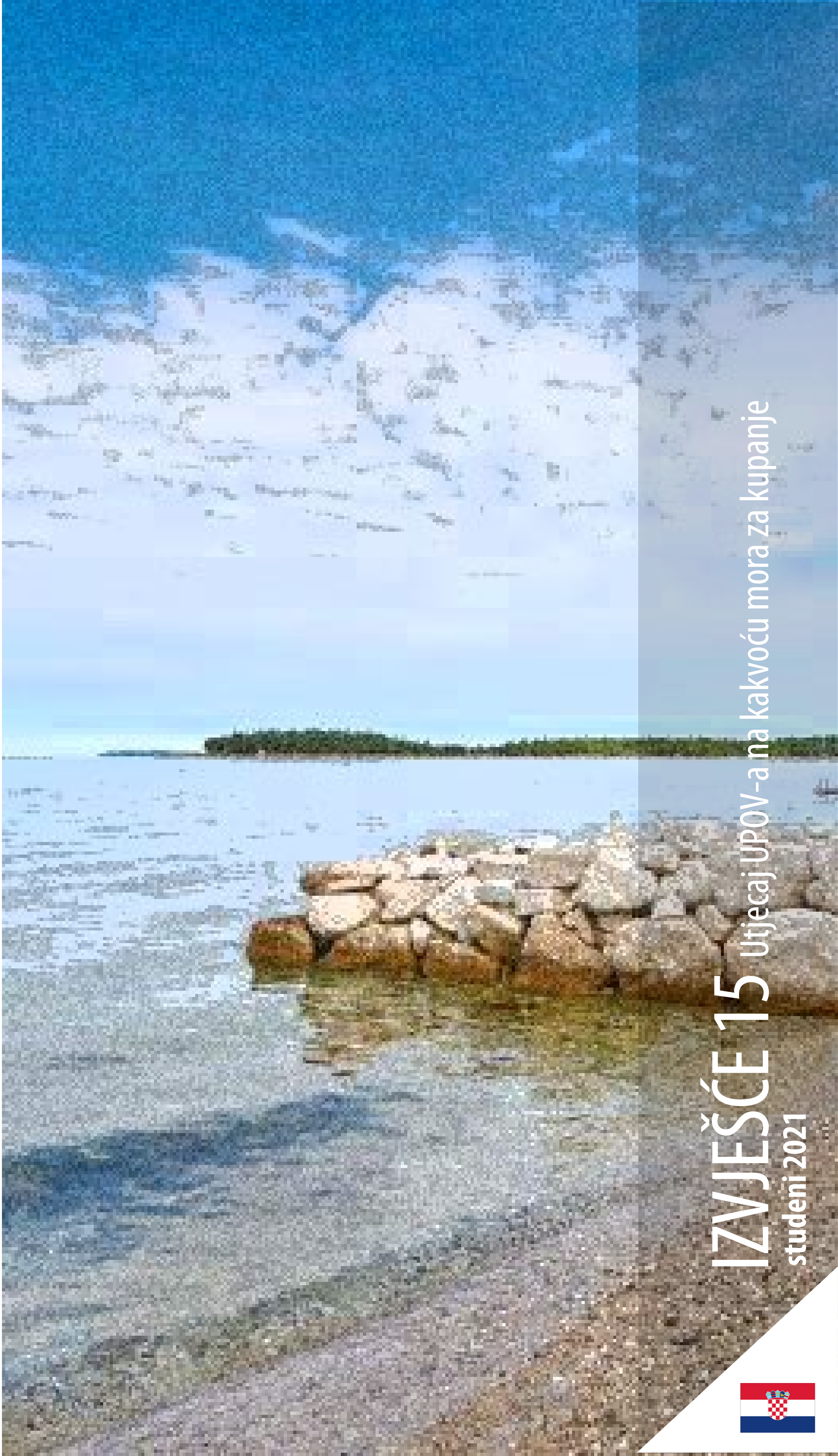
Zajednica izvršitelja

Naručitelj

Krajnji korisnik

STUDIJA OCJENE I PRAĆENJA UČINKOVITOSTI PROVEDBE PROJEKTA
IZGRADNJE KANALIZACIJSKE MREŽE I ANALIZA UČINKOVITOSTI RADA UREĐAJA
ZA PROČIŠĆAVANJE OTPADNIH VODA U GRADU POREČU – STUDIJA POREČ



IZVJEŠĆE 15 Utjecaj UPOV-a na kakvoću mora za kupanje

studeni 2021

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IZVJEŠĆE 15

UTJECAJ UPOVa NA KAKVOĆU MORA ZA KUPANJE

13. studeni 2021

mr.sc. Božidar Deduš, dipl. ing.
Ovlaštenik Zajednice izvršitelja
Proning DHI d.o.o.

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United Nations
Cultural Organization
IHE DELFT
Institute for
Water Education
under the auspices
of UNESCO

prof.dr.sc. Damir Brdjanović, dipl.ing.
Voditelj stručnog tima
IHE Delft

HRVATSKE VODE

REPORT

HRVATSKE VODE

Sea Water Quality Modelling Istria

Impact of WWTP on bathing water quality: scenario modelling

8 December 2021 - version 1.0

International Marine & Dredging Consultants

Colophon

International Marine & Dredging Consultants

Address: Van Immerseelstraat 66, 2018 Antwerp, Belgium

☎: + 32 3 270 92 95

🖷: + 32 3 235 67 11

Email: info@imdc.be

Website: www.imdc.be

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Contact within IMDC

Name	Bart Verheyen
Phone number	+32 3 270 92 95
e-mail	vba@imdc.be

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1	Pdf	Damir Brdjanovic (IHE-UNESCO)

Abstract

This report is part of the sea water quality modelling study of the dispersion of sewage effluent (faecal bacteria) along the Istrian coast. The report studies the impact of the WWTP on bathing water quality. This is preformed through modelling different scenarios representing different performances of the WWTP, varying between no filtering (similar to present situation), use of membrane filters and full reuse of the effluent. Different sea water conditions represented by a winter and summer season and a future condition in 2040 have been studies as well.

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1. INTRODUCTION

1.1 THE ASSIGNMENT

Large investments in the public sector are ongoing along part of the Istrian coast including the renewal and extension of the existing drainage system and the construction of new waste water treatment plants for the purpose of protecting the city of Poreč and surroundings.

IMDC was requested to perform sea water quality modelling of the dispersion of sewage effluent (faecal bacteria) along the Istrian coast, Croatia. Using numerical models, the bathing water quality has been investigated in the present situation as well as after the installation of the treatment plants. The study assesses the risk of E-Coli (EC) and Intestinal Enterococci (IE) pollution (as indicator for the bathing water quality) at the beaches and the added value of treatment plants to reduce this risk. The study is part of the overall assignment “Study evaluation and monitoring of the effectiveness of the implementation of the construction project of sewerage network and analysis of the effectiveness of waste water treatment plant operation Poreč” issued by Hrvatske Vode (Croatian Waters) with the tender OP 2015/227. The work was assigned to the consortium including IMDC and represented by PRONING DHI as Lead Member with the contract on 19/07/2018, Class: 325-01/15-10/148, Reg: 374- 1- 3-18-35. A consortium agreement was concluded on 13/05/2016 and extended with annex I on 13/11/2018.

IMDC will contribute to the following requested deliverables:

- Report on hydrodynamic model setup (IMDC, 2019a);
- Report on hydrodynamic model calibration and modelling of present situation (IMDC, 2019b);
- Report on sea water quality model calibration and modelling of present situation (IMDC, 2021);
- Report on the impact of WWTP on bathing water quality: scenario modelling (this report);
- Report on the impact of WWTP on bathing water quality: model validation;
- Report on model handover and training (IMDC, 2020).

1.2 SCOPE OF THE REPORT

This report describes the near field modelling of the dispersion of the sewage effluent and the water quality calibration for the mid field coastal model. The results of the performed scenario simulations are presented and the implications of each scenario on the water quality conditions are shown.

The report studies the impact of the WWTP on bathing water quality. This is preformed through modelling different scenarios representing different performances of the WWTP, varying between no filtering (similar to present situation), use of membrane filters and full reuse of the effluent. Different sea water conditions represented by a winter and summer season and a future condition in 2040 have been studies as well.

1.3 READING GUIDANCE

A description of the data that is used in this study is presented in chapter 2. The water quality model setup and scenario description are presented in chapter 3. The results of the scenario simulations and the implications on the water quality are described in chapter 4. Conclusions of this study are presented in chapter 5.

2. DATA

This section outlines the data that is used to perform the scenario study, which is mostly based on the information used for the water quality calibration and reference is made to the water quality calibration report for more details (IMDC, 2021).

2.1 OUTFALL DATA

Characteristics of the outfall are required to be able to determine adequate input conditions for the water quality models. The characteristics are related to the design and position of the outfall and the upstream discharge conditions. Detailed information on the outfalls can be found in the water quality calibration report (IMDC, 2021).

Figure 2-1 illustrates the outfalls in use after the WWTP are operational. Compared to the situation without WWTP this means that the smaller outfalls that were included in the water quality calibration exercise (IMDC, 2021) are not considered in the scenario modelling for the effect of WWTP on bathing water quality. The smaller outfalls are Cervar (connected to Poreč North), Sint Nicholas, and Coversada (connected to Vrsar).

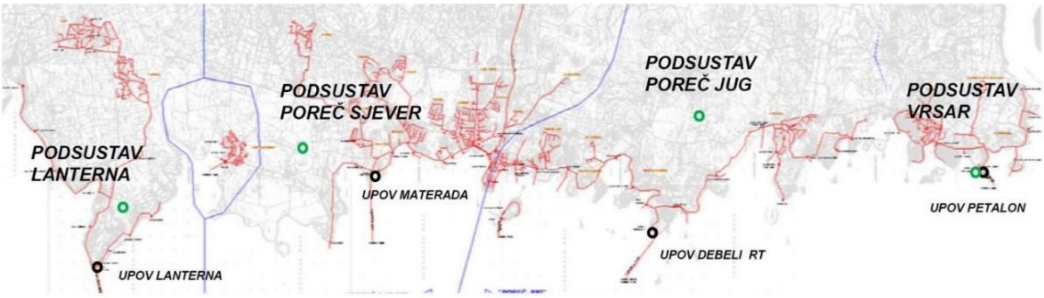

Figure 2-1: Study area, outfall locations (black circles) and treatment plants (green circles).

For the major outfalls the waste water is collected in collectors before it is either mechanically flushed or flushed by pumps towards the Adriatic Sea via a diffusor or an open end pipe. It is understood that there will be no changes to these collectors and diffusors when the WWTP are operational. Therefore the same characteristics, such as volumes of collectors and lengths and characteristics of diffusors at the different outfalls are considered as during the water quality calibration (IMDC, 2021). Table 2-1 gives an overview of the different design and discharge conditions near the outfalls.

The upstream discharges towards the outfalls are based on the sewage modelling study reported in (Proning DHI, 2020) which presents dischargers at each of the four major outfalls for winter and summer and for present (2022) and future (2040) conditions which are used in the WWTP modelling studies in (ASM Design, 2021a), (ASM Design, 2021b), (ASM Design, 2021c) and (ASM Design, 2021d). An overview of these discharges is given in Table 2-2.

Table 2-1: Overview of the outfall design characteristics (IMDC, 2021).

Outfall	Type	Volume collector [m³]	L to diffusor [m]	L diffusor [m]	Number of opening [-]	D opening [m]	Q_{max} [m³/s]
Lanterna	Diffusor	50	500	86	13	0.1	0.11
Poreč North	Diffusor	50	900	100	20	0.1	0.11
Poreč South	Diffusor	50	800	90	20	0.1	0.14
Vrsar	Single pipe	25	488	-	1	0.5	0.075

Table 2-2: Overview of the upstream discharges based on the sewage and WWTP modelling.

Outfall	Summer		Winter	
	[m³/day] in 2022	[m³/day] in 2040	[m³/day] in 2022	[m³/day] in 2040
Lanterna	2500	2737	251	287
Poreč North	4399	5096	1909	2376
Poreč South	6132	7045	814	925
Vrsar	1959	2251	344	369

2.2 WATER QUALITY PARAMETERS

The water quality parameters used by the model to calculate the impact of the effluent, are based on the calibrated water quality model (IMDC, 2021). Reference is made to this report for a detailed discussion on the parameters. The most important calibrated water quality parameter is the decay rate. The final selected decay rates have been based on the experiments performed by Ruđer Bošković Institute (Korlević and Markovski, 2019) that have been subsequently calibrated in the water quality model to represent the faecal dispersion behaviour. A distinction between day and night is made. Table 2-3 gives an overview of the applied decay rates.

Table 2-3 Decay rates (T_{90}-values) [h] of faecal bacteria (IMDC, 2021).

Parameter	Combined decay rate (T_{90}-value) [h]
ECOLI (day)	9.5
IE (day)	10.5
ECOLI (night)	54
IE (night)	84

For the scenario modelling modifications have been made to the discharges (see previous sections) and to the concentrations of faecal bacteria at the outfall. Representative concentrations have been determined averaged out over the outfalls (see calibration report in (IMDC, 2021)), but varying over seasons due to different populations and depending on the considered scenario as presented in Table 2-4 (see chapter 3 for a presentation on the scenario). In case of unfiltered effluent the same concentrations as in the water quality calibration exercise have been applied. In case of filtered effluent, it is assumed that the membrane filter leads to a reduction to 0.1% in the concentration of faecal bacteria. This assumption is based on the average performance of the membrane filter in filtering out VSS particles as found in the WWTP modelling studies (ASM Design, 2021a), (ASM Design, 2021b), (ASM Design, 2021c) and (ASM Design, 2021d). It is assumed that the same performance can be applied on the faecal bateria concentration. In case of full reuse of effluent there is no discharge of polluted effluent and the concentration is zero.

Table 2-4: Overview of the input faecal concentrations (CFU/100mL) for the different outfalls, seasons and scenario's.

Scenario	Season	ECOLI Flux CFU/100mL]	IE Flux [CFU/100mL]
No filtering	Summer	3.50 e+7	2.50 e+7
	Winter	1.50 e+7	1.10 e+7
Filtering	Summer	3.50 e+4	2.50 e+4
	Winter	1.50 e+4	1.10 e+4
Full reus	Summer	0.00	0.00
	Winter	0.00	0.00

3. IMPACT OF WWTP: WATER QUALITY SCENARIOS

3.1 INTRODUCTION

The evolution of the Escherichia coli (ECOLI) and Enterococci (IE) bacteria, which are introduced to the Adriatic sea through outfall discharges, is studied along the Istrian coast by performing simulations with the mid-field water quality model presented in (IMDC, 2021).

In this study, scenario simulations are performed for various treatment scenarios of the WWTP in order to investigate the implications of the current and future expected faecal discharge on the water quality near Istria. For this, simulations are performed of ten-day periods that correspond to the dates of the measurement campaigns of January 2019 and July 2019 to investigate the effect during stratified (summer) and mixed (winter) sea water conditions.

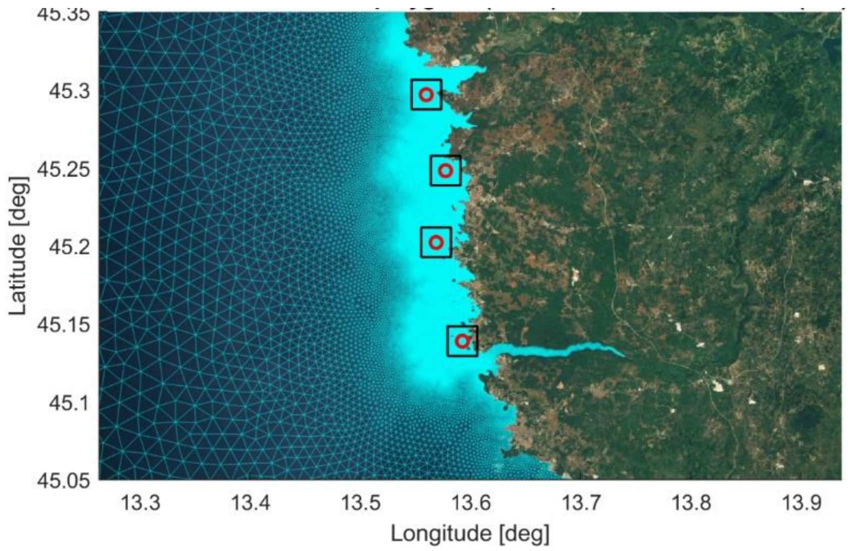

Figure 3-1 Mesh of the mid-field water quality model near Istria, overlaid with calibration 3x3 [km] polygons (black squares) and outfall locations (red circles).

3.2 MODEL SETUP

The mid-field water quality model is based on the hydrodynamic model of IMDC (IMDC, 2019a). Details regarding the setup of the model (model grid resolution, boundary conditions, settings, etc.) can be found in the hydrodynamic model setup report (IMDC, 2019a). For this part of the study, the hydrodynamic model is coupled to the in TELEMAC available water quality module WAQTEL. The TELEMAC-3D part of the mid-field water quality model has the same setup as the hydrodynamic model, though it includes some extra features which are required for modelling of water quality:

- Module for introducing the bacterial discharge, coupling the near field and mid field model
- Implementation of the decay rate of the bacteria

Details regarding the setup of the water quality model and its calibration can be found in the calibration report (IMDC, 2021).

3.3 SCENARIO DESCRIPTION

Different scenarios have been defined representing different treatment scenarios for the WWTP which will have a different impact on the sea water quality. An overview of all treatment scenarios is given in Figure 3-2. A distinction has been be made between:

1. Reuse of effluent (TER). In this case there is a full reuse of the effluent and as such there is no discharge of polluted effluent to the Adriatic Sea. As the concentration on faecal bacteria in this case is zero, this treatment scenario is not modelled with the sea water quality model.
2. Filtered effluent (OED). In this case the effluent is treated with a membrane filter. A reduced concentration of faecal bacteria is introduced in the water quality model. Based on performance calculations of the WWTP, a reduction of the concentration due to filtering to 0.1% of the initial faecal concentrations is applied, as presented in section 2.2.
3. Unfiltered effluent, no treatment (NOT). No treatment is performed, and similar as the situation before WWTP, the total load of faecal bacteria is discharged to the sea without any reduction, see section 2.2 for the concentrations. This forms the worst case situation in terms of risk on bathing water quality.

These treatment scenarios can take place in both summer and winter conditions.

Based on the overall list of treatment situations in Figure 3-2, a selection of simulations have been performed with the sea water quality model, based on the following considerations:

- For both summer and winter season, the situation of unfiltered (worst case) and filtered effluent has been simulated for the present situation (2022).
- In the simulations, typically all four WWTP’s are included, meaning there is effluent discharge (filtered or unfiltered depending on the scenario) from all four outfalls in one simulation.
- As summer conditions are coinciding most with swimming season, they are focused on more for the bathing water quality analysis. Therefore additional more in depth simulations have been performed for this season:
    - In all simulations, all WWTP are active simultaneously during the simulation period except for the worst case situation of unfiltered effluent during summer, in which also simulations have been performed with each WWTP included separately to analyse each individual impact.
    - The future conditions in 2040 have been simulated as well focusing on the summer season for filtered and unfiltered effluent.

