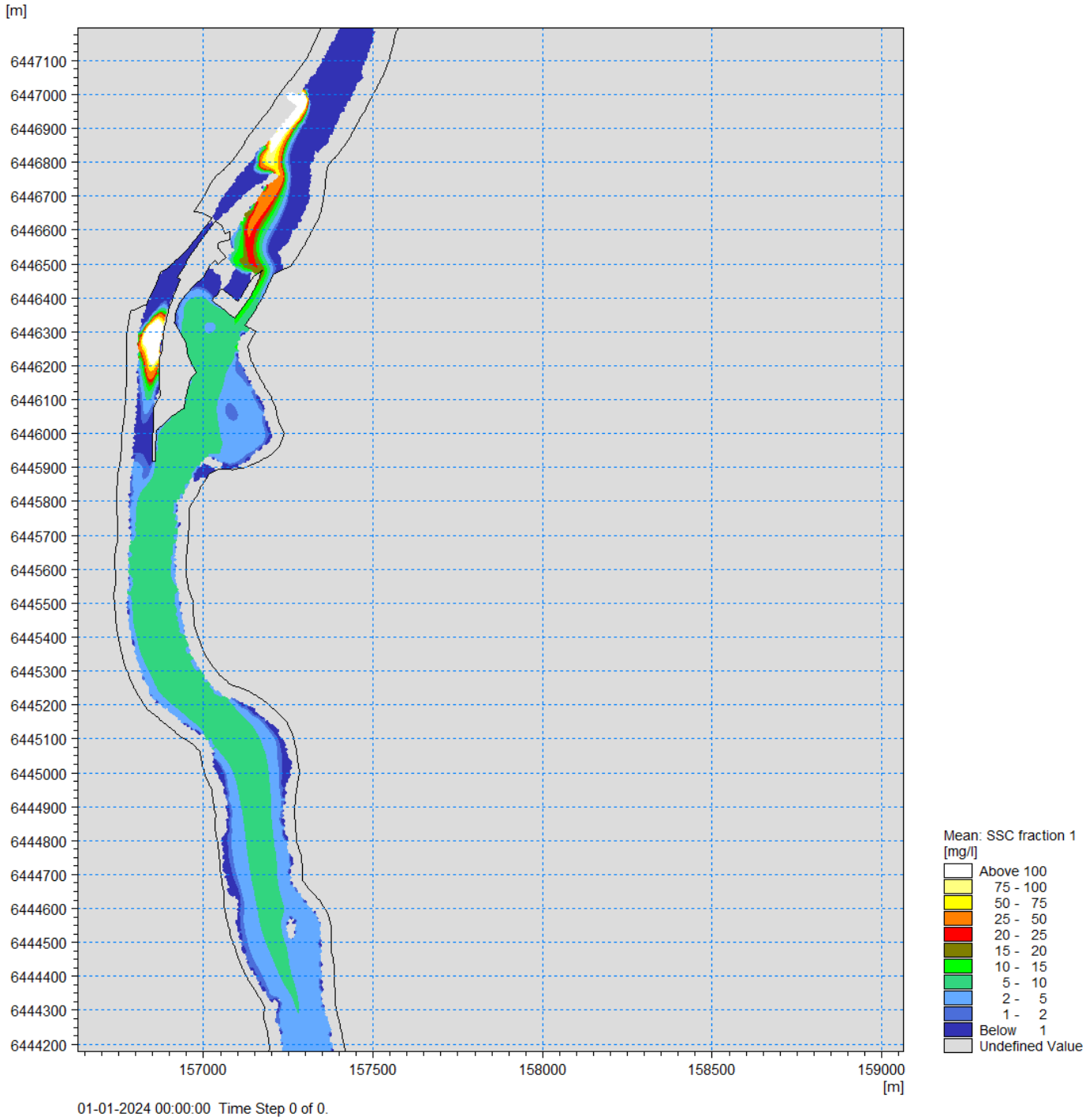

Figure 4-10 Mean sediment concentration during dredging operations up stream and down stream of the lock. Flow is 140 m³/s. All flow through the hydro power plant.