An overview of the performed simulations is given in Table 3-1. Based on the results of these simulations all treatment scenarios in Figure 3-2 can be discussed.

The following sections give more details on the performed simulations.

MODELLING SCENARIOS PROJEKT POREČ

- Four sub-catchments will be modelled each including two sub-systems - sewerage network and wastewater treatment plant (WWTP). The third sub-system - coastal seawater quality will be modelled as one common system for all four sub-catchments.
- Two main seasons will be taken into account – summer (high) season and winter (low) season.
- Two main situation with regard to WWTP will be considered – with WWTP in operation and without (NOT).
- For operational WWTPs two scenarios will be studied – with 100% reuse of treated effluent (TER) and with emergency discharge of treated effluent into the sea (OED).
- In summary, there will be 4 different model simulations for sewerage system, WWTP and seawater quality for each of 4 sub-catchments.
- And several worst case sub-scenarios for seawater quality modelling will be carried out in emergencies when one or more plants are out of operation during high season

Sc.	Season	TER/OED/NOT	Flow/Load	Sewerage	WWTP	Sea	Comment
S1	Summer	TER	Max	■	■	X	No need to model sea due to 100% reuse of the effluent
S2		OED				■	Low risk impact on the sea due to functioning of WWTP with UF MBR
S3		NOT			X	■[1]	High risk on the sea due to no treatment and max flow/load (scenarios S3.1-S3.5)
S4		TER/OED	Min	■	■	X	No need to model sea due to 100% reuse of the effluent / UF MBR, and S2 in place
W1	Winter	TER	Max	■	■	X	No need to model sea due to 100% reuse of the effluent
W2		OED				■	Low risk impact on the sea due to functioning of WWTP with UF MBR
W3		NOT			X	■	Medium risk impact on the sea due to less flow/load and winter – no bathing
W4		TER/OED	Min	■	■	X	No need to model sea due to 100% reuse of the effluent / UF MBR, and W2 in place

TER: Treated Effluent Reuse

OED: Offshore Emergency Discharge

NOT: No Treatment (Note[1]: Seawater modelling in this high risk case will examine 4 sub-scenarios: S3.1 – S3.4, one WWTP out of operation at the time, and one worst case scenario: S3.5 with all 4 WWTP out of operation simultaneously, with optional dynamic simulation of day/night conditions, depending on data available).

Figure 3-2 Defined scenarios in consultation with the client (the water quality model simulations are indicated in the column "Sea" with square blocks indicating the cases that are simulated).

Table 3-1: Overview of performed scenario simulations with the water quality model.

Nr	Season	Reference	Scenario	WWTP
1	Summer	2022	Unfiltered effluent (NOT) – S3.1	All
2			Unfiltered effluent (NOT) – S3.2	Lanterna
3			Unfiltered effluent (NOT) – S3.3	Porec North
4			Unfiltered effluent (NOT) – S3.4	Porec South
5			Unfiltered effluent (NOT) – S3.5	Vrsar
6			Filtered effluent (OED) – S2	All
7	Winter	2022	Unfiltered effluent (NOT) – W3	All
8			Filtered effluent (OED) – W2	All
9	Summer	2040	Unfiltered effluent (NOT) – S3	All
10			Filtered effluent (OED) – S2	All

3.3.1 Summer 2022 discharge - Stratified conditions

3.3.1.1 Unfiltered effluent

The period of the summer scenario with stratified conditions is from 13-07-2019 till 24-07-2019 and corresponds to the summer period in the calibration phase (period in which measurements were performed at the outfalls (Korlević and Markovski, 2019)). Figure 3-3 shows the vertical water density variation over the ten day modelling period of July 2019. It shows that density variations of maximal 2 [kg/m^3] are present in this period. Moreover a density increase in the downward direction with occasionally sharp gradients is visible, thus showing a stratified layering with density variations on a daily scale. The wind conditions during this simulation period (Figure 3-4) were moderate, with a dominant easterly wind (towards the west).

The parameters applied for the summer scenario are shown in Table 3-2. In this scenario, no membrane filter is applied to reduce the faecal bacteria in the effluent.

In order to study the impact of each single outfall on the water quality, additional simulations have been performed for each of the four outfalls separately (sub-scenarios S3.1 – S3.4, Figure 3-2 and Table 3-1). Results of these additional simulations are provided in section 6.A.1.

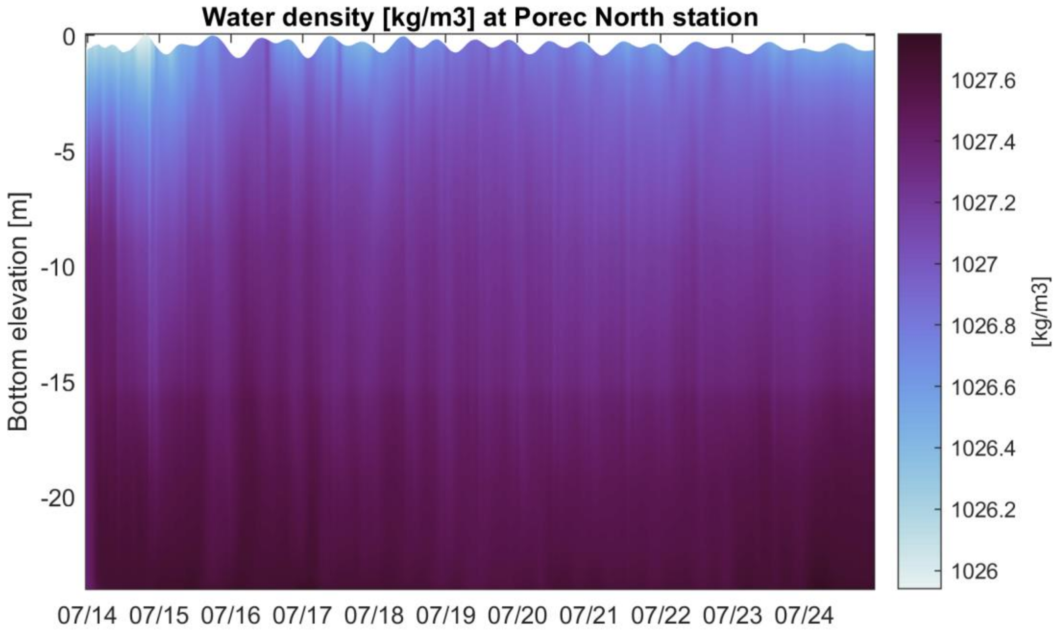

Figure 3-3 Evolution of the water density [kg/m^3] in time (14 till 24-July 2019) over the water column at Poreč North station.

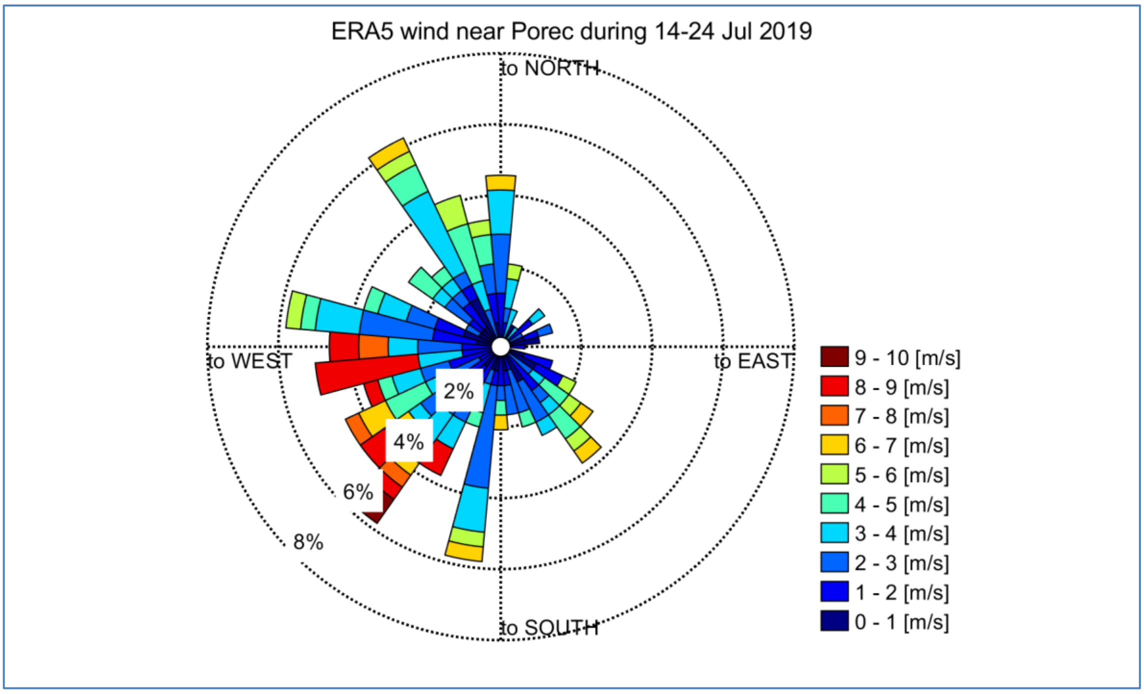

Figure 3-4 Wind rose displaying occurrence of ERA5 wind direction and speed conditions near Poreč during the summer period of 14 till 24-July-2019.

Table 3-2 Parameter settings for faecal bacteria plume simulations in TELEMAC-3D based on near field simulations (Stratified conditions – summer scenario, 2022 discharge). Here is Z_{min} the minimal depth of the plume, Z_{max} the maximal depth of the plume, L the horizontal halflength of the plume, B the horizontal halfwidth of the plume, θ is the angle of the plume with respect to the vertical (θ = 0 [deg] is vertical plane) and Φ the angle of the plume with respect to the horizontal (Φ = 0 [deg] is east-west orientation).

Outfall	**ECOLI Flux [KVE/s]**	**IE Flux [KVE/s]**	**Time flush [s]**	**Time interval [s]**	**Z_{min} [m]**	**Z_{max} [m]**	**L [m]**	**B [m]**	**θ [deg]**	**Φ [deg]**
Laterna	3.85E+10	2.75E+09	455	1728	Z_{max} - 11	-6	10	45	0	110
Poreč North	3.85E+10	2.75E+09	455	928	-16	-6	10	50	0	97
Poreč South	4.90E+10	3.50E+09	357	704	Z_{max} - 10	-6	10	10	0	94
Vrsar	2.65E+10	1.88E+09	333	1102	Z_{max} - 2	-6	10	34	0	94

3.3.1.2 Filtered effluent

In this scenario, the effect of a membrane filter at the waste water treatment plants on the water quality near the coast is investigated for 2022 summer discharge conditions by reducing the concentration of the faecal bacteria in the effluent to 0.1 percent of its original value, see discussion in section 2.2.

Apart from the reduced faecal baterica in the effluent, this scenario uses the same summer met-ocean boundary conditions and model settings as the preceding scenario (section 3.3.1.1).

3.3.1.3 Reuse of effluent

By reusing 100 percent of the effluent, no faecal bacteria from the wastewater treatment plant will end up in the Adriatic Sea. Hence, there is no need to model the water quality for this 2022 summer scenario.

3.3.2 Winter 2022 discharge - Mixed conditions

3.3.2.1 Unfiltered effluent

The period of the winter scenario with mixed conditions is from 18-01-2019 till 28-01-2019 and corresponds to the period, when measurements were performed at the outfalls by the Ruđer Bošković Institute. Figure 3-5 shows the water density variation in the vertical over the ten day modelling period of January 2019. It shows that density variations are minor with a maximum of 0.1 [kg/m^3] and that these variations are randomly mixed throughout the water column. The wind conditions during this simulation period (Figure 3-6) were strong, with a persistent wind towards the south-west during most of the simulation period.

The parameters applied for the winter scenario are shown in Table 3-3. In this scenario, no membrane filter is applied to reduce the faecal bacteria in the effluent.

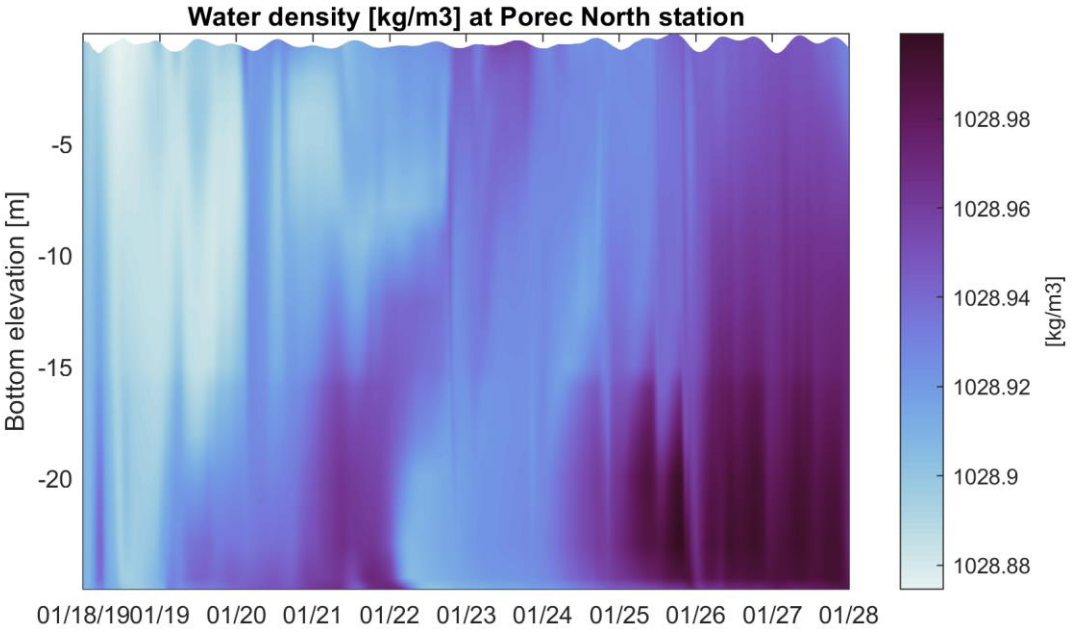

Figure 3-5 Evolution of the water density [kg/m^3] in time (18 till 28-January 2019) over the water column at Poreč North station.

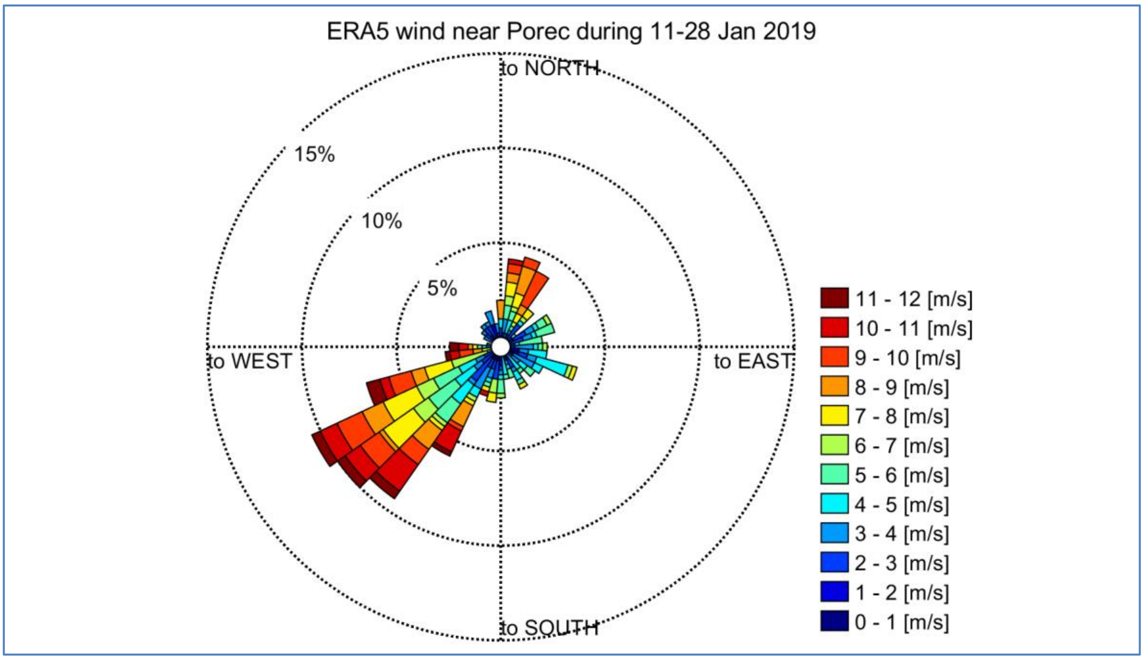

Figure 3-6 Wind rose displaying occurrence of ERA5 wind direction and speed conditions near Poreč during the winter simulation period of 11 till 28-January-2019.

Table 3-3 Parameter settings for faecal bacteria plume simulations in TELEMAC-3D based on near field simulations (Mixed conditions – winter scenario, 2022 discharge). Here is Zmin the minimal depth of the plume, Zmax the maximal depth of the plume, L the horizontal halflength of the plume, B the horizontal halfwidth of the plume, θ is the angle of the plume with respect to the vertical (θ = 0 [deg] is vertical plane) and Φ the angle of the plume with respect to the horizontal (Φ = 0 [deg] is east-west orientation).

Parameter	ECOLI Flux [KVE/s]	IE Flux [KVE/s]	Time flush [s]	Time interval [s]	Z_{min} [m]	Z_{max} [m]	L [m]	B [m]	θ [deg]	Φ [deg]
Laterna	1.43E+11	1.21E+09	455	17181	Z_{max} - 24	Water surface	10	110	0	110
Poreč North	1.43E+11	1.21E+09	455	2263	-16	Water surface	10	60	0	97
Poreč South	1.82E+11	1.54E+09	357	5306	Z_{max} - 10	Water surface	10	10	0	94
Vrsar	9.75E+10	8.25E+08	333	6285	Z_{max} - 3	Water surface	10	39	0	94

3.3.2.2 Filtered effluent

In this scenario, the effect of a membrane filter at the waste water treatment plants on the water quality near the coast is investigated for 2022 winter discharge conditions, by reducing the concentration of the faecal bacteria in the effluent to 0.1 percent of its original value, see discussion in section 2.2.

Apart from the reduced faecal baterica in the effluent, this scenario uses the same winter met-ocean boundary conditions and model settings as the preceding scenario (section 3.3.2.1).

3.3.2.3 Reuse of effluent

By reusing 100 percent of the effluent, no faecal bacteria from the wastewater treatment plant will end up in the Adriatic Sea. Hence, there is no need to model the water quality for this 2022 winter scenario.

3.3.3 Summer 2040 discharge - Stratified conditions

3.3.3.1 Unfiltered effluent

The metocean settings for the summer 2040 discharge scenario are equal to the ones used in the summer 2022 scenario (section 3.3.1.1). However, the parameter settings for the sewage effluent are now representative for expected discharge in 2040. The applied parameters are shown in Table 3-4. In this scenario, no membrane filter is applied to reduce the faecal bacteria in the effluent.

Table 3-4 Parameter settings for faecal bacteria plume simulations in TELEMAC-3D based on near field simulations (Stratified conditions – summer scenario, 2040 discharge). Here is Z_{min} the minimal depth of the plume, Z_{max} the maximal depth of the plume, L the horizontal halflength of the plume, B the horizontal halfwidth of the plume, θ is the angle of the plume with respect to the vertical (θ = 0 [deg] is vertical plane) and Φ the angle of the plume with respect to the horizontal (Φ = 0 [deg] is east-west orientation).