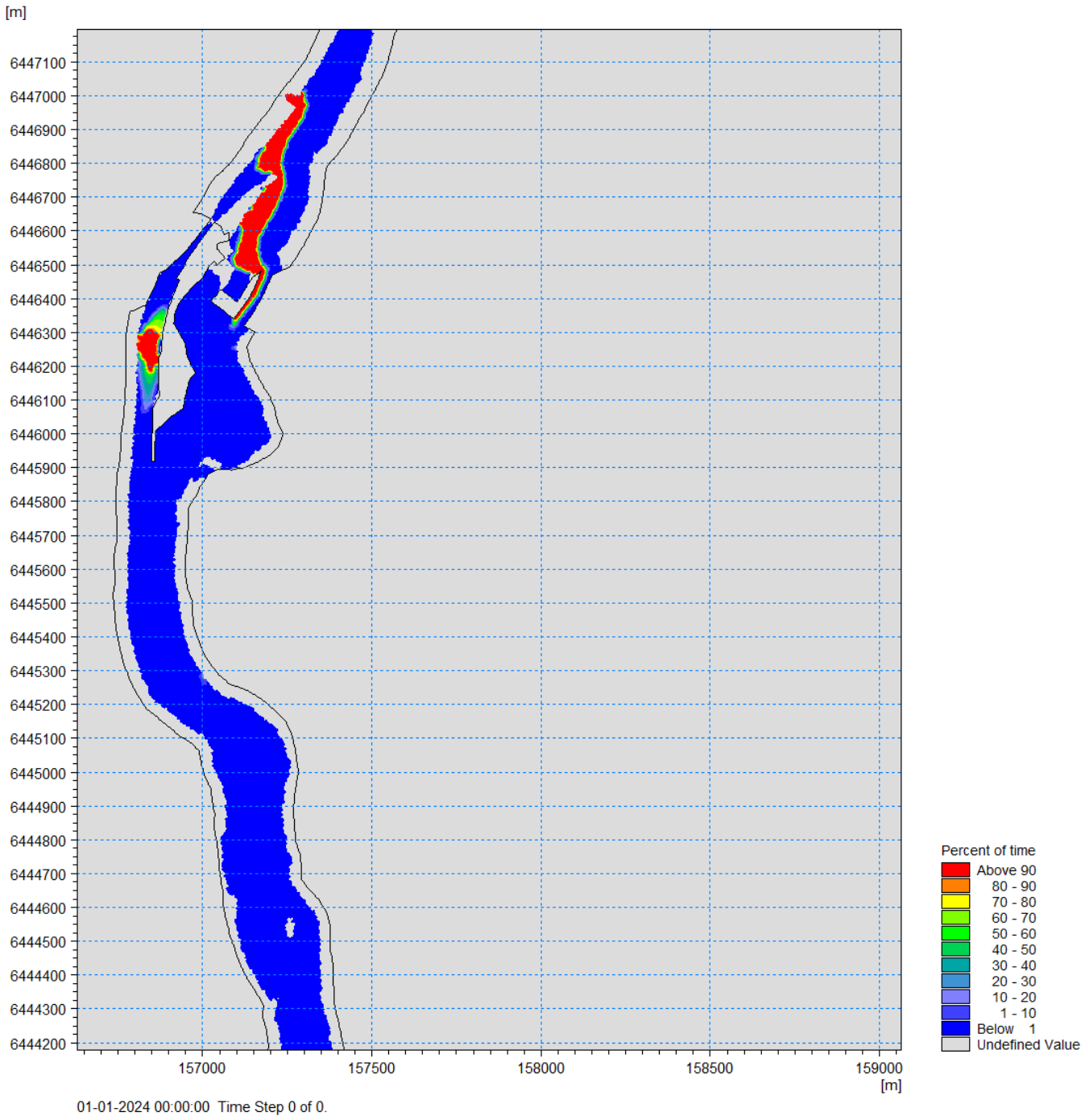

Figure 4-11 Percent of time during dredging where the sediment concentration exceeds 10 mg/l. Flow is 140 m3/s. All flow through the hydro power plant.

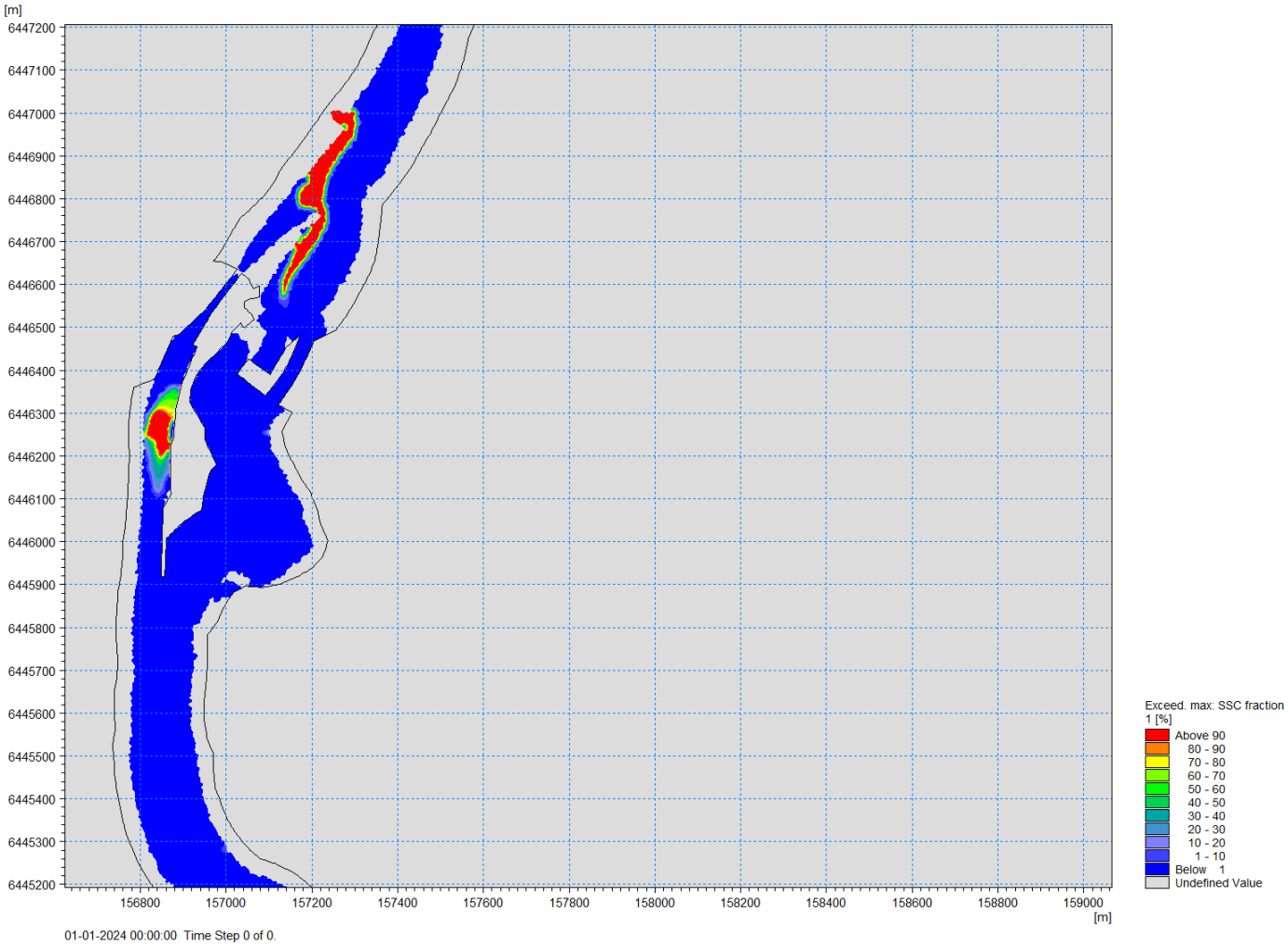

Figure 4-12 Percent of time during dredging where the sediment concentration exceeds 25 mg/l. Flow is 140 m3/s. All flow through the hydro power plant.