Outfall	ECOLI Flux [KVE/s]	IE Flux [KVE/s]	Time flush [s]	Time interval [s]	Z_{min} [m]	Z_{max} [m]	L [m]	B [m]	θ [deg]	Φ [deg]
Laterna	3.85E+10	2.75E+09	455	1579	Z_{max} - 11	-6	10	45	0	110
Poreč North	3.85E+10	2.75E+09	455	848	-16	-6	10	50	0	97
Poreč South	4.90E+10	3.50E+09	357	613	Z_{max} - 10	-6	10	10	0	94
Vrsar	2.65E+10	1.88E+09	333	960	Z_{max} - 2	-6	10	34	0	94

3.3.3.2 Filtered effluent

In this scenario, the effect of a membrane filter at the waste water treatment plants on the water quality near the coast is investigated for 2040 summer discharge conditions, by reducing the concentration of the faecal bacteria in the effluent to 0.1 percent of its original value, see discussion in section 2.2.

Similar met-ocean boundary conditions and model settings as the preceding scenario (section 3.3.1.1) are used. Apart from the reduced faecal baterica in the effluent, the discharge settings of this scenario are based on the 2040 scenario (section 3.3.3.1).

3.3.3.3 Reuse of effluent

By reusing 100 percent of the effluent, no faecal bacteria from the wastewater treatment plant will end up in the Adriatic Sea. Hence, there is no need to model the water quality for this 2040 summer scenario.

4. SCENARIO RESULTS

4.1 INTRODUCTION

In this chapter, the behaviour of the faecal bacterial plumes are discussed together with an assessment of the water quality for the performed modelling scenarios during summer (stratified conditions) and winter (mixed conditions). An overview of the scenarios can be found in section 3.3. Reference values for the assessment of microbial sea quality are adapted from Korlević and Markovski (2019) and shown in Table 4-1. Based on this, the water quality in this study is assessed as insufficient for concentrations of IE > 200 [CFU/ 100 ml] and ECOLI > 300 [CFU/ 100 ml].

Table 4-1 Reference values for the assessment of microbial sea quality after each examination specified by the Republic of Croatia (NN 73/2008). Adapted from Korlević and Markovski (2019)

Parameter	Excellent quality	Good quality	Sufficient	Reference methods
Intestinal enterococci [CFU / 100 ml)]	< 60	61 - 100	101 - 200	HRN EN ISO 7899-1 or HRN EN ISO 7899-2
Escherichia coli [CFU / 100 ml]	< 100	101 - 200	201 - 300	HRN EN ISO 9308-1 or HRN EN ISO 9308-3

The scenario simulation results are illustrated based on

- Exceedance maps showing how often the water quality threshold is exceeded at the water surface, including the contours of the 5th, 50th and 95th percentile. Here, the 5th percentile represents the contour where the threshold is exceeded 5% of the time.
- For Escherichia coli (ECOLI) and Intestinal enterococci (IE) bacteria seperately.
- Maps are shown for the entire Istrian coast, and when relevant for a Northern zoom, a zoom in the middle and a zoom in the South.
- In addition the 300m seaward contour from the beaches is indicated in the maps to assess whether or not the effluent can reach this contour towards the beaches.

4.2 STRATIFIED CONDITIONS – SUMMER SCENARIO 2022 DISCHARGE

4.2.1 Unfiltered effluent

Based on microbial sea quality criteria of Table 4-1, maps with probabilities of exceeding the water quality threshold were determined for the 2022 summer scenario (Figure 4-1 till Figure 4-5). These maps help identify the areas of highest exposure and highest risk of reduced water quality.

At the water surface, where the water quality is measured, only the 5th percentile is reached (meaning exceeded in 5% of the time), and then only at locations around the outfalls at sea. The largest exposure for potential transport towards the beaches can be observed in the south near Vrsar where the water quality contour for ECOLI is larger than in the other areas. However, the contour is not within 300 [m] distance of the beaches, thus posing no risk to having poor swimming water quality. Near the Poreč south outfall, only the small island of Otočić Altijež has the potential of being exposed to higher concentrations for 5% of the time within 300 [m] of its beaches. In case of the IE bacteria, the 5th percentile of probability of exceeding 200 [CFU/100 ml] is not reached in the Istrian sea (Figure 4-5).

Overall, due to the trapping of the waste water plume in deeper water layers during summer as a result of the stratified water column, the water quality at the water surface near the coast/beaches is sufficient in summer. It should however be noted that in conditions when this stratification of the water column is not present there may be a larger risk of exposure.

Figures of scenario simulations with single outfall discharge for each WWTP separately are shown for all four outfalls in Annex A (scenarios S3.2 to S3.5). Based on these results it can be concluded there is no accumulation or overlap of effluent between the different outfalls and WWTP.

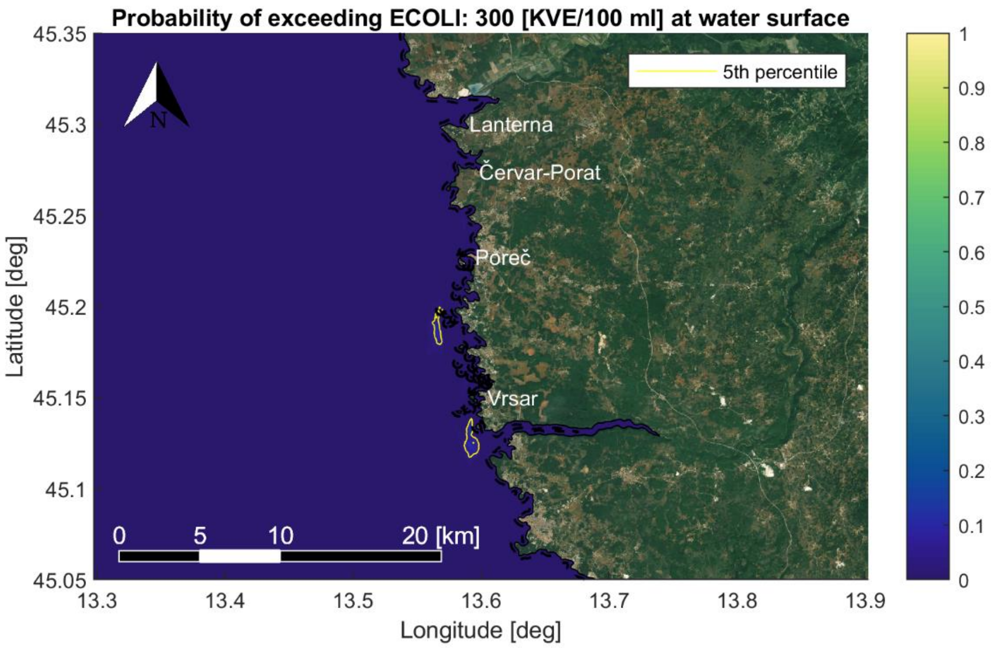

Figure 4-1 Summer scenario 2022 discharge: Probability of exceeding ECOLI concentrations of 300 [CFU/ 100 ml] at the water surface. Yellow contours show 5th percentile; Orange contours show 50th percentile; Red contours show 95th percentile. Dashed black lines indicate the 300 [m] contour around a land boundary.

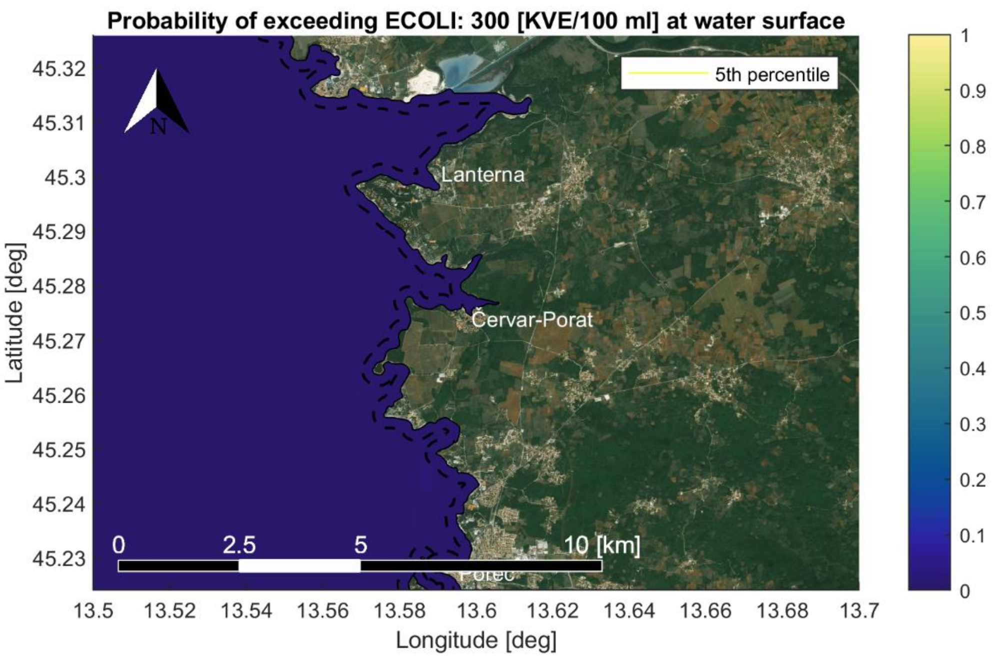

Figure 4-2 Summer scenario 2022 discharge, North zoom: Probability of exceeding ECOLI concentrations of 300 [CFU/ 100 ml] at the water surface. Yellow contours show 5th percentile; Orange contours show 50th percentile; Red contours show 95th percentile. Dashed black lines indicate the 300 [m] contour around a land boundary.

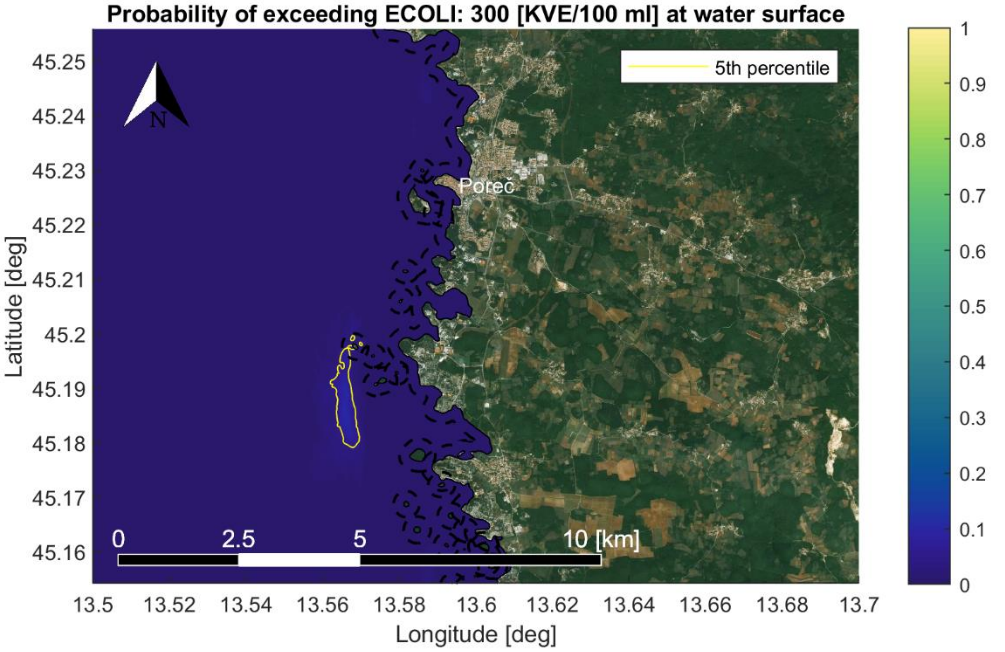

Figure 4-3 Summer scenario 2022 discharge, Middle zoom: Probability of exceeding ECOLI concentrations of 300 [CFU/ 100 ml] at the water surface. Yellow contours show 5th percentile; Orange contours show 50th percentile; Red contours show 95th percentile. Dashed black lines indicate the 300 [m] contour around a land boundary.

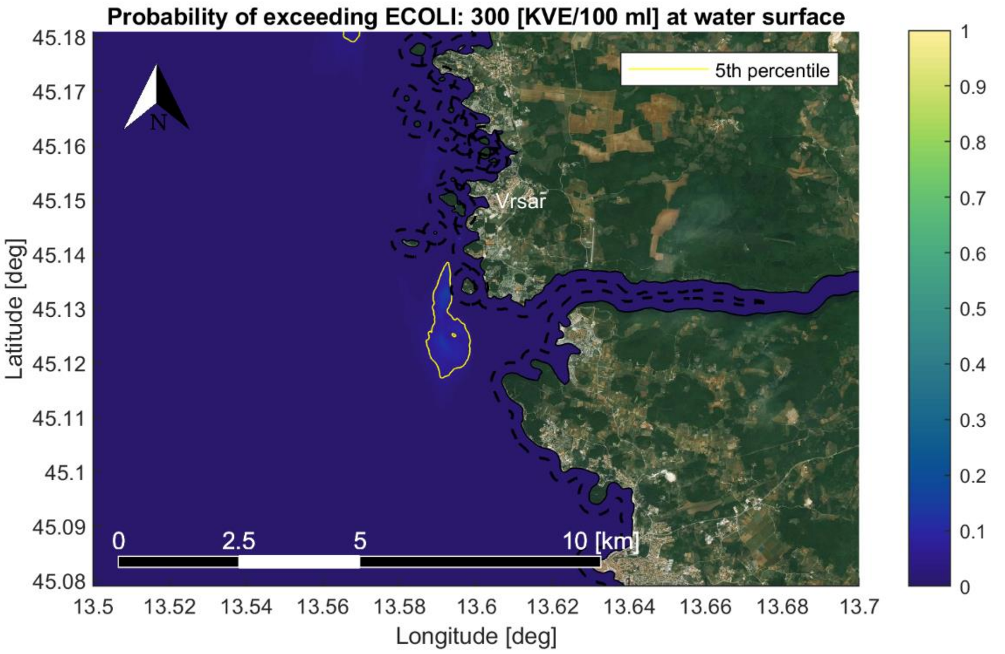

Figure 4-4 Summer scenario 2022 discharge, South zoom: Probability of exceeding ECOLI concentrations of 300 [CFU/ 100 ml] at the water surface. Yellow contours show 5th percentile; Orange contours show 50th percentile; Red contours show 95th percentile. Dashed black lines indicate the 300 [m] contour around a land boundary.

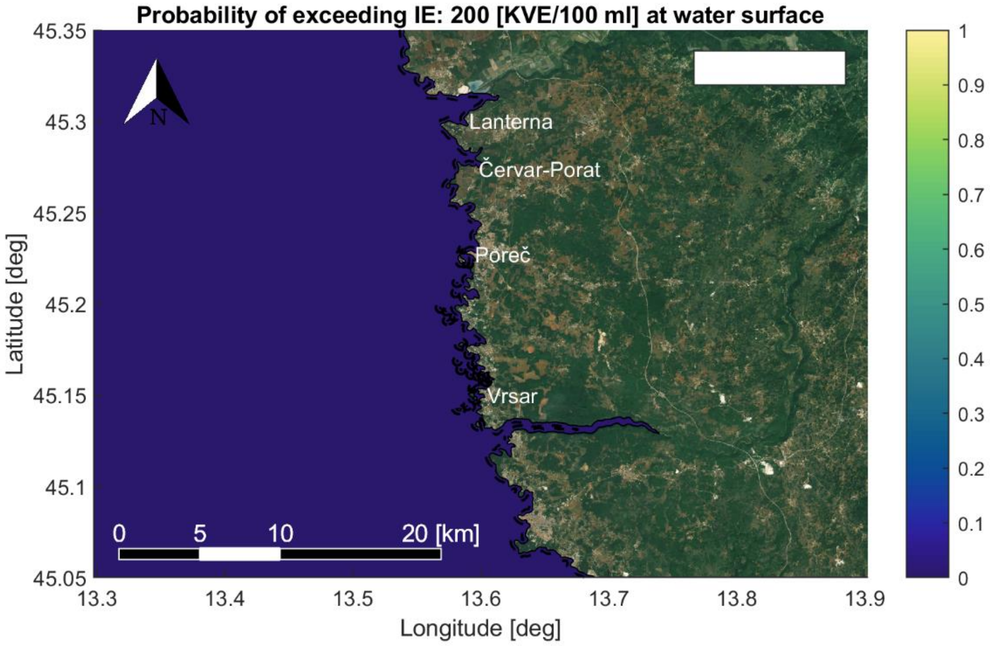

Figure 4-5 Summer scenario 2022 discharge: Probability of exceeding IE concentrations of 200 [CFU/ 100 ml] at the water surface. Yellow contours show 5th percentile; Orange contours show 50th percentile; Red contours show 95th percentile. Dashed black lines indicate the 300 [m] contour around a land boundary.

4.2.2 Filtered effluent

The 2022 summer scenario with membrane filter shows that there is no exceedance of ECOLI concentrations above 300 [CFU/ 100 ml] and IE concentrations above 200 [CFU/ 100 ml] at the water surface to be found (Figure 4-6 till Figure 4-10). This shows the effectiveness of the membrane filter in providing sufficient water quality conditions near the coast. Even though the main impact on water quality was occurring around the outfalls when unfiltered effluent was discharged (see previous section), the simulation results below illustrate that the WWTP, leading to discharge of filtered effluent, improve the sea water quality, showing no more exceedances at sea.

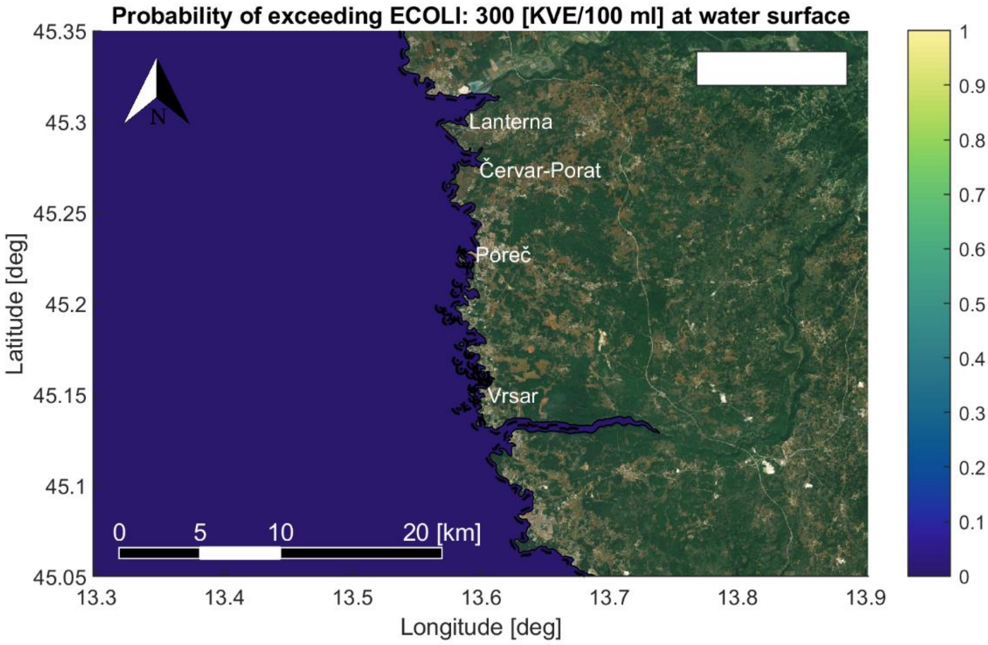

Figure 4-6 Summer scenario 2022 discharge with filter: Probability of exceeding ECOLI concentrations of 300 [CFU/ 100 ml] at the water surface. Yellow contours show 5th percentile; Orange contours show 50th percentile; Red contours show 95th percentile. Dashed black lines indicate the 300 [m] contour around a land boundary.