4.5 SEDIMENT CONCENTRATIONS DOWN STREAM FROM LILLA EDET

Sediment concentrations from dredging at Lilla Edet are shown on Figure 4-13 and **Error! Reference source not found.**. The concentration of spilled sediment drops to 3-4 mg/l 1 km down stream from the work sites and drops further down to 2-3 mg/l for the following 6 km after which the concentration is below 2 mg/l rest of the way down to the sea where the concentration is around 1 mg/l.

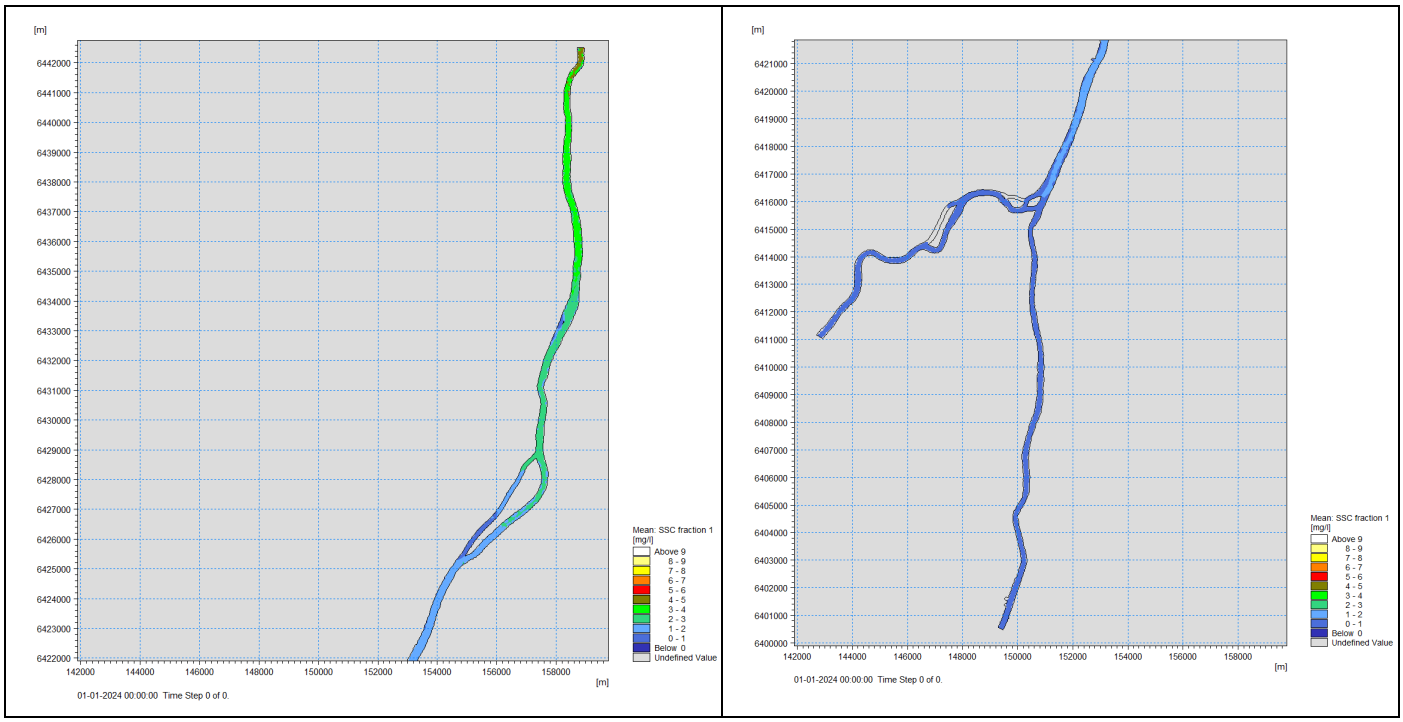

Figure 4-13 Sediment concentrations down stream from Lilla Edet. Flow 300 m³/s

4.6 SEDIMENT ACCUMULATION

Sediment accumulation after 24 days of dredging is shown on Figure 4-14 Sediment can only accumulate around the dredging positions where the current is weak. A larger pool of accumulated sediment is seen around the down stream work site where the lock prevents stronger currents from reaching the sediment.