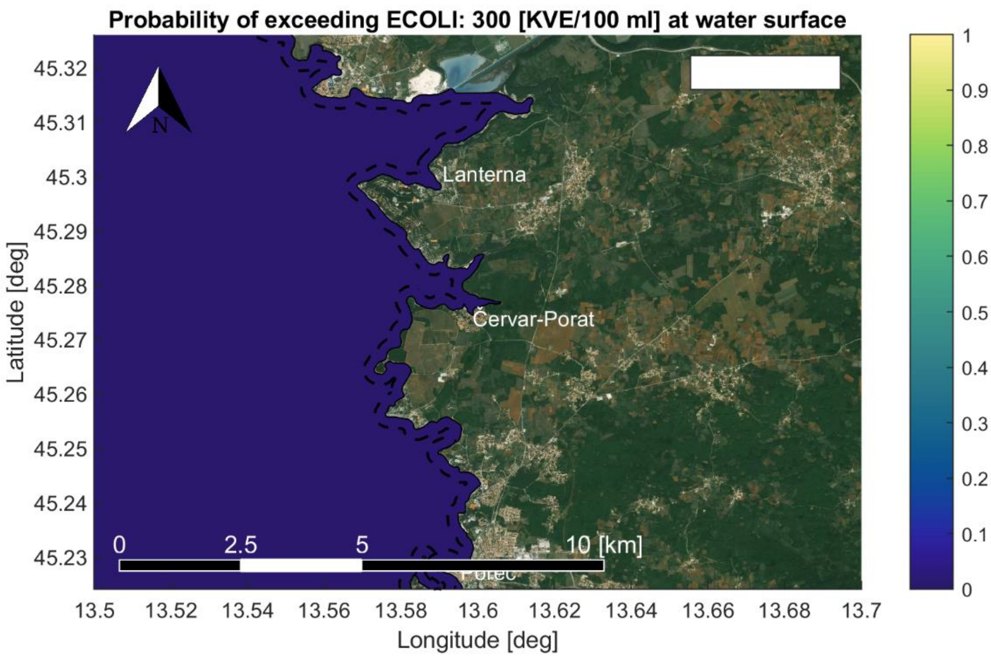

Figure 4-7 Summer scenario 2022 discharge with filter, <u>North zoom</u>: Probability of exceeding ECOLI concentrations of 300 [CFU/ 100 ml] at the water surface. Yellow contours show 5th percentile; Orange contours show 50th percentile; Red contours show 95th percentile. Dashed black lines indicate the 300 [m] contour around a land boundary.

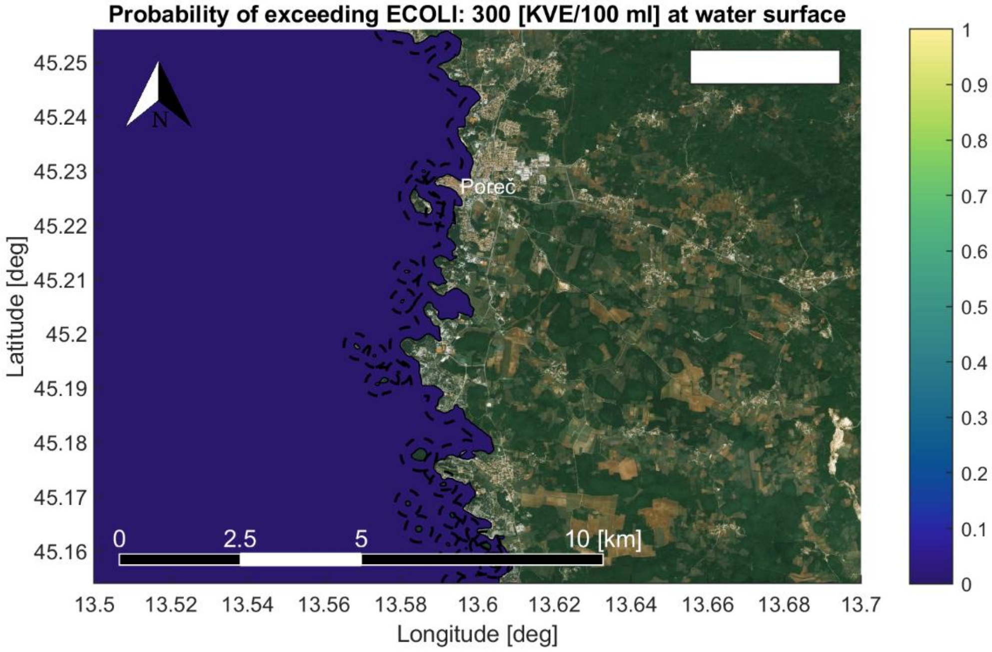

Figure 4-8 Summer scenario 2022 discharge with filter, Middle zoom: Probability of exceeding ECOLI concentrations of 300 [CFU/ 100 ml] at the water surface. Yellow contours show 5th percentile; Orange contours show 50th percentile; Red contours show 95th percentile. Dashed black lines indicate the 300 [m] contour around a land boundary.

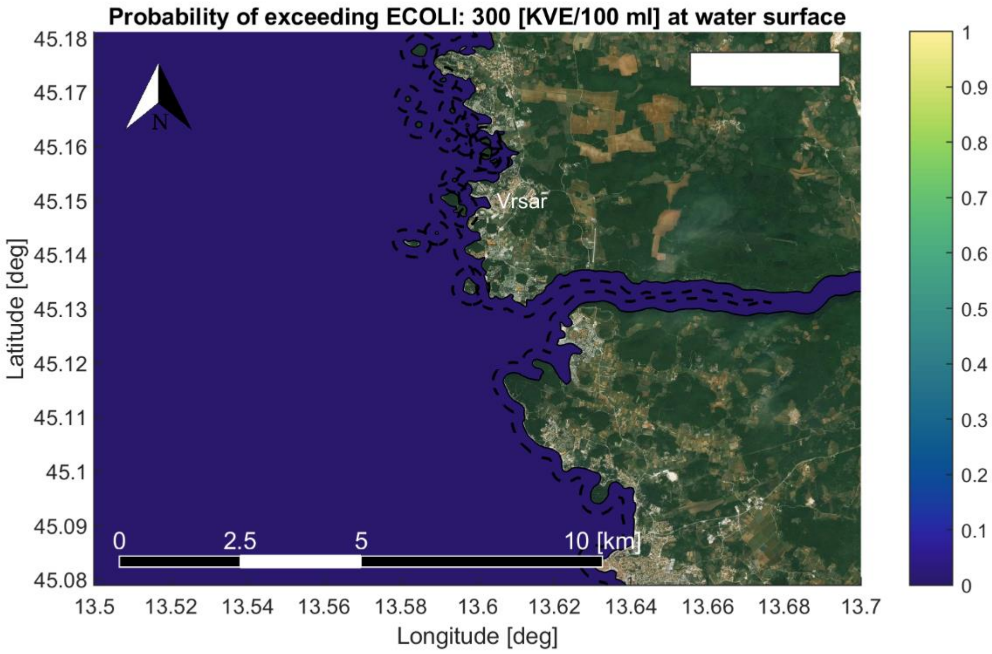

Figure 4-9 Summer scenario 2022 discharge with filter, South zoom: Probability of exceeding ECOLI concentrations of 300 [CFU/ 100 ml] at the water surface. Yellow contours show 5th percentile; Orange contours show 50th percentile; Red contours show 95th percentile. Dashed black lines indicate the 300 [m] contour around a land boundary.

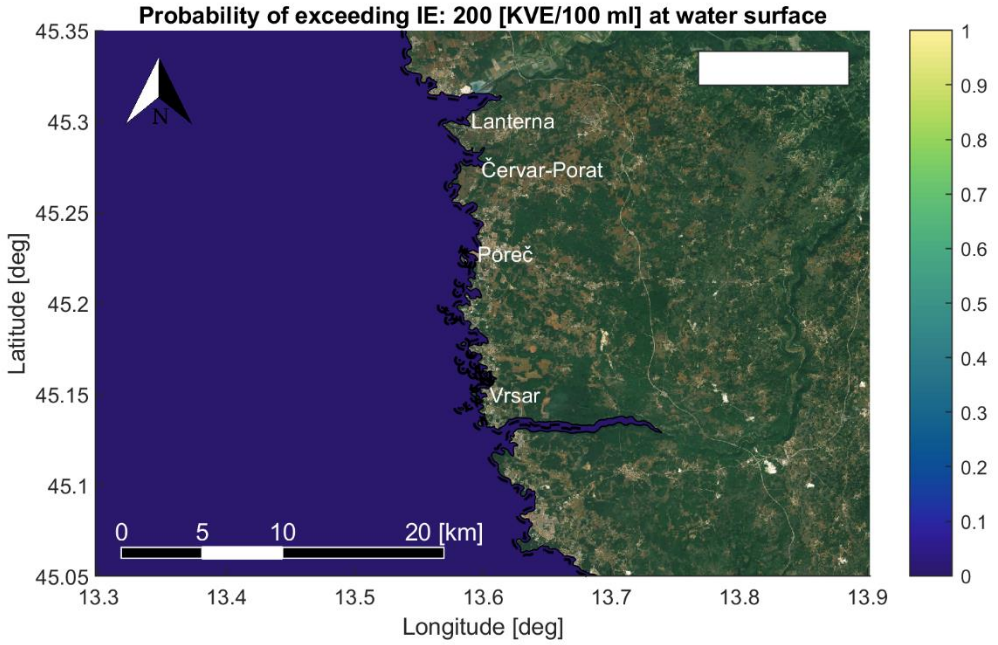

Figure 4-10 Summer scenario 2022 discharge with filter: Probability of exceeding IE concentrations of 200 [CFU/ 100 ml] at the water surface. Yellow contours show 5th percentile; Orange contours show 50th percentile; Red contours show 95th percentile. Dashed black lines indicate the 300 [m] contour around a land boundary.

4.2.3 Reuse of effluent

In this summer scenario, 100 percent of the effluent is being reused. Therefore, no faecal bacteria from the wastewater treatment plant will end up in the Istrian sea. This implies that there is no risk of insufficient water quality near the coast in this summer scenario.

4.3 MIXED CONDITIONS – WINTER SCENARIO 2022 DISCHARGE

4.3.1 Unfiltered effluent

Based on microbial sea water quality criteria of Table 4-1, maps with probabilities of exceeding the water quality threshold were constructed for the 2022 winter scenario (Figure 4-11 till Figure 4-15). They show that the highest probability of exceedance occurs around the discharge outfalls, but compared to the summer scenario with stratified conditions, the mixed water conditions lead to larger exceedance contours at the surface where they have a more offshore directed extend compared to summer. The exposure of the waste water plume during the mixed winter conditions towards the beaches (see zooms in Figure 4-12 and Figure 4-14) is therefore larger than during the stratified summer conditions.

At Lanterna the exceedance contour remains close to the outfall with no exposure to beaches. Near the outfall of Poreč North the water quality contour extends close towards the beaches north of it (close to AC Ulika) where there might be some risk, since the contour is just within 300 [m] reach of the coastline. Around Poreč South the exceedance contour is mainly oriented towards offshore leading to a limited risk of exceedance near the island of Otočić Altijež. In the south, near Vrsar, the exceedance contour is also mainly directed offshore but extends towards some of the offshore islands (Otočić Lunga, Otočić Galopun and Koversada) where there might be a limited risk of exceedance within 300 [m] of the beaches. In case of the IE bacteria, the 5th percentile of probability of exceeding 200 [CFU/100 ml] is found only around the outfall locations, without exposure within 300 [m] of the beaches (Figure 4-15).

Overall, except for some locations listed above, for most beaches the risk on exceedance of water quality is limited in mixed conditions.

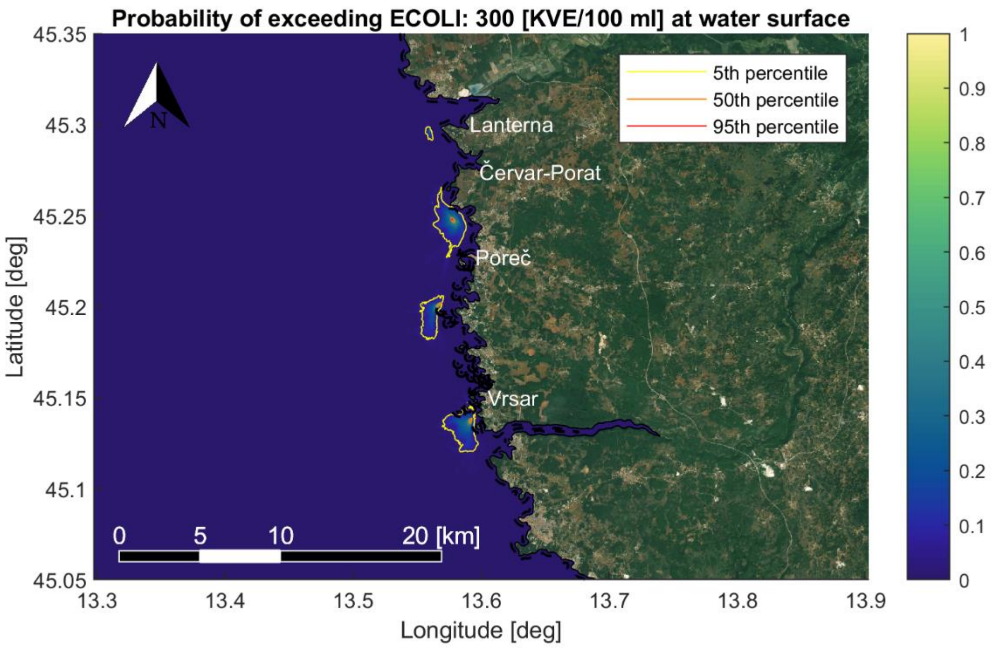

Figure 4-11 Winter scenario 2022 discharge: Probability of exceeding ECOLI concentrations of 300 [CFU/ 100 ml] at the water surface. Yellow contours show 5th percentile; Orange contours show 50th percentile; Red contours show 95th percentile. Dashed black lines indicate the 300 [m] contour around a land boundary.

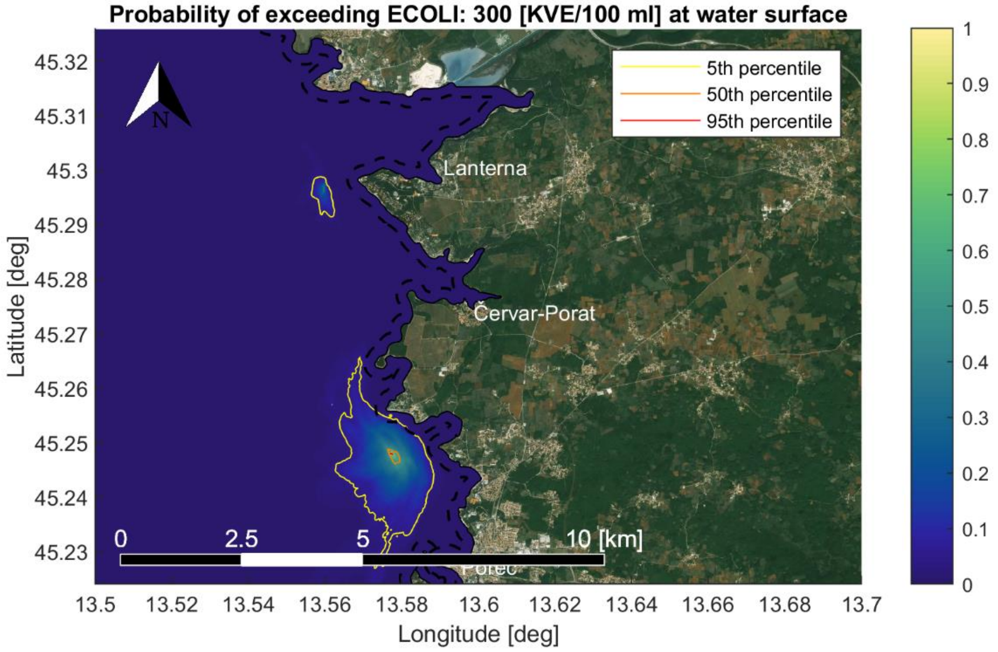

Figure 4-12 Winter scenario 2022 discharge, North zoom: Probability of exceeding ECOLI concentrations of 300 [CFU/ 100 ml] at the water surface. Yellow contours show 5th percentile; Orange contours show 50th percentile; Red contours show 95th percentile Dashed black lines indicate the 300 [m] contour around a land boundary.

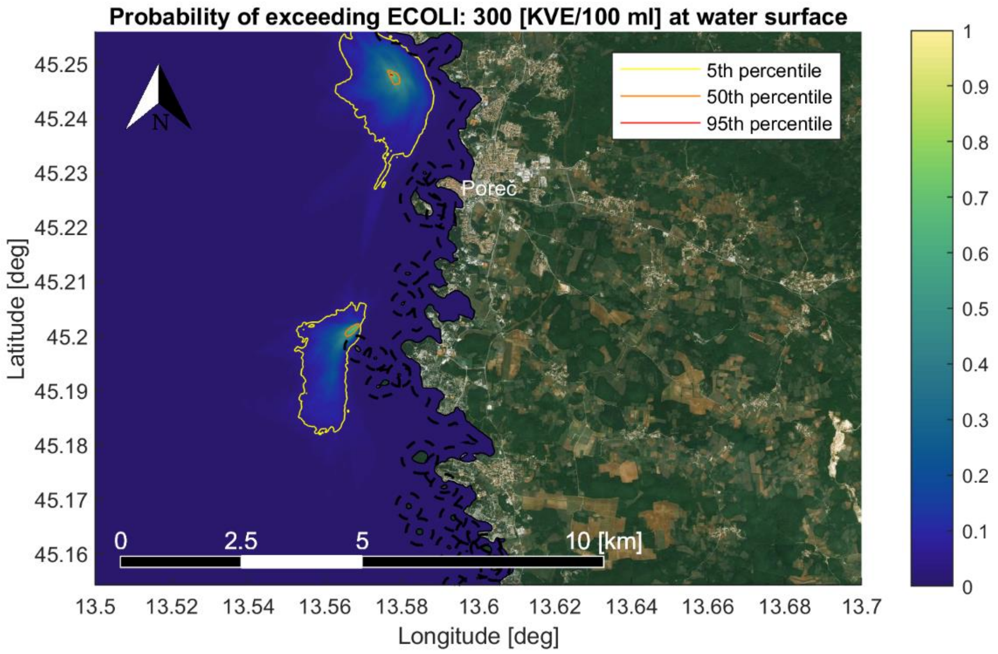

Figure 4-13 Winter scenario 2022 discharge, Middle zoom: Probability of exceeding ECOLI concentrations of 300 [CFU/ 100 ml] at the water surface. Yellow contours show 5th percentile; Orange contours show 50th percentile; Red contours show 95th percentile Dashed black lines indicate the 300 [m] contour around a land boundary.