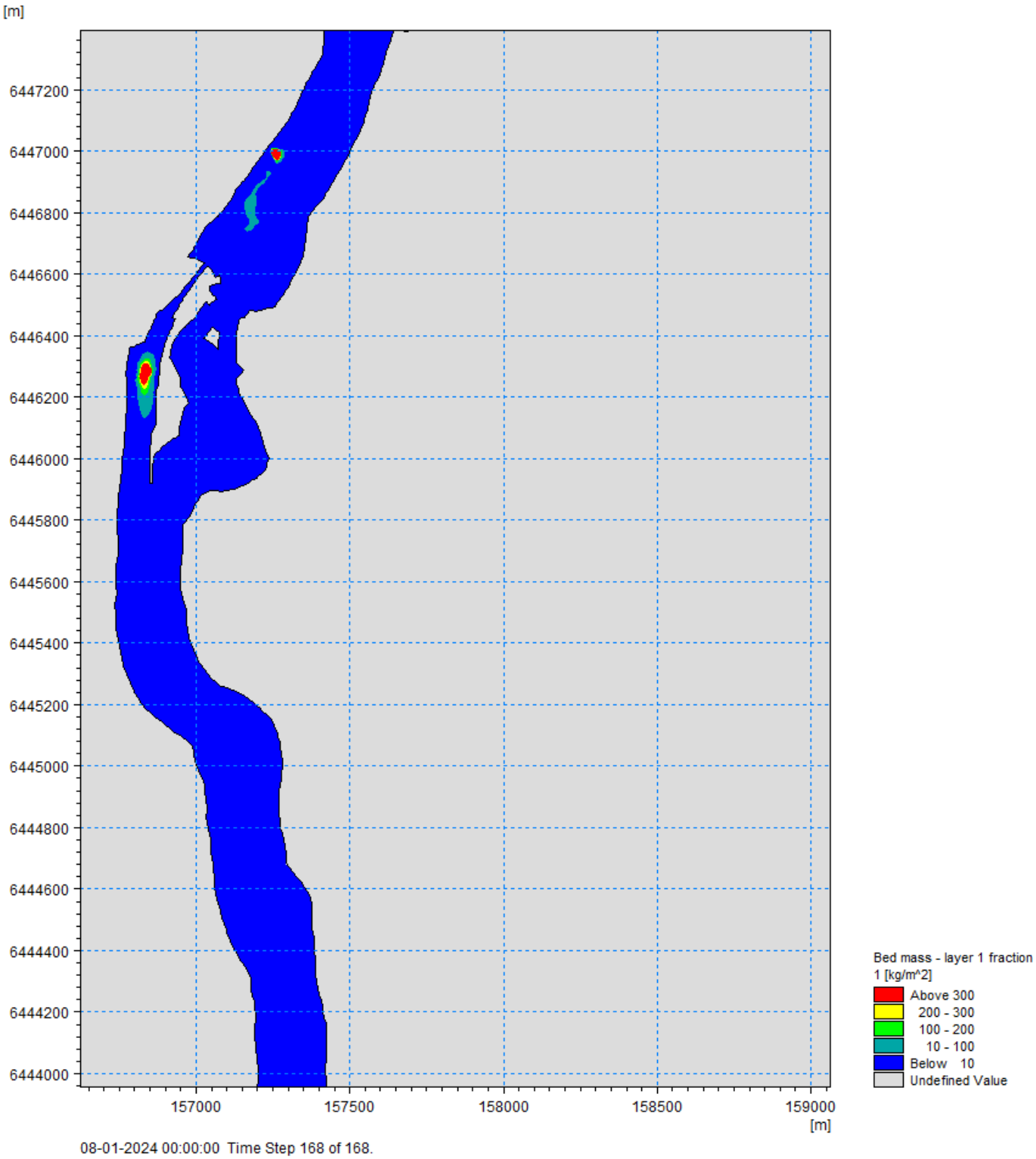

Figure 4-14 Sediment accumulation after 24 days of dredging. Flow 300 m³/s.

5 CONCENTRATIONS OF CONTAMINANTS

Concentrations of contaminants found in the material which will be dredged is shown in Table 3-1. Based on the 300 m3 flow scenario, the resulting concentration of these substances in the river has been calculated by multiplying the modelled sediment concentration with the concentrations of contaminants found in the sediment.

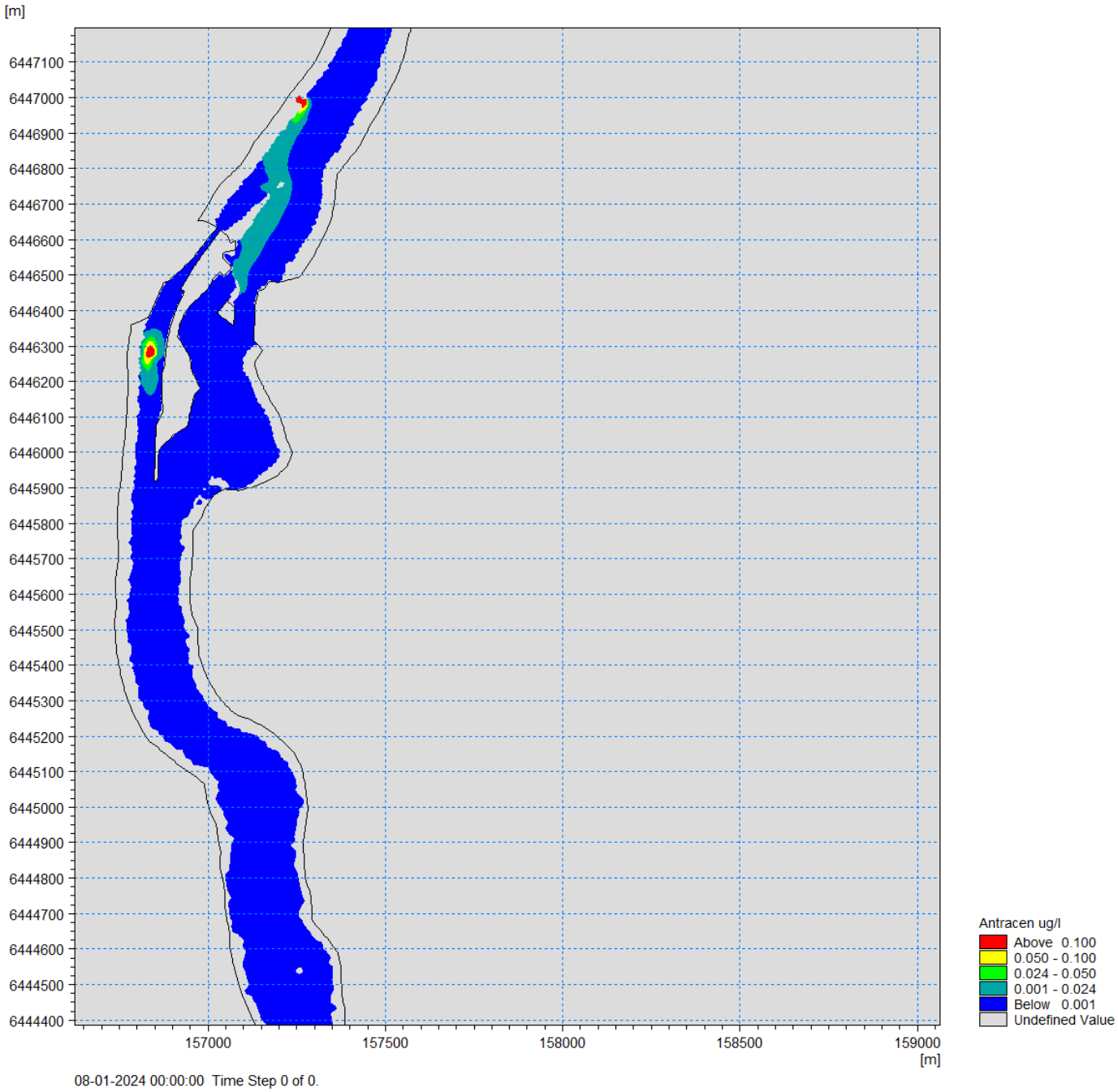

Figure 5-1 Concentration of Antracen. Water quality criteria value is 0.024 µg/l.