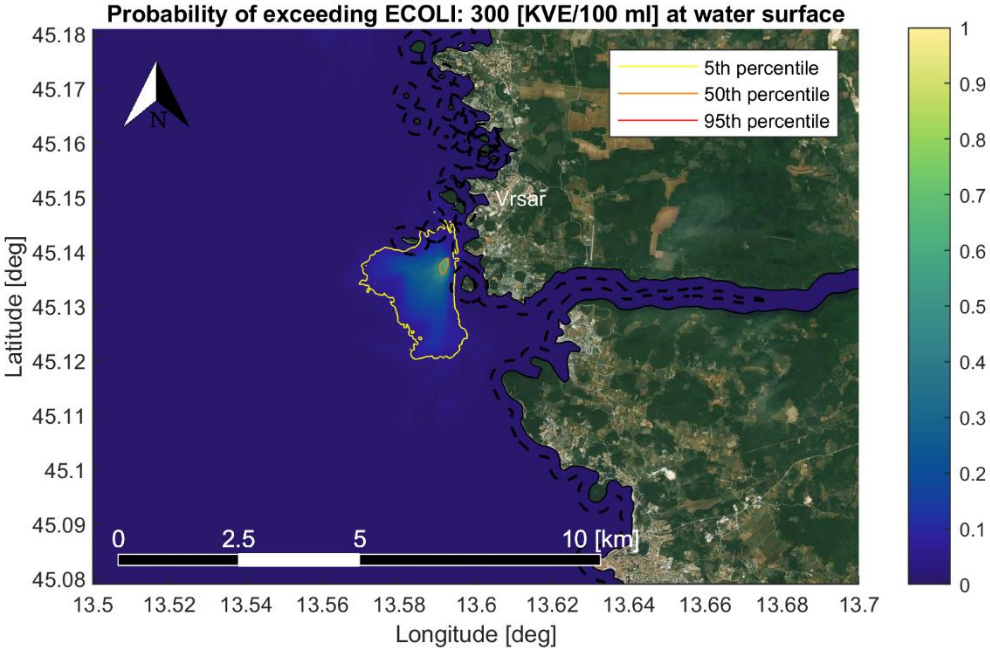

Figure 4-14 Winter scenario 2022 discharge, South zoom: Probability of exceeding ECOLI concentrations of 300 [CFU/ 100 ml] at the water surface. Yellow contours show 5th percentile; Orange contours show 50th percentile; Red contours show 95th percentile Dashed black lines indicate the 300 [m] contour around a land boundary.

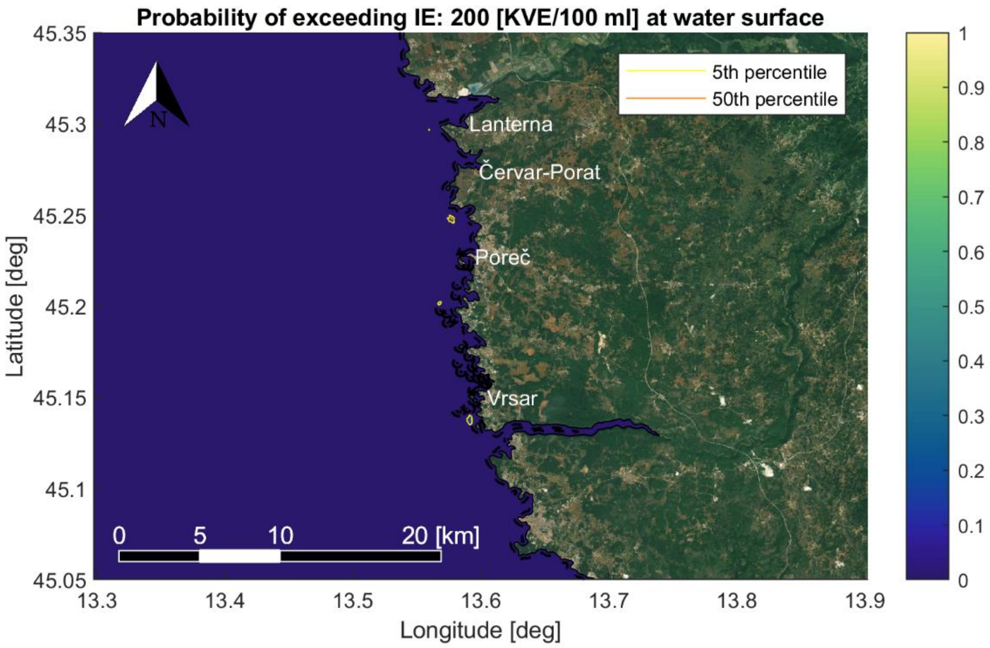

Figure 4-15 Winter scenario 2022 discharge: Probability of exceeding IE concentrations of 200 [CFU/ 100 ml] at the water surface. Yellow contours show 5th percentile; Orange contours show 50th percentile; Red contours show 95th percentile. Dashed black lines indicate the 300 [m] contour around a land boundary.

4.3.2 Filtered effluent

The 2022 winter scenario with membrane filter shows that there is no exceedance of ECOLI concentrations above 300 [CFU/ 100 ml] at the water surface to be found (Figure 4-16 till Figure 4-20). This shows the effectiveness of the membrane filter in providing sufficient water quality conditions near the coast. Compared to the situation with discharging unfiltered effluent, the simulation results below illustrate that the WWTP in operation (discharging filtered effluent) leads to an improved sea water quality.

In case the waste water treatment plants stop working due to a malfunction, due to which the membrane filtering lacks, it is advised to perform temporary measurements near the outfall locations of Poreč North & South and Vrsar with highest risk of poor water quality within 300 [m] of the coast. This way, the water quality is monitored whereupon decisive measures can be taken.

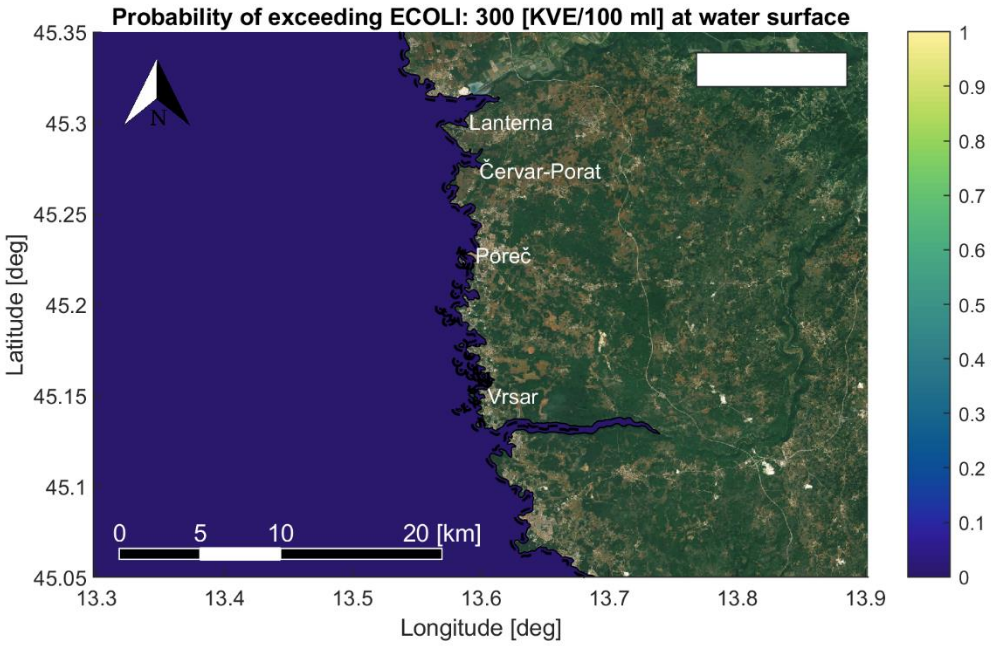

Figure 4-16 Winter scenario 2022 discharge with filter: Probability of exceeding ECOLI concentrations of 300 [CFU/ 100 ml] at the water surface. Yellow contours show 5th percentile; Orange contours show 50th percentile; Red contours show 95th percentile. Dashed black lines indicate the 300 [m] contour around a land boundary.

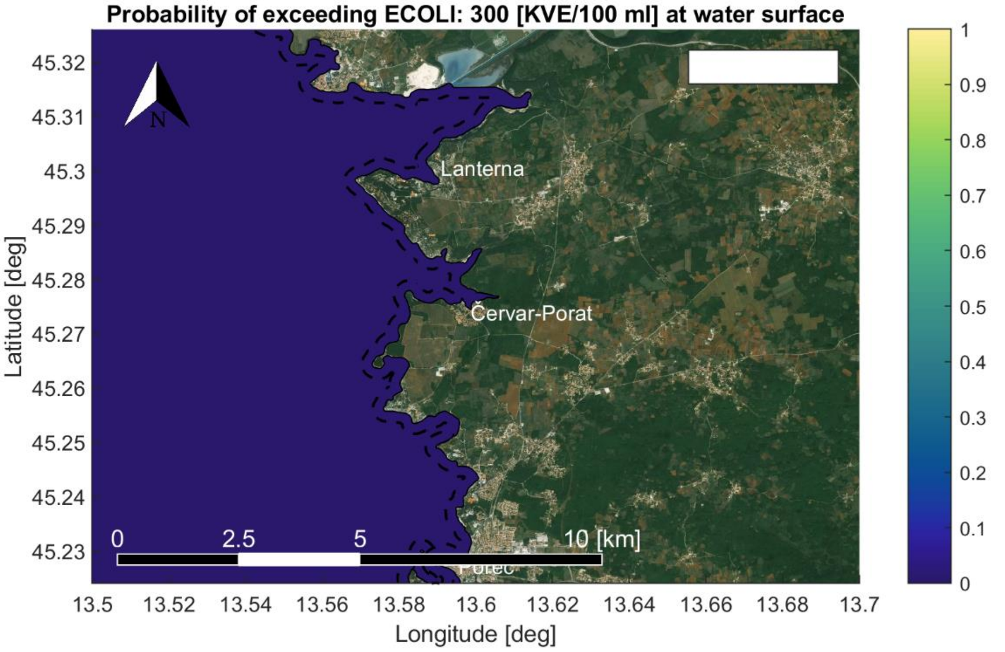

Figure 4-17 Winter scenario 2022 discharge with filter, North zoom: Probability of exceeding ECOLI concentrations of 300 [CFU/ 100 ml] at the water surface. Yellow contours show 5th percentile; Orange contours show 50th percentile; Red contours show 95th percentile. Dashed black lines indicate the 300 [m] contour around a land boundary.

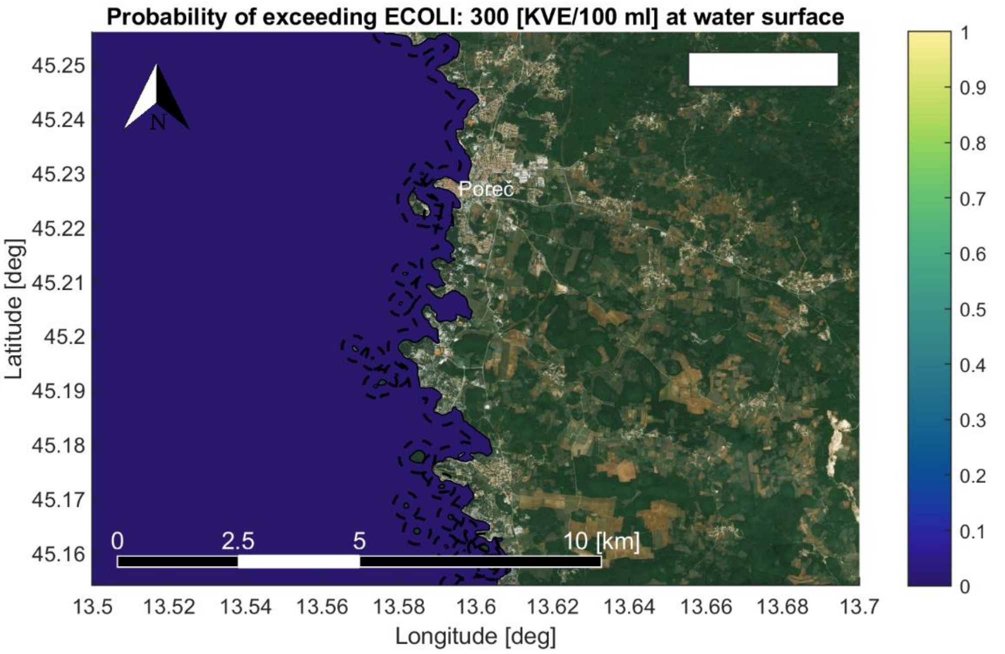

Figure 4-18 Winter scenario 2022 discharge with filter, Middle zoom: Probability of exceeding ECOLI concentrations of 300 [CFU/ 100 ml] at the water surface. Yellow contours show 5th percentile; Orange contours show 50th percentile; Red contours show 95th percentile. Dashed black lines indicate the 300 [m] contour around a land boundary.

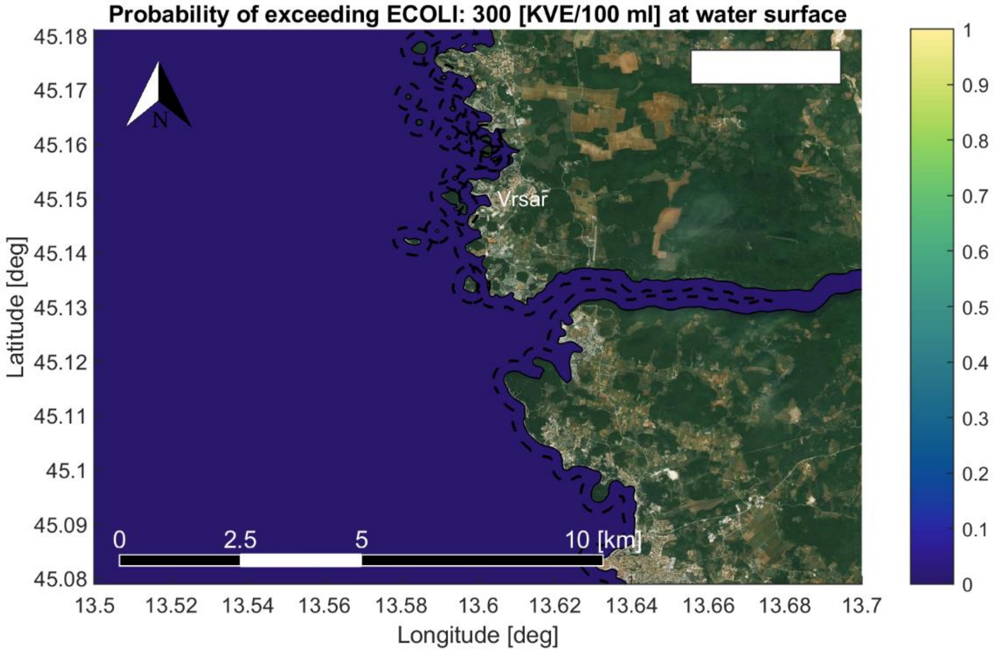

Figure 4-19 Winter scenario 2022 discharge with filter, South zoom: Probability of exceeding ECOLI concentrations of 300 [CFU/ 100 ml] at the water surface. Yellow contours show 5th percentile; Orange contours show 50th percentile; Red contours show 95th percentile. Dashed black lines indicate the 300 [m] contour around a land boundary.

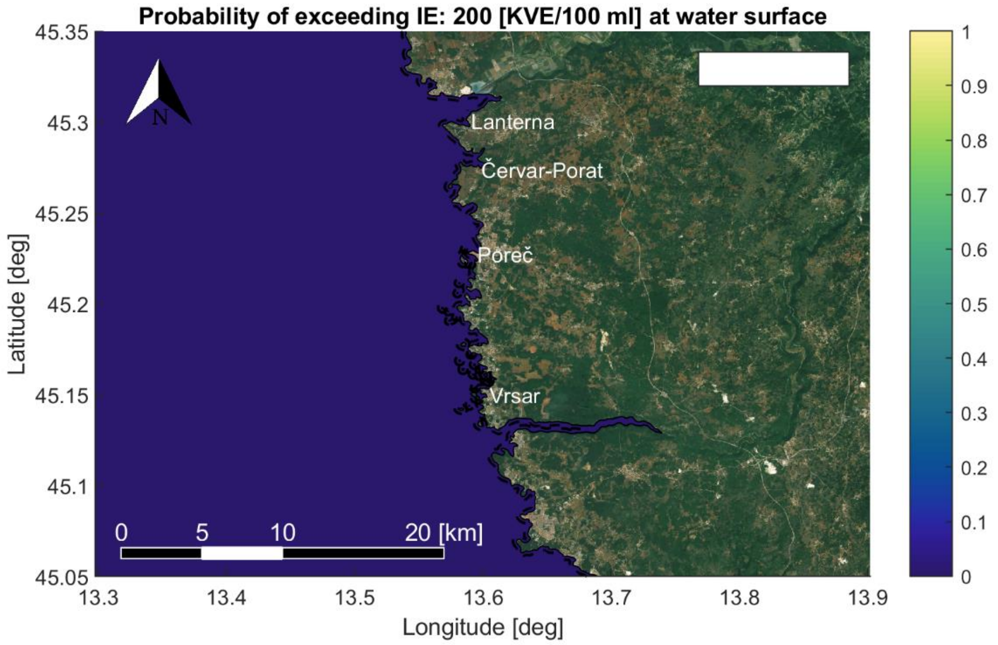

Figure 4-20 Winter scenario 2022 discharge with filter: Probability of exceeding IE concentrations of 200 [CFU/ 100 ml] at the water surface. Yellow contours show 5th percentile; Orange contours show 50th percentile; Red contours show 95th percentile. Dashed black lines indicate the 300 [m] contour around a land boundary.

4.3.3 Reuse of effluent

In this winter scenario, 100 percent of the effluent is being reused. Therefore, no faecal bacteria from the wastewater treatment plant will end up in the Istrian sea. This implies that there is no risk of insufficient water quality near the coast in this winter scenario.

4.4 STRATIFIED CONDITIONS – SUMMER SCENARIO 2040 DISCHARGE

4.4.1 Unfiltered effluent

In case of the summer scenario with discharges for the year 2040 (Figure 4-21 till Figure 4-25), the fields of probability of exceedance of ECOLI concentrations above 300 [CFU/ 100 ml] and IE concentrations above 200 [CFU/ 100 ml] at the water surface are very similar to the previous scenario with discharges for the year 2022. No additional exceedance within 300 [m] of land is found.