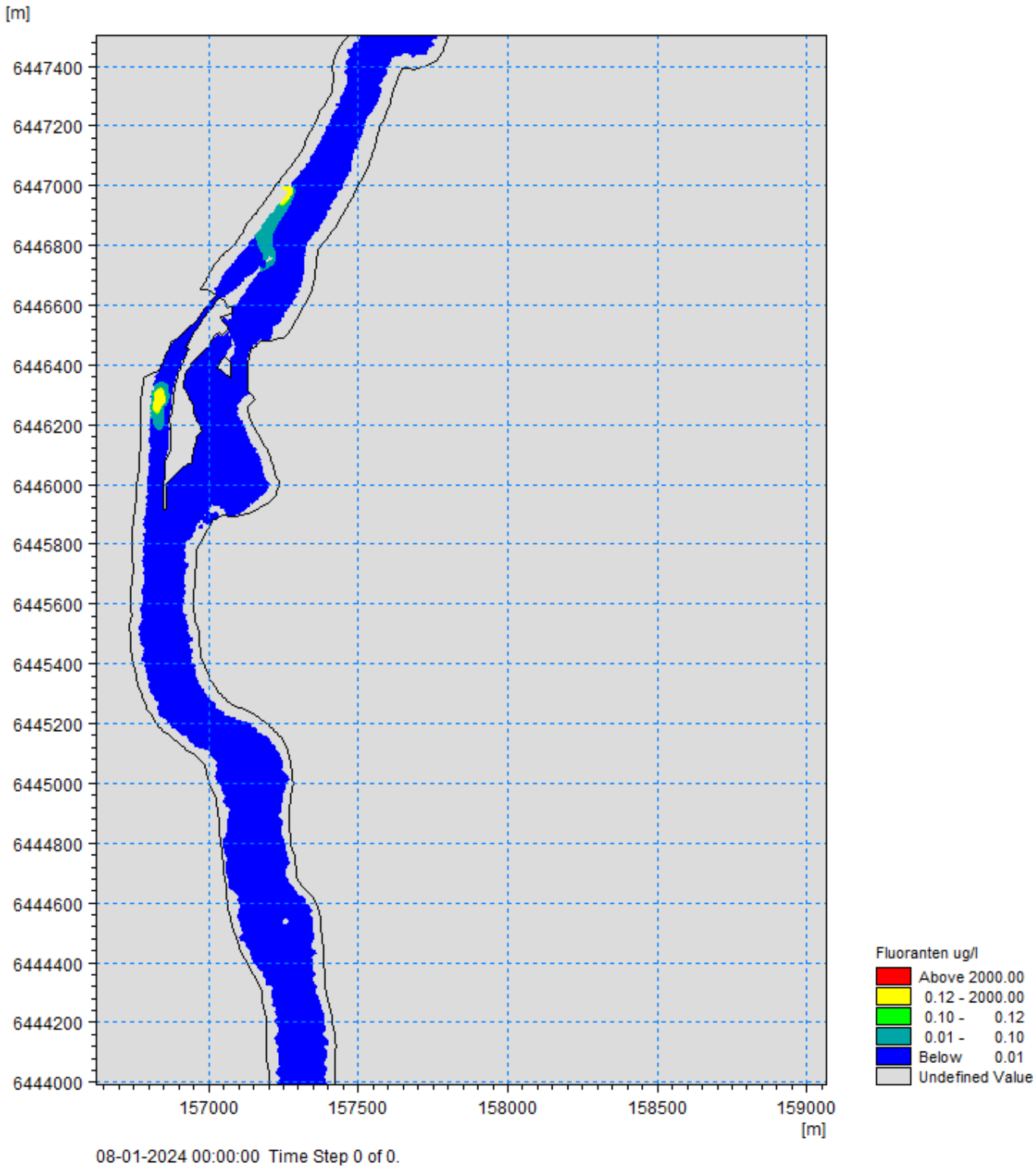

Figure 5-2 Concentration of Fluoranten. Water quality criteria value is 2000 µg/l.

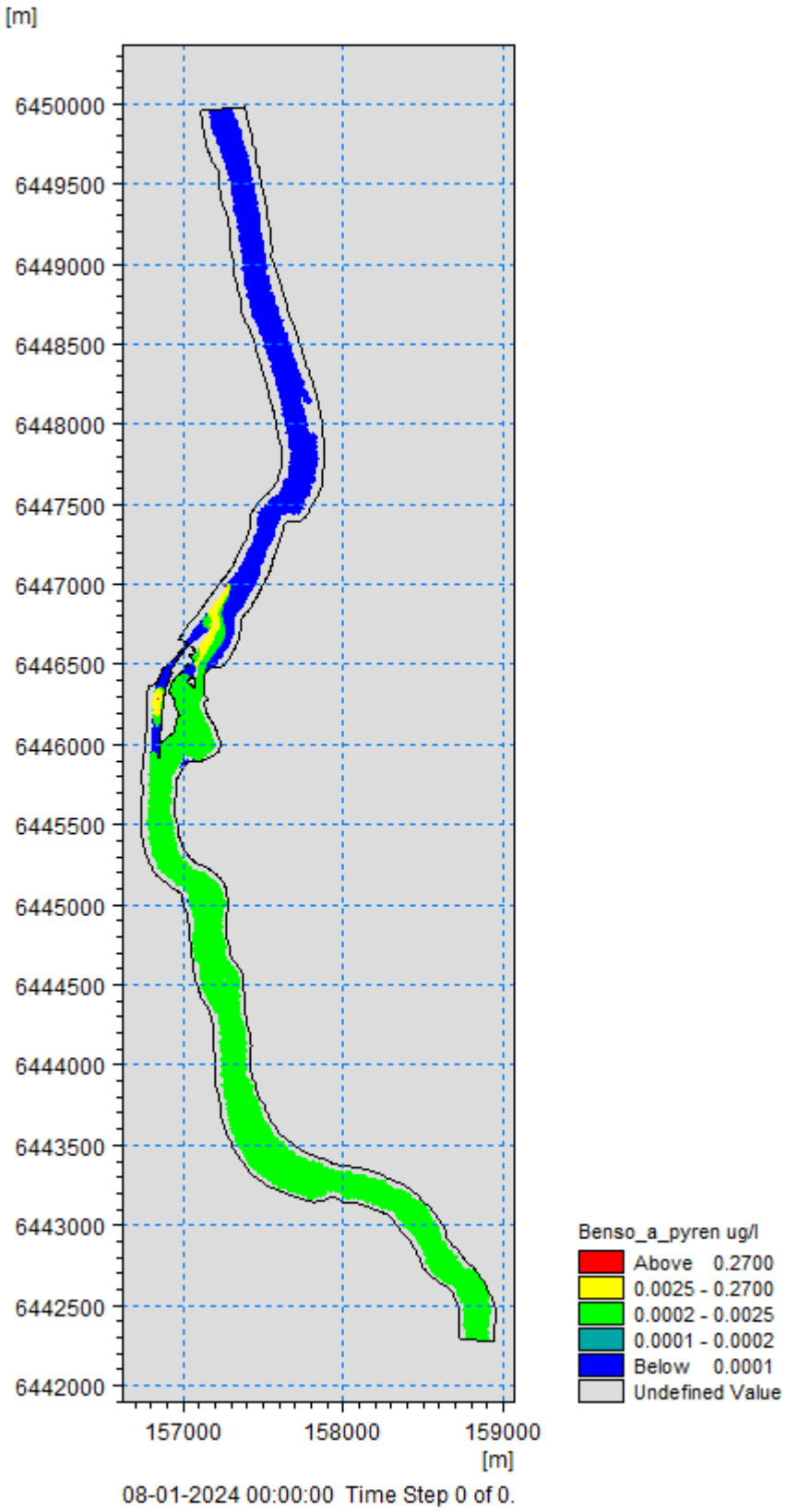

Figure 5-3 Concentration of Benso(a)pyren. Water quality criteria value is not defined, but the concentration should not exceed 0.27 µg/l.

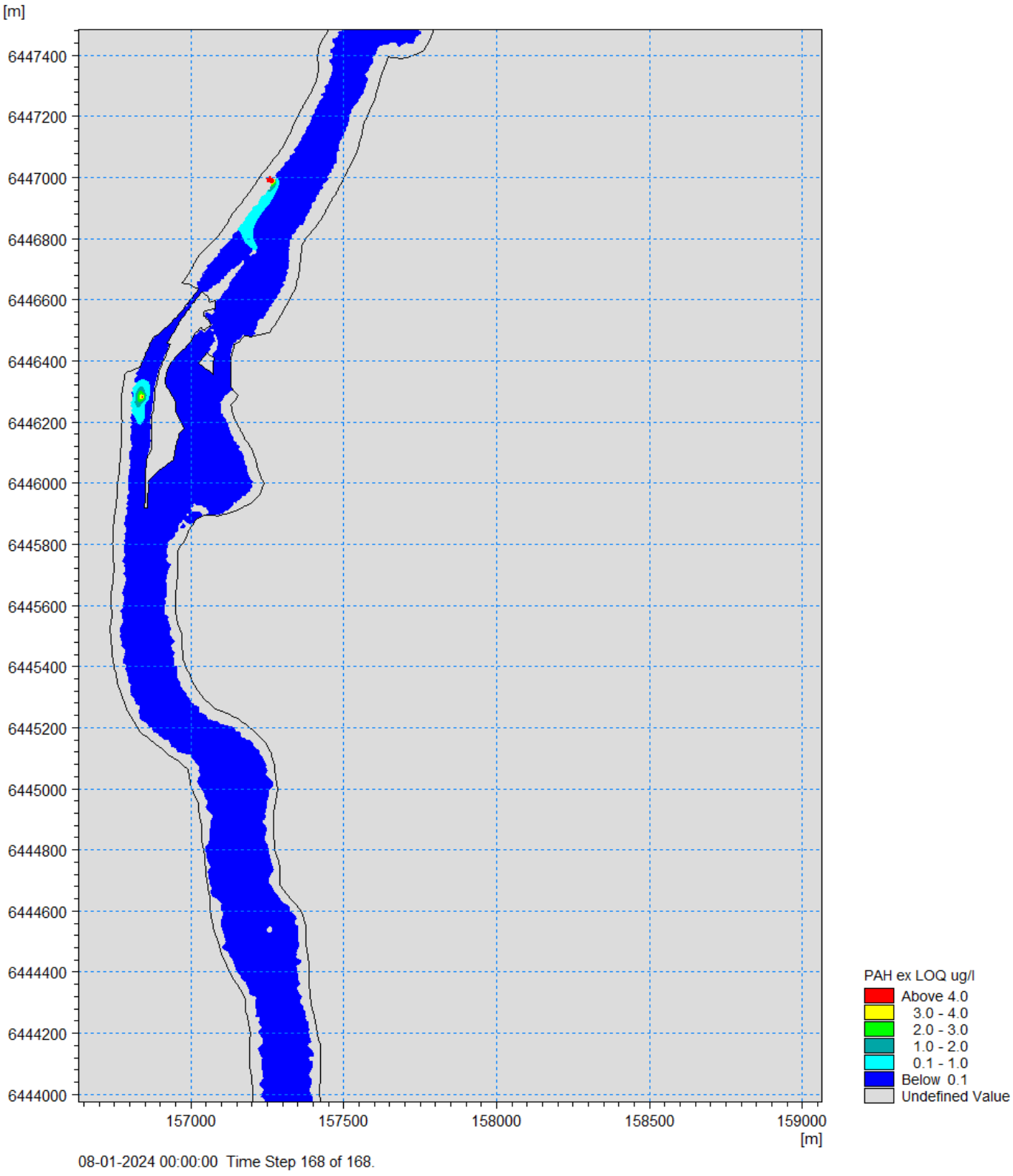

Figure 5-4 Concentration of total 16 EPA-PAH ex. LOQ. Water quality criteria value is not defined.