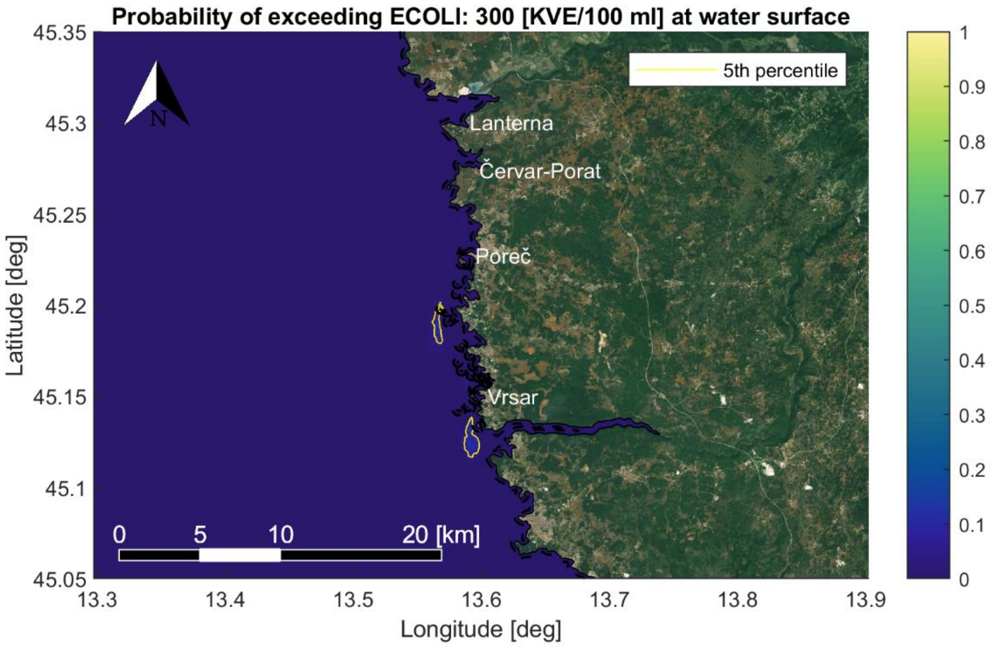

Figure 4-21 Summer scenario 2040 discharge: Probability of exceeding ECOLI concentrations of 300 [CFU/ 100 ml] at the water surface. Yellow contours show 5th percentile; Orange contours show 50th percentile; Red contours show 95th percentile. Dashed black lines indicate the 300 [m] contour around a land boundary.

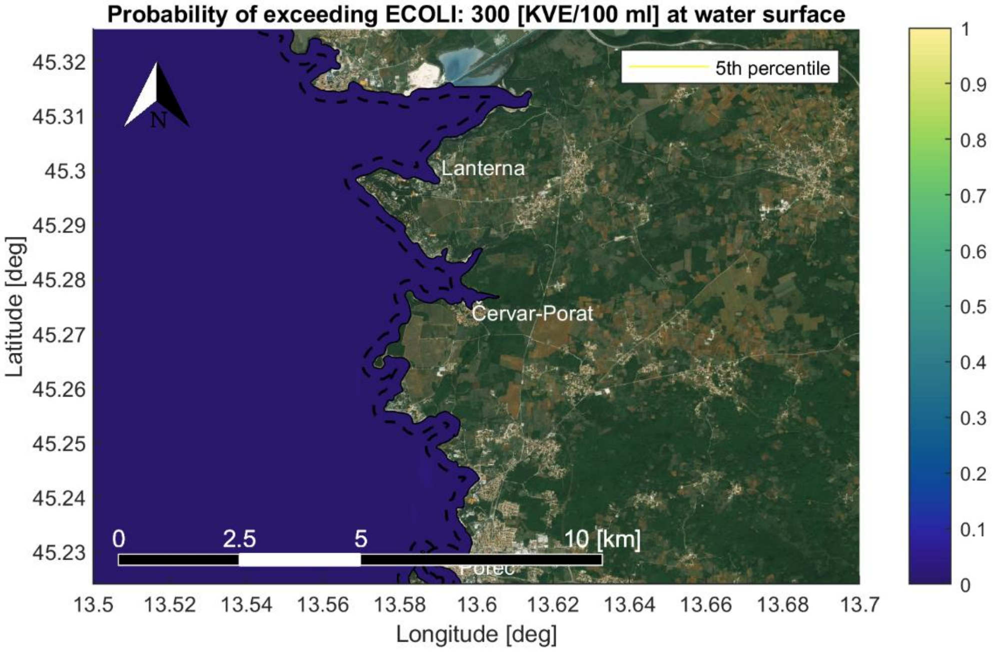

Figure 4-22 Summer scenario 2040 discharge, North zoom: Probability of exceeding ECOLI concentrations of 300 [CFU/ 100 ml] at the water surface. Yellow contours show 5th percentile; Orange contours show 50th percentile; Red contours show 95th percentile. Dashed black lines indicate the 300 [m] contour around a land boundary.

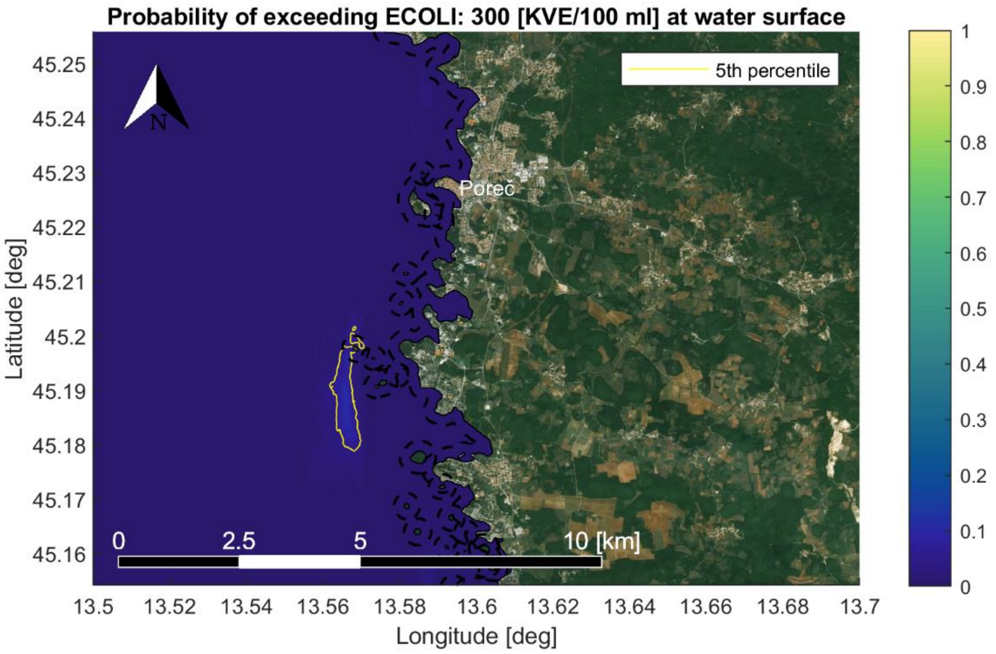

Figure 4-23 Summer scenario 2040 discharge, Middle zoom: Probability of exceeding ECOLI concentrations of 300 [CFU/ 100 ml] at the water surface. Yellow contours show 5th percentile; Orange contours show 50th percentile; Red contours show 95th percentile. Dashed black lines indicate the 300 [m] contour around a land boundary.

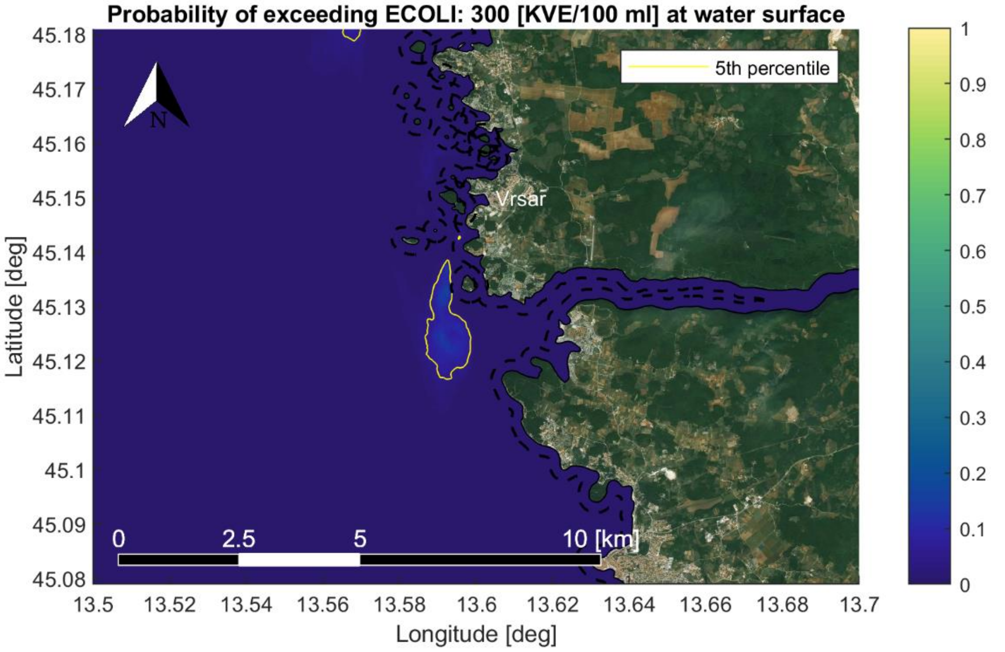

Figure 4-24 Summer scenario 2040 discharge, South zoom: Probability of exceeding ECOLI concentrations of 300 [CFU/ 100 ml] at the water surface. Yellow contours show 5th percentile; Orange contours show 50th percentile; Red contours show 95th percentile. Dashed black lines indicate the 300 [m] contour around a land boundary.

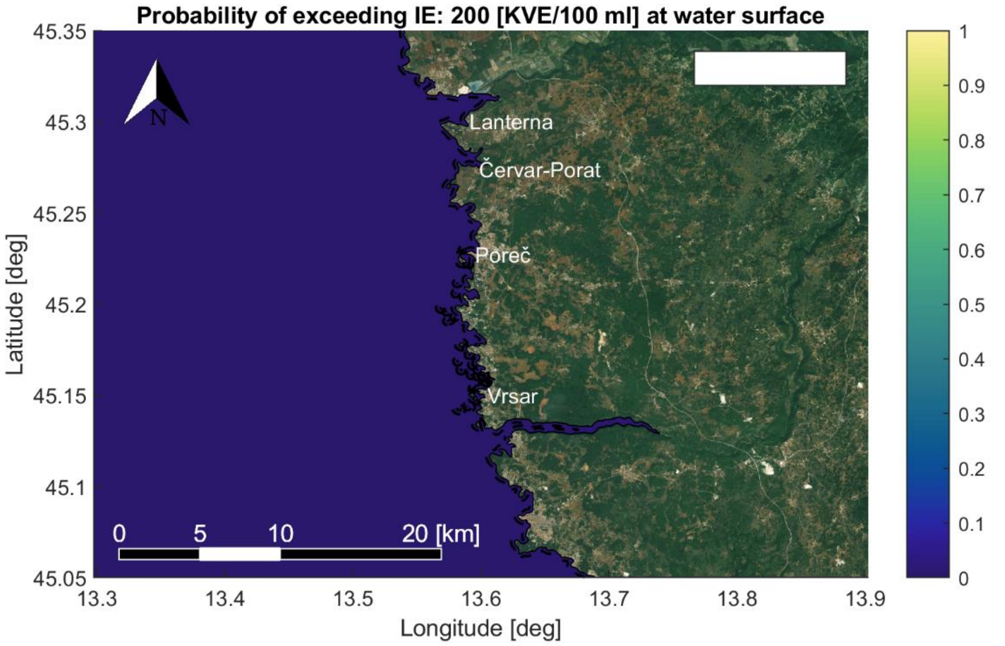

Figure 4-25 Summer scenario 2040 discharge: Probability of exceeding IE concentrations of 200 [CFU/ 100 ml] at the water surface. Yellow contours show 5th percentile; Orange contours show 50th percentile; Red contours show 95th percentile.

4.4.2 Filtered effluent

The summer 2040 scenario with membrane filter shows that there is no exceedance of ECOLI concentrations above 300 [CFU/ 100 ml] and IE concentrations above 200 [CFU/ 100 ml] at the water surface to be found (Figure 4-26 till Figure 4-30). This shows the effectiveness of the membrane filter in providing sufficient water quality conditions near the coast.

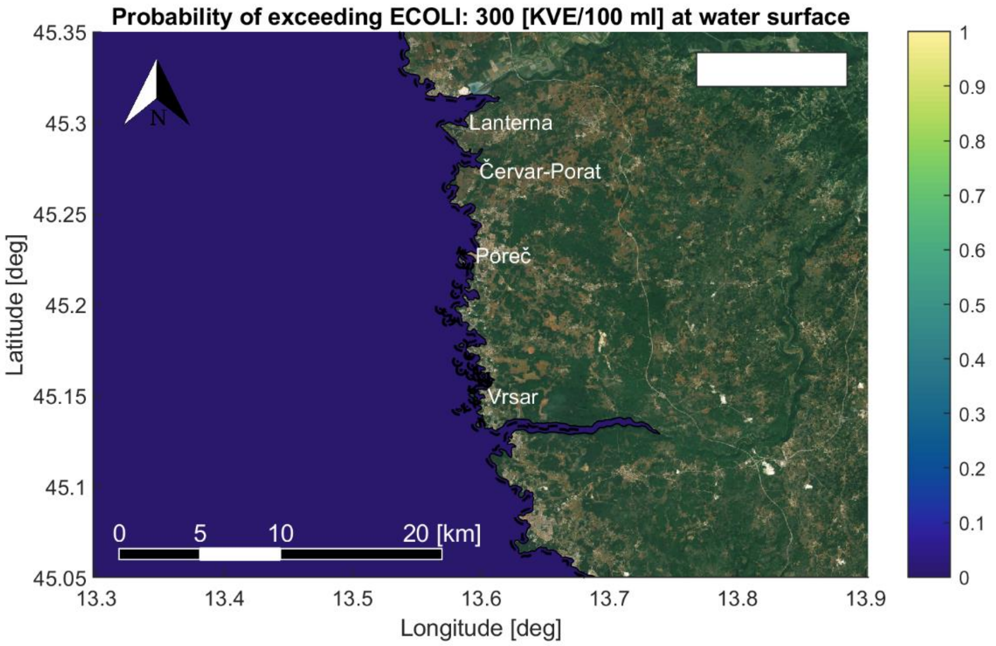

Figure 4-26 Summer scenario 2040 discharge with filter: Probability of exceeding ECOLI concentrations of 300 [CFU/ 100 ml] at the water surface. Yellow contours show 5th percentile; Orange contours show 50th percentile; Red contours show 95th percentile. Dashed black lines indicate the 300 [m] contour around a land boundary.

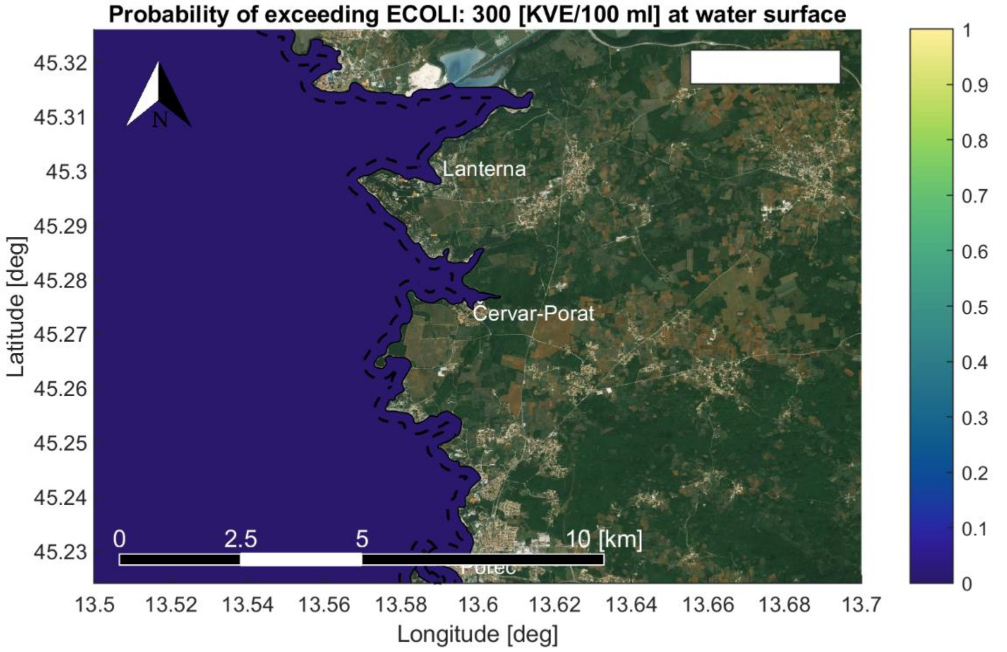

Figure 4-27 Summer scenario 2040 discharge with filter, North zoom: Probability of exceeding ECOLI concentrations of 300 [CFU/ 100 ml] at the water surface. Yellow contours show 5th percentile; Orange contours show 50th percentile; Red contours show 95th percentile. Dashed black lines indicate the 300 [m] contour around a land boundary.

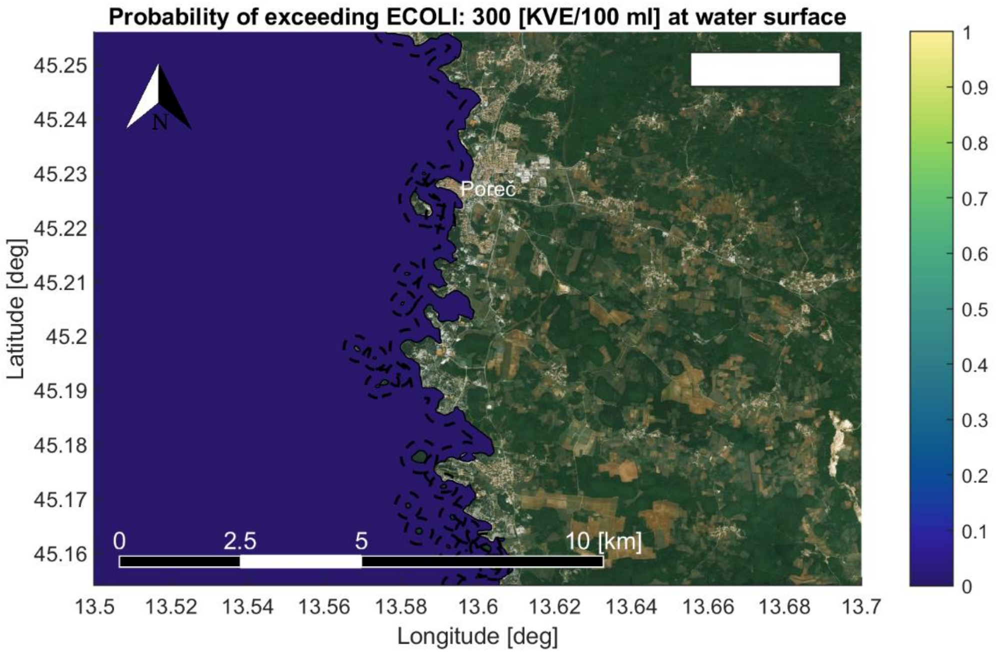

Figure 4-28 Summer scenario 2040 discharge with filter, Middle zoom: Probability of exceeding ECOLI concentrations of 300 [CFU/ 100 ml] at the water surface. Yellow contours show 5th percentile; Orange contours show 50th percentile; Red contours show 95th percentile. Dashed black lines indicate the 300 [m] contour around a land boundary.