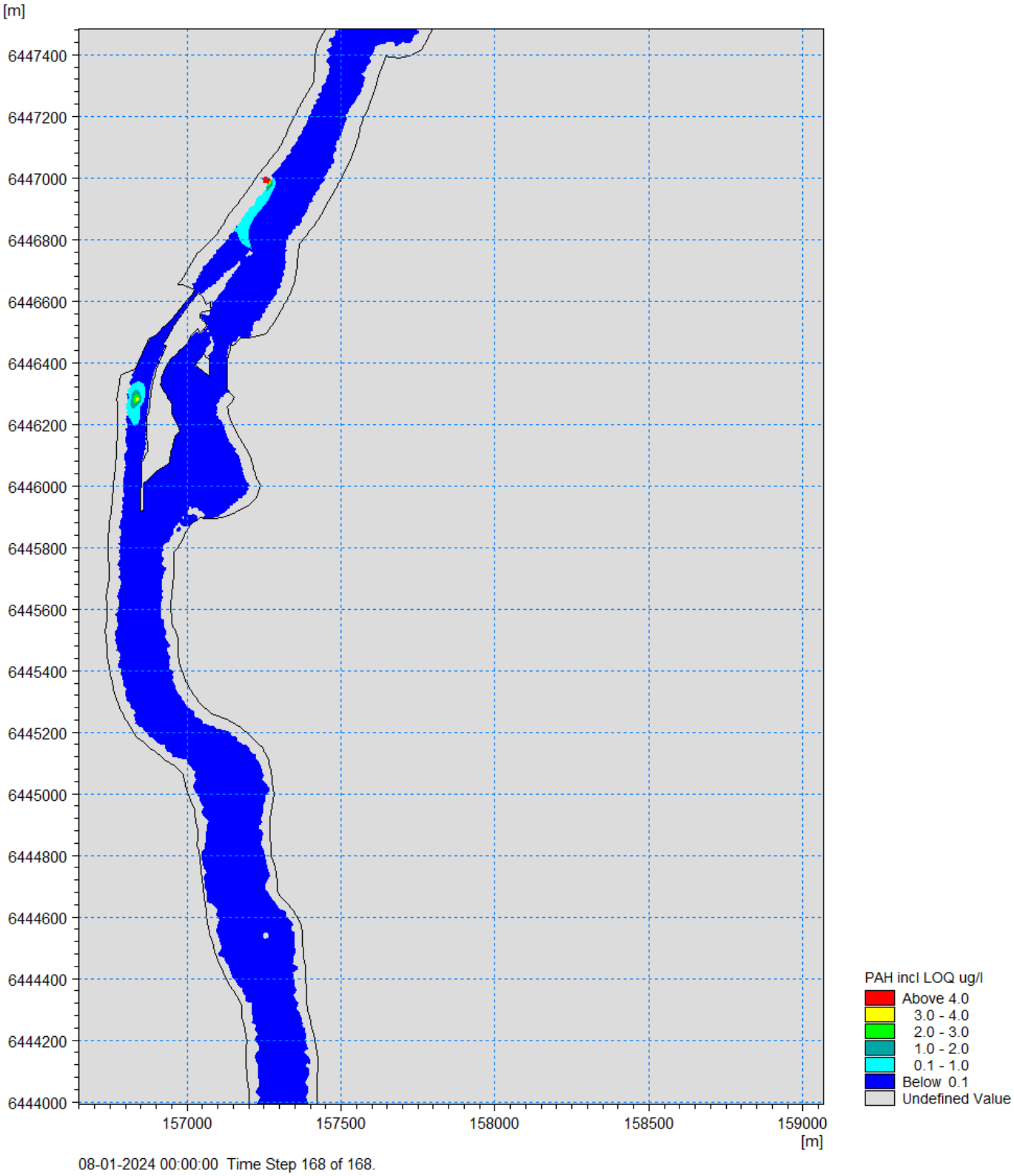

Figure 5-5 Concentration of total 16 EPA-PAH incl.. LOQ. Water quality criteria value is not defined.