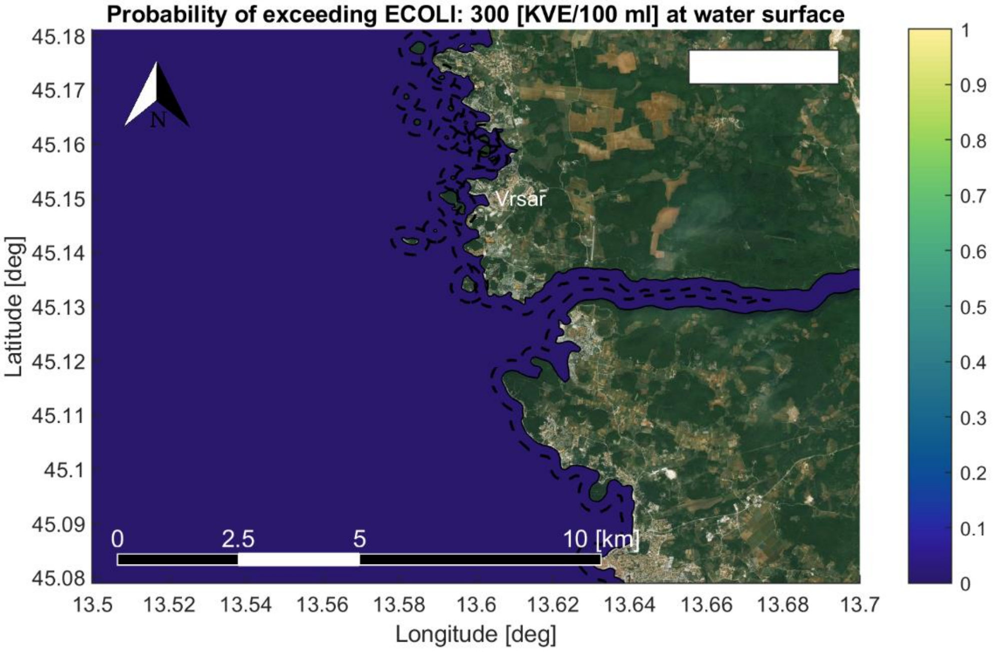

Figure 4-29 Summer scenario 2040 discharge with filter, South zoom: Probability of exceeding ECOLI concentrations of 300 [CFU/ 100 ml] at the water surface. Yellow contours show 5th percentile; Orange contours show 50th percentile; Red contours show 95th percentile. Dashed black lines indicate the 300 [m] contour around a land boundary.

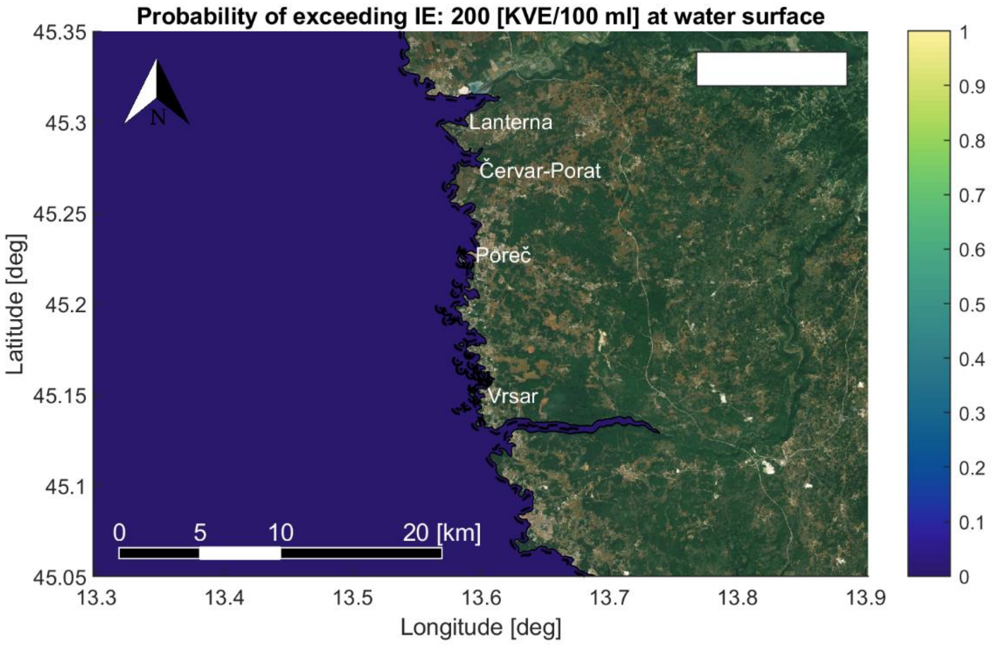

Figure 4-30 Summer scenario 2040 discharge with filter: Probability of exceeding IE concentrations of 200 [CFU/ 100 ml] at the water surface. Yellow contours show 5th percentile; Orange contours show 50th percentile; Red contours show 95th percentile.

4.4.3 Reuse of effluent

In this summer scenario, 100 percent of the effluent is being reused. Therefore, no faecal bacteria from the wastewater treatment plant will end up in the Istrian sea. This implies that there is no risk of insufficient water quality near the coast in this summer scenario.

5. CONCLUSIONS

In this report, the impact of the WWTP on bathing water quality is studied by use of scenario modelling with the water quality model. Different treatment situations have been studied representing the discharge of unfiltered effluent, the discharge of filtered effluent and the situation of reuse of the effluent. With the water quality model, the dispersion of sewage effluent and the water quality near the beaches for these different treatment situations has been examined. This has been done for winter season (representing mixed sea water conditions) and summer season (representing stratified sea water conditions) and for present (2022) and future (2040) conditions.

The general conclusion is that in all cases, for both faecal indicator bacteria, for both winter and summer season and discharge scenario's up to 2040, the scenario modelling results indicate an improvement of the water quality due to the filtering from the WWTP. Exceedance contours with faecal bacteria concentrations above the thresholds of sufficient water quality that are present in the situation without filtering (no WWTP operational) are reduced in size or are no longer present when the effluent is filtered by the WWTP. **With the WWTP in use (filtered effluent case or reuse of effluent), all beaches are within sufficient water quality criteria**.

Although water quality criteria are met in all cases when the WWTP is operational (use of membrane or full reuse of effluent), there are differences between the seasons in the dispersion patterns of faecal bacteria and the potential risk of exposure when the WWTP is not operational (unfiltered effluent).

For the **stratified summer scenarios** with 2022 and 2040 discharge of unfiltered effluent, the water quality is considered sufficient at the water surface near the coast/beaches. The stratification of the water column during summer helps reducing the faecal bacteria dispersion towards the surface. It should be noted that in conditions when this stratification of the water column is not present, there may be a larger risk of exposure. However, it can be observed from the model results with the unfiltered effluent that there are two locations with a significant effluent plume extend near the water surface. The first (and largest) exposure can be observed in the south near Vrsar. It does however not extend into the 300 [m] contour of the beaches, thus posing no risk to having a potential of reduced swimming water quality. The second exposure is near the Poreč south outfall, where only the small island of Otočić Altiječ has the potential of being exposed to higher concentrations within 300 [m] of its beaches.

When a membrane filter is applied at the waste water treatment plants, model results of filtered effluent show that it effectively reduces the amount of faecal bacteria in the water. There is no location with insufficient water quality and the potential exposures near Vrsar and Poreč south for the unfiltered effluent are removed.

An additional analysis of the effluent plumes from the unfiltered effluent simulations of each individual WWTP indicates there is no accumulation or overlap between the effluents of the different outfalls.

For the **mixed winter scenarios** with 2022 discharge, it can be observed that with unfiltered effluent that for most beaches the risk on exceedance of water quality is limited, except for the islands of Otočić Altiječ, Otočić Lunga, Otočić Galopun and Koversada, near the outfall locations of Poreč South and Vrsar. When a membrane filter is applied at the waste water treatment plants, model results show that it effectively reduces the amount of faecal bacteria in the water and therefore there is no location with insufficient water quality.

The scenario simulations illustrate that with the WWTP operational (filtered effluent or reuse of effluent) the water quality at the water surface near the coast/beaches is sufficient. However **when the WWTP is not operational** and unfiltered effluent is discharged there may be a risk of poor water quality within 300 [m] of the coast near the outfall locations of Poreč North & South and Vrsar during the winter season and potentially during the summer season when there is no stratification of the water column present. If one of the WWTP is not operational for some reason and unfiltered effluent is discharged, it is therefore advised to follow up the risk, especially during winter season, and potentially during summer season when there would be no stratification of the sea water column. The occurrence of stratification in the sea water column can for instance be followed up by use of CTD measurements. Additionally, it is recommended to monitor the risk on poor water quality by performing water quality measurements to support potential management actions.

6. REFERENCES

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Annex A Model results scenarios S3.1 – S3.4

A.1 Summer 2022 (single outfall simulations)

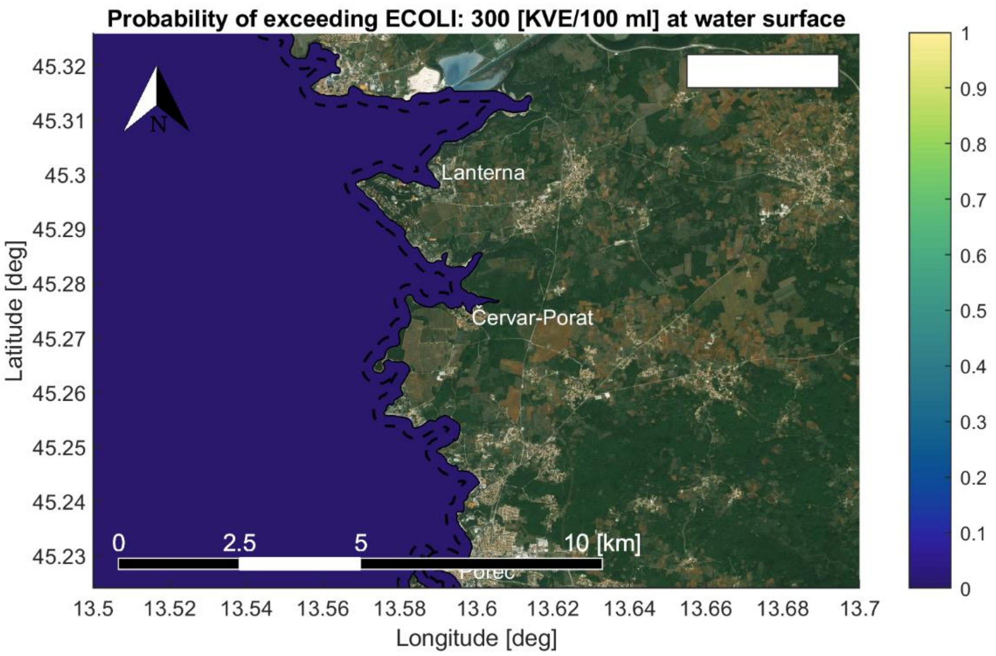

Figure Annex A-1 Summer scenario discharge Lanterna only, North zoom: Probability of exceeding ECOLI concentrations of 300 [CFU/ 100 ml] at the water surface. Yellow contours show 5th percentile; Orange contours show 50th percentile; Red contours show 95th percentile. Dashed black lines indicate the 300 [m] contour around a land boundary.

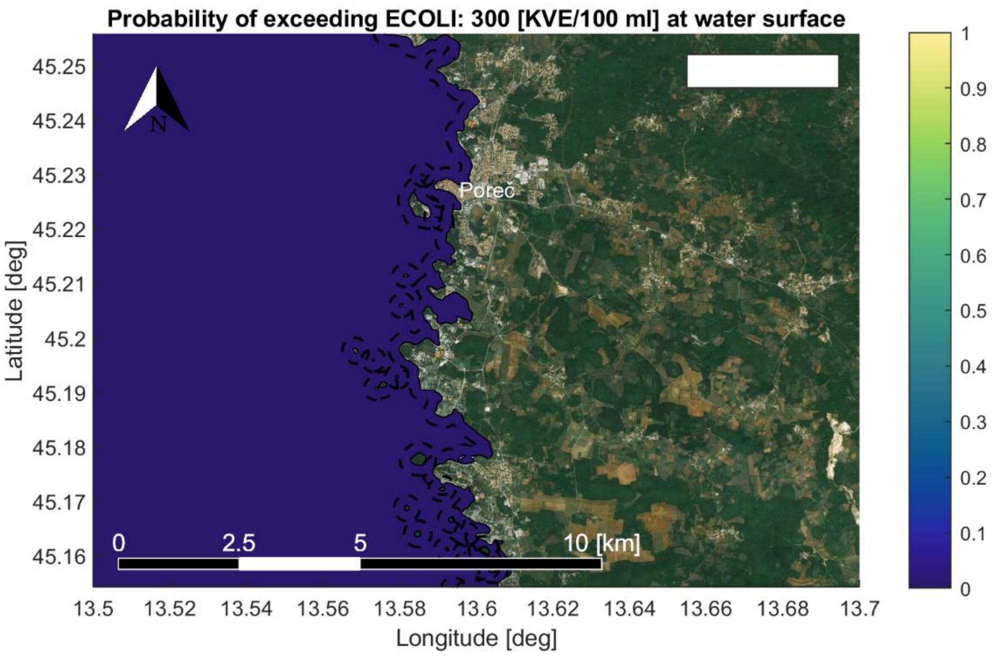

Figure Annex A-2 Summer scenario discharge Lanterna only, Mid zoom: Probability of exceeding ECOLI concentrations of 300 [CFU/ 100 ml] at the water surface. Yellow

contours show 5th percentile; Orange contours show 50th percentile; Red contours show 95th percentile. Dashed black lines indicate the 300 [m] contour around a land boundary.

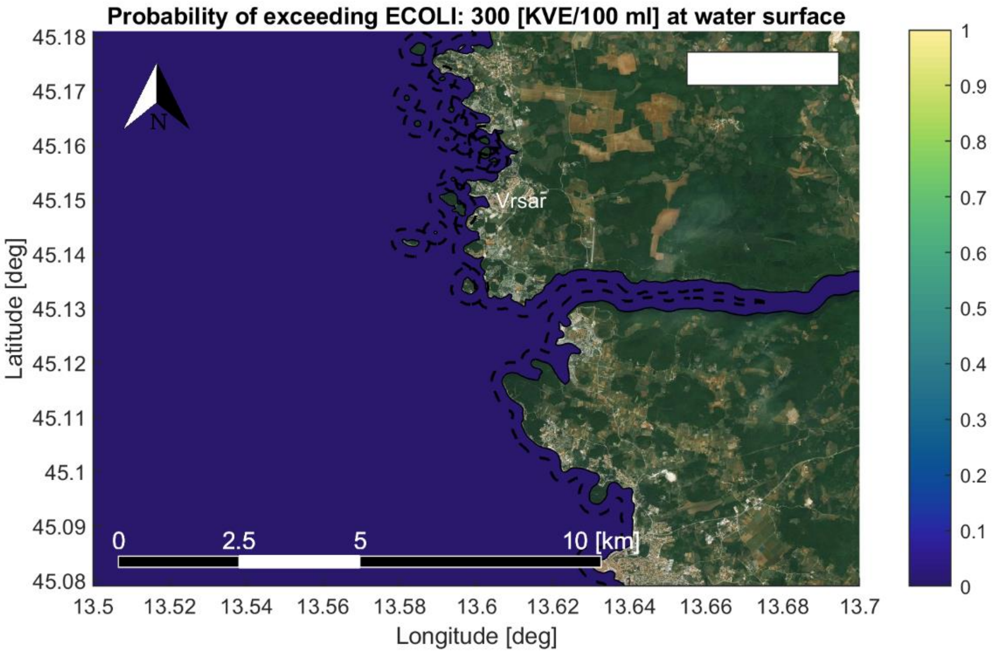

Figure Annex A-3 Summer scenario discharge Lanterna only, South zoom: Probability of exceeding ECOLI concentrations of 300 [CFU/ 100 ml] at the water surface. Yellow contours show 5th percentile; Orange contours show 50th percentile; Red contours show 95th percentile. Dashed black lines indicate the 300 [m] contour around a land boundary.

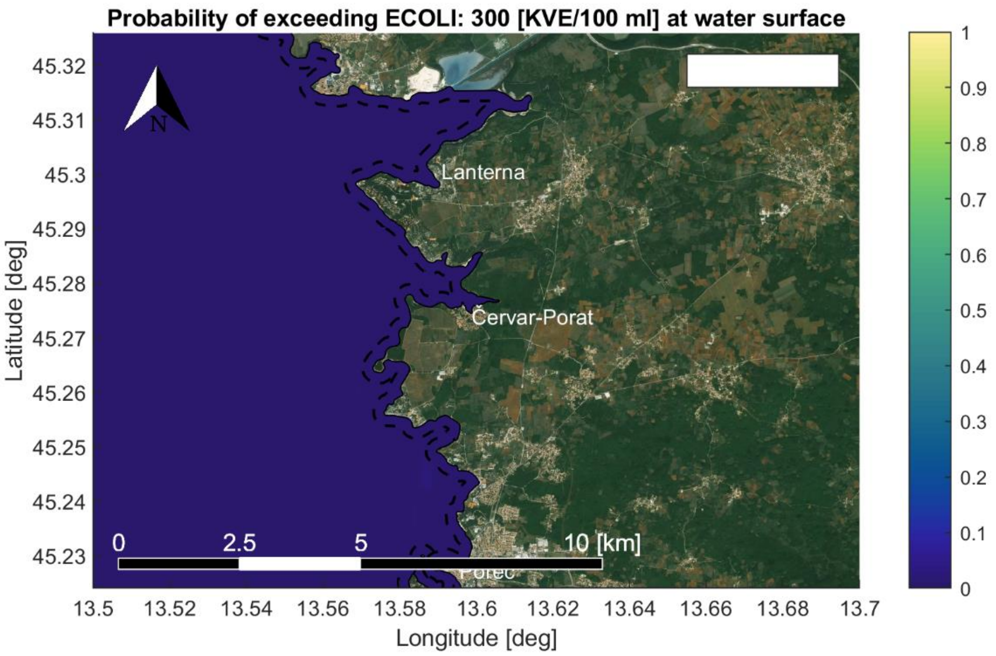

Figure Annex A-4 Summer scenario discharge Poreč-North only, North zoom: Probability of exceeding ECOLI concentrations of 300 [CFU/ 100 ml] at the water surface. Yellow

contours show 5th percentile; Orange contours show 50th percentile; Red contours show 95th percentile. Dashed black lines indicate the 300 [m] contour around a land boundary.

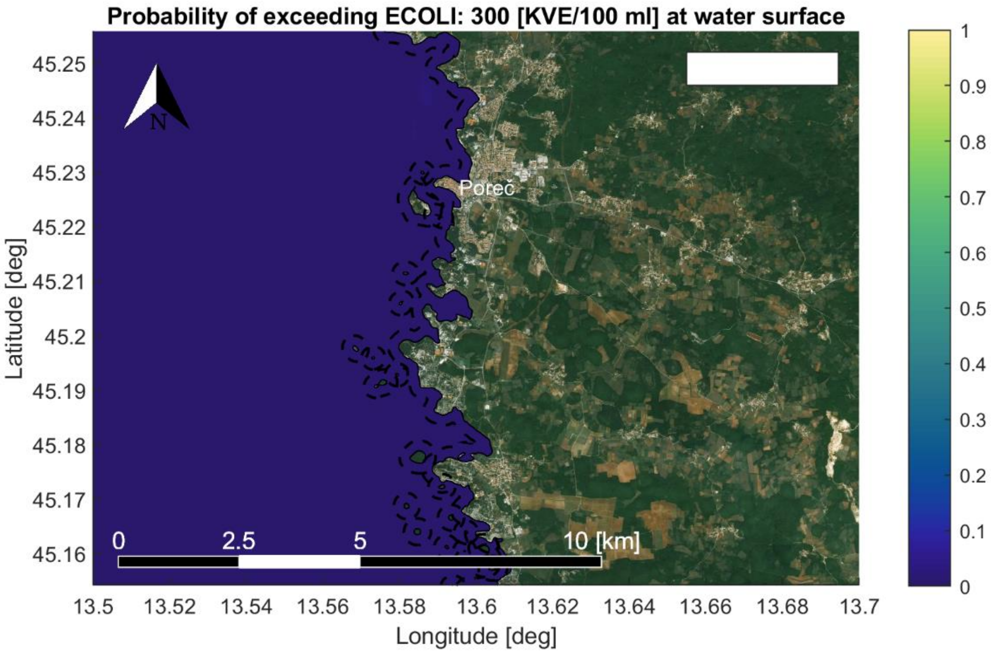

Figure Annex A-5 Summer scenario discharge Poreč-North only, Middle zoom: Probability of exceeding ECOLI concentrations of 300 [CFU/ 100 ml] at the water surface. Yellow contours show 5th percentile; Orange contours show 50th percentile; Red contours show 95th percentile. Dashed black lines indicate the 300 [m] contour around a land boundary.

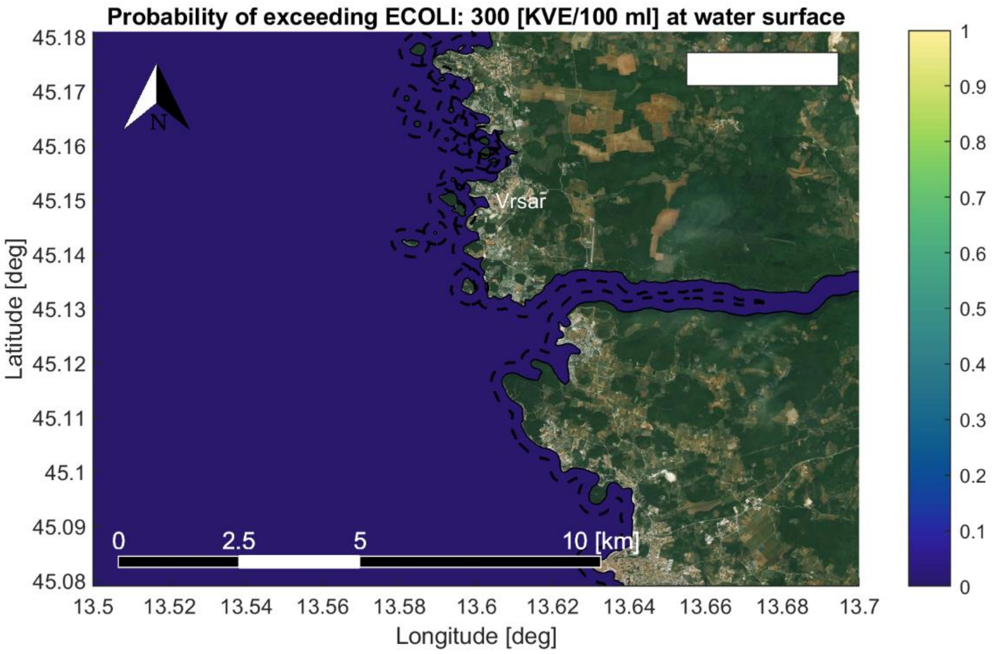

Figure Annex A-6 Summer scenario discharge Poreč-North only, South zoom: Probability of exceeding ECOLI concentrations of 300 [CFU/ 100 ml] at the water surface. Yellow

contours show 5th percentile; Orange contours show 50th percentile; Red contours show 95th percentile. Dashed black lines indicate the 300 [m] contour around a land boundary.

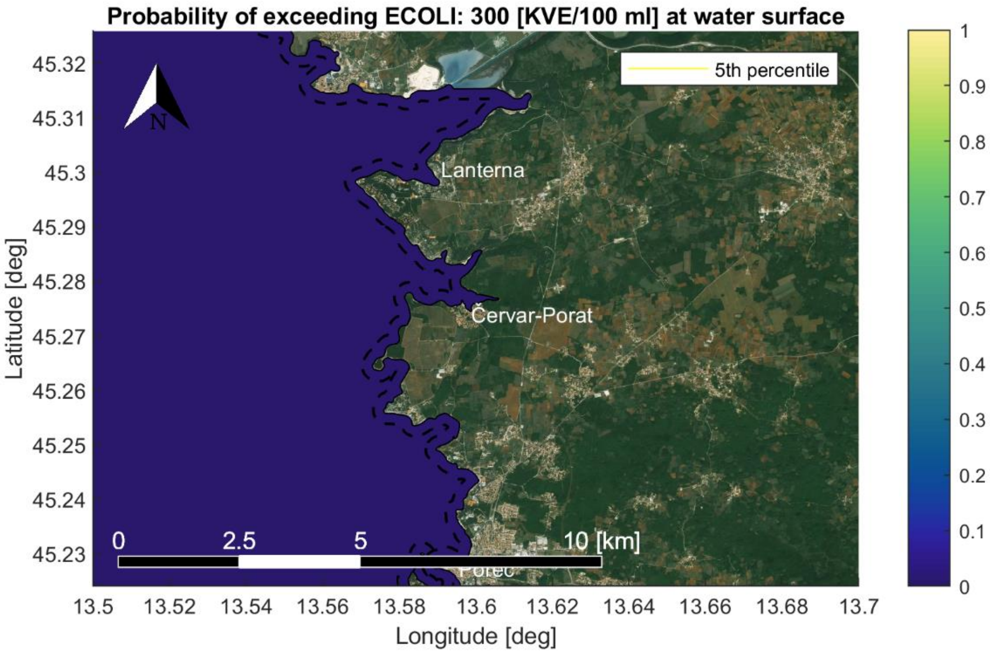

Figure Annex A-7 Summer scenario discharge Poreč-South only, North zoom: Probability of exceeding ECOLI concentrations of 300 [CFU/ 100 ml] at the water surface. Yellow contours show 5th percentile; Orange contours show 50th percentile; Red contours show 95th percentile. Dashed black lines indicate the 300 [m] contour around a land boundary.

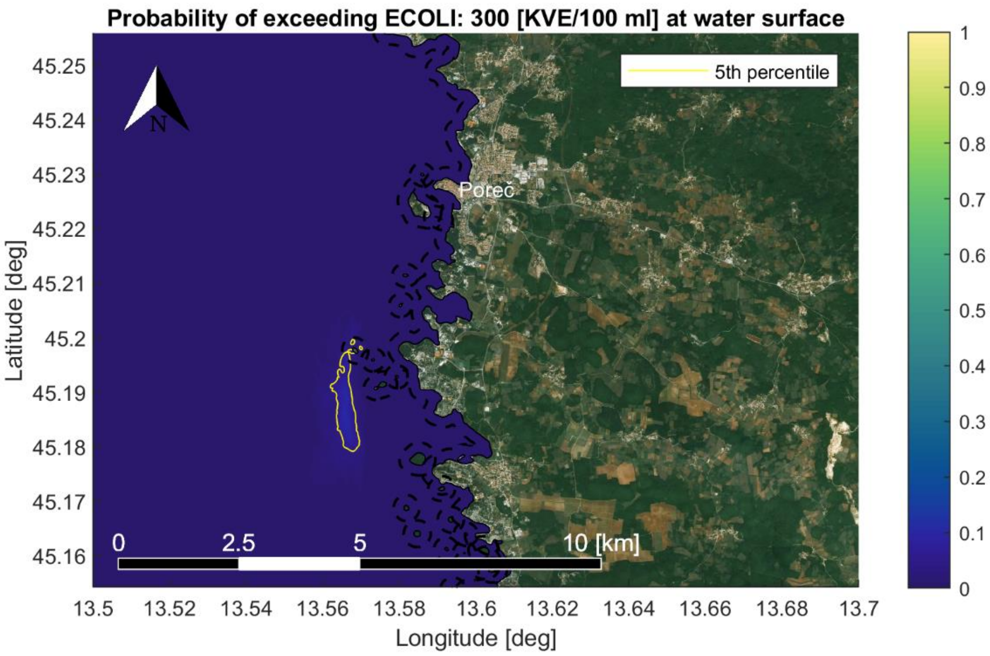

Figure Annex A-8 Summer scenario discharge Poreč-South only, Middle zoom: Probability of exceeding ECOLI concentrations of 300 [CFU/ 100 ml] at the water surface. Yellow *contours show 5th percentile; Orange contours show 50th percentile; Red contours show 95th percentile. Dashed black lines indicate the 300 [m] contour around a land boundary.*

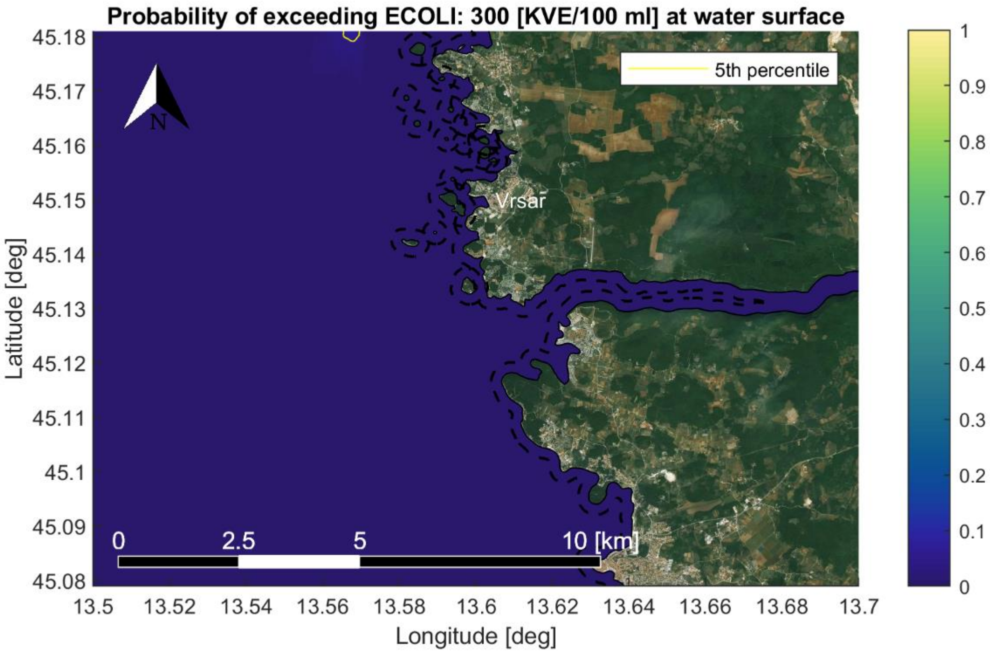

Figure Annex A-9 Summer scenario discharge Poreč-South only, South zoom: Probability of exceeding ECOLI concentrations of 300 [CFU/ 100 ml] at the water surface. Yellow contours show 5th percentile; Orange contours show 50th percentile; Red contours show 95th percentile. Dashed black lines indicate the 300 [m] contour around a land boundary.

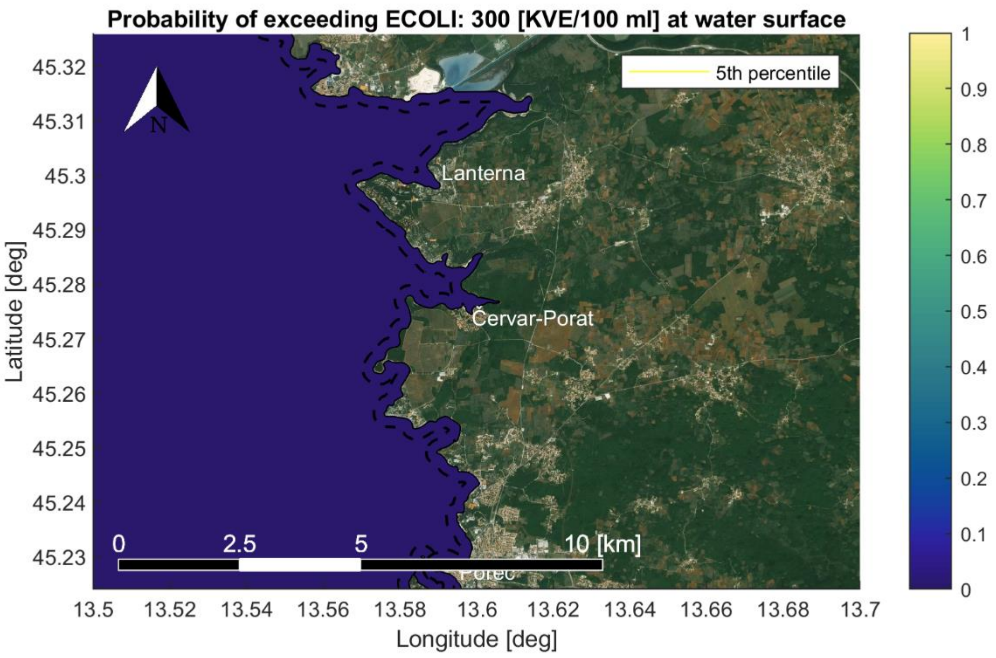

Figure Annex A-10 Summer scenario discharge Vrsar only, <u>North zoom</u>: Probability of exceeding ECOLI concentrations of 300 [CFU/ 100 ml] at the water surface. Yellow contours show 5th percentile; Orange contours show 50th percentile; Red contours show 95th percentile. Dashed black lines indicate the 300 [m] contour around a land boundary.

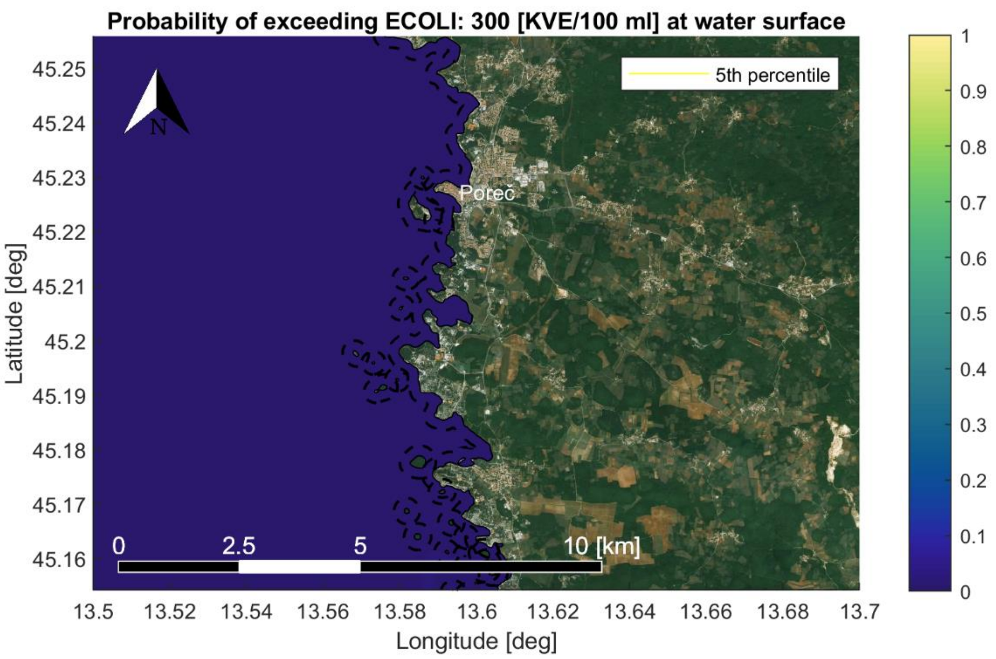

Figure Annex A-11 Summer scenario discharge Vrsar only, <u>Middle zoom</u>: Probability of exceeding ECOLI concentrations of 300 [CFU/ 100 ml] at the water surface. Yellow contours show 5th percentile; Orange contours show 50th percentile; Red contours show 95th percentile. Dashed black lines indicate the 300 [m] contour around a land boundary.

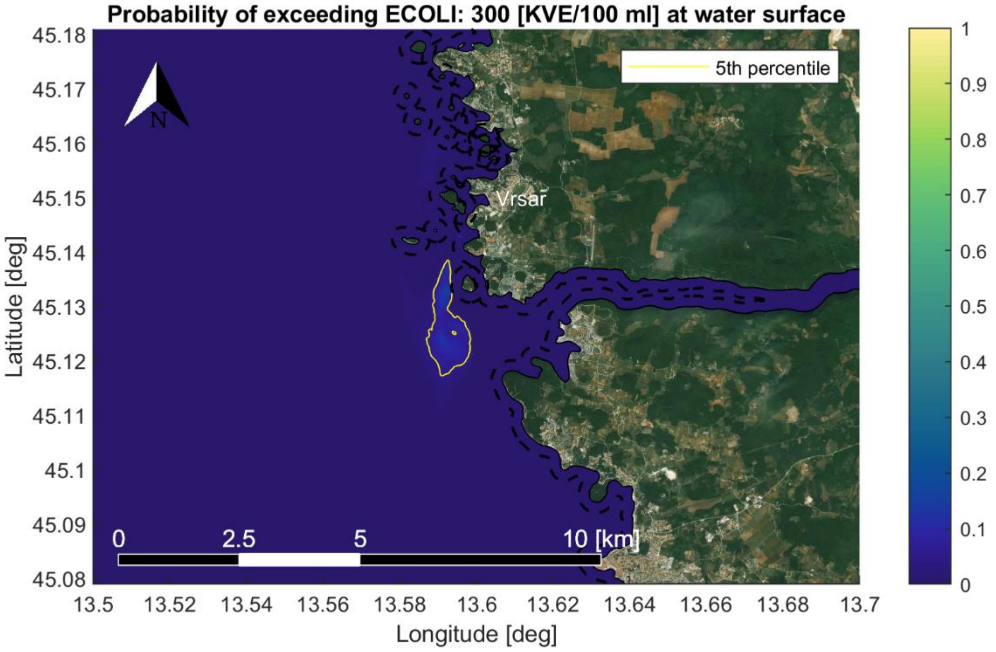

Figure Annex A-12 Summer scenario discharge Vrsar only, South zoom: Probability of exceeding ECOLI concentrations of 300 [CFU/ 100 ml] at the water surface. Yellow contours show 5th percentile; Orange contours show 50th percentile; Red contours show 95th percentile. Dashed black lines indicate the 300 [m] contour around a land boundary.