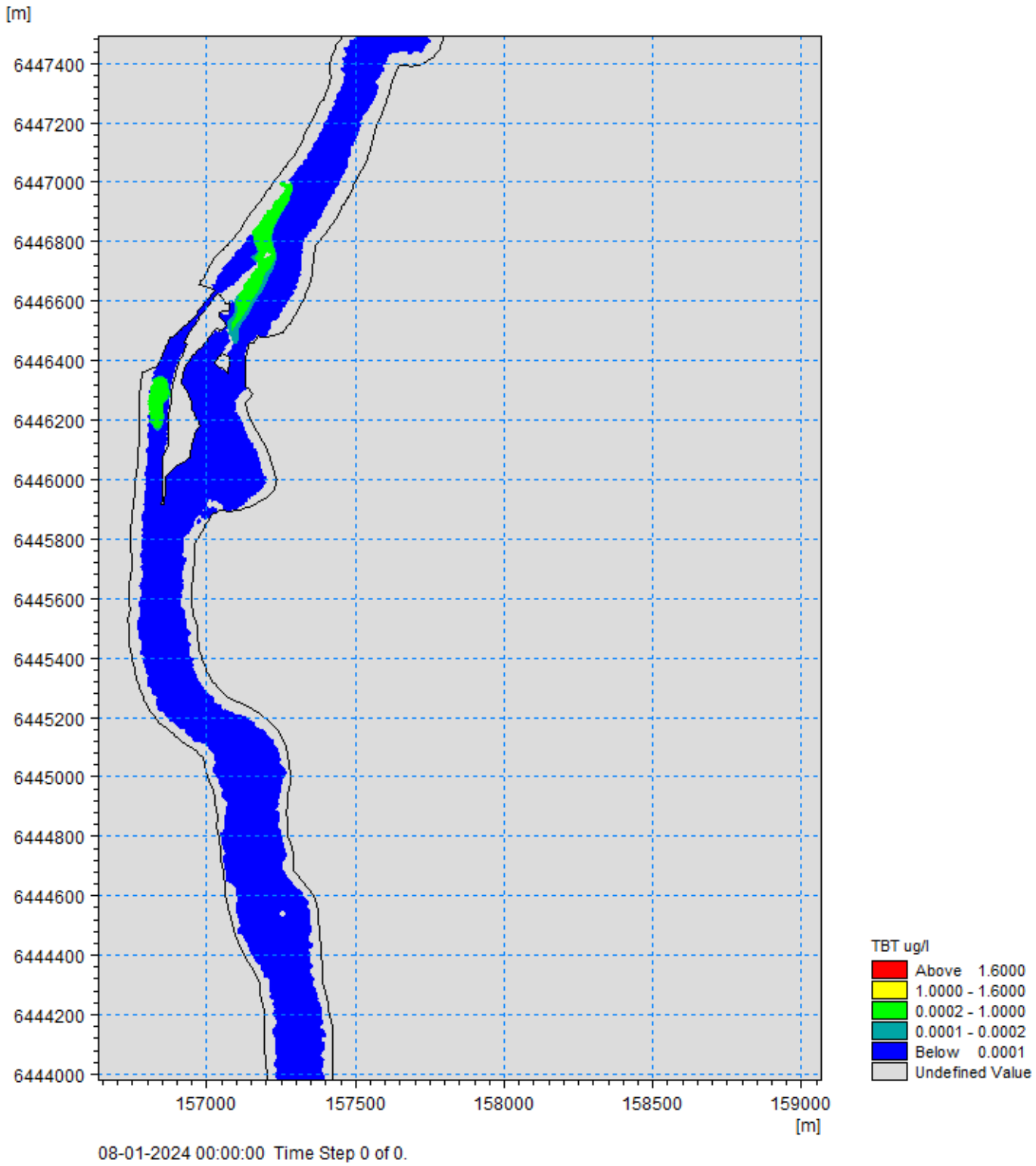

Figure 5-6 Concentration of TBT. Water quality criteria value is 1.6 µg/l.

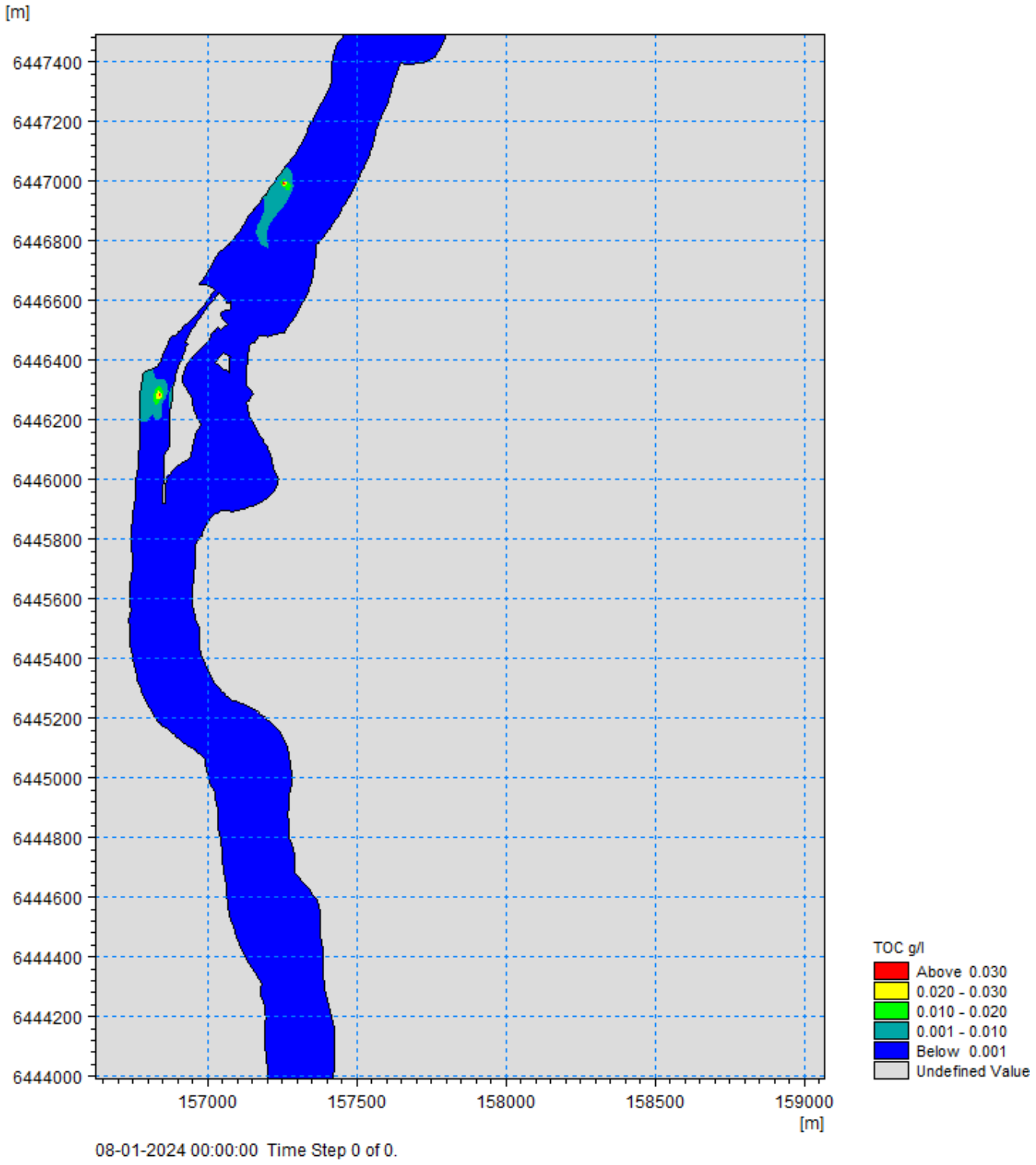

Figure 5-7 Concentration of TOC. Water quality criteria value is not defined